Stock Profiles and Ecosystem Considerations (SPECs) in Alaska groundfish fishery management plans

S. Kalei Shotwell, Dana H. Hanselman, Stephani Zador, and Kerim Aydin
September 2016

Executive Summary

A number of national initiatives such as stock/habitat assessment prioritization and fish stock climate vulnerability have highlighted and enhanced the MSA mandate to sustain marine fish and associated habitats by moving toward an ecosystem approach to fisheries management (EAFM). At the same time, the integration of ecosystem information directly into the stock assessment process is receiving substantial attention for effective marine conservation and management. As EAFM becomes part of operations, it is imperative that a clear avenue exist for providing ecological context for a stock assessment and allows for including relevant ecosystem data directly into the assessment model.

For the North Pacific region, the Ecosystem Considerations chapter of the Alaska groundfish stock assessment and fishery evaluation (SAFE) report is a leading example of EAFM. The compendium provides an ecosystem synthesis of Alaska's four large marine ecosystems and is updated annually by incorporating new information from a variety of ecosystem surveys and research projects. However, data in this report is difficult to incorporate within the ecosystem considerations sections of the individual stock or stock complex SAFE chapters. We propose a new framework for incorporating ecosystem information into the individual SAFE chapters termed the Species Profiles and Ecosystem Considerations (SPECs). This approach utilizes pre-existing data collected through national initiatives to generate an ecosystem baseline of information for the stock or stock complex. A baseline SPEC would include a stock-specific ecosystem status rating, a stock life history conceptual model, a stock profile, and a stock report card of relevant indicators. Ecosystem terms of reference (eco-TOR) would also be included to guide priorities for future research.

We provide an example baseline SPEC created for Alaska sablefish as a case study of the framework. Options for improving the baseline using information from current ecosystem surveys and research are explored in the discussion. Since a baseline SPEC can be created from data already collected through national initiatives, the work associated with creating the SPEC is minimized and this framework can be applied to numerous stock assessments in multiple regions. Ultimately, the synthesis of the national initiatives through the SPEC framework will provide the necessary building blocks to move toward the next generation of integrated ecosystem stock assessments.

Introduction

Under the mandate of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), National Standard 1 and 2 guidelines contain specific language that requires the consideration of ecosystem processes with regard to specifying optimum yield and informing the regional Councils through the stock assessment and fishery evaluation (SAFE) report (16 U.S.C. 1851 (1,2)). Because of this, ecosystem-based science is at the forefront for effective marine conservation and resource management (Levin et al., 2009). In general, this approach consists of two main components: 1) a comprehensive ecosystem assessment and 2) an assessment of a changing environment on a stock in the fishery (Hollowed et al., 2014). Since 1995, the North Pacific Fishery Management Council (NPFMC) Groundfish Plan Teams along with scientists from the Alaska Fisheries Science Center (AFSC) have implemented an ecosystem approach to fisheries management (EAFM) through the Ecosystem Considerations report (e.g. Livingston 1999, Zador 2015). This compendium contains ecosystem assessments, indicators, and report cards that functionally generate a synthesis of the four large marine ecosystems (LME) in Alaska (Bering Sea, Aleutian Islands, Gulf of Alaska, and Arctic). The report is presented to the Plan Teams and Council at the same time as the other individual groundfish stock assessment chapters so that harvest recommendations can be evaluated within the context of the current status of the ecosystem (Zador et al. 2016).

Through the AFSC SAFE report guidelines, stock assessment scientists are encouraged to include an ecosystem considerations section within the individual chapters to provide an ecological context for the stock or stock complex. Generally, these ecosystem considerations sections are stock specific and evaluate ecosystem effects on the stock and fishery effects on the ecosystem. Initially, stock assessment authors were encouraged to use data from the Ecosystem Considerations report as auxiliary information within the individual stock assessment chapters. The ultimate goal of this would be to incorporate relevant ecosystem data directly into an assessment model and or inform harvest recommendations (Townsend et al. 2008). Realistically, however, the large-scale regional synthesis approach of the Ecosystem Considerations report is limited in identifying specific indicators for use in single-species stock assessments. Also given the time constraints surrounding the operational stock assessment process, the ecosystem considerations sections within the individual SAFE chapters are rarely updated.

Over the past decade, numerous ecosystem surveys and process studies have emerged to monitor and assess the Alaska LMEs. Several regional collaborative integrated ecosystem research projects (IERPs) have been funded through the North Pacific Research Board (NPRB) to gain understanding of population fluctuations in relation to the surrounding environment. The Bering Sea IERP and the Gulf of Alaska IERP are two such examples of these efforts. Products of these programs include high resolution oceanographic, plankton, and fish models (e.g. ROMS, NPZ, FEAST, IBMs) that can be utilized to understand system connectivity and generate estimates of ecosystem and fish population trajectories. When coupled with *in situ* observations from fully-integrated ecosystem surveys of the region, the synthesis products of these programs have highlighted the primary ecosystem drivers by LME. Due to the organization of the Ecosystem Considerations report, a clear and direct avenue exists for including this new information within the report. Several IERP products have been utilized within the report to develop the ecosystem assessment of the LMEs and provide a large variety of indicators to create valuable and representative regional report cards (Zador 2015). However, assimilation into single-species stock assessment has remained limited. This is in a large part due the limited time for updating an ecosystem section following the large effort required to assimilate new stock assessment survey data, run and evaluate stock assessment models, and provide harvest recommendations. Integrating a template directly within the SAFE report for stock assessment authors to follow would allow assessors to capitalize on the increasing amount of ecosystem information and integrate the data appropriately in a timely manner within the stock assessment framework.

A proposal to re-organize the Alaska groundfish NPFMC stock-specific ecosystem considerations sections was unveiled in 2014. The goal was to first identify trends in the population assessment and then define potential ecosystem, habitat, and/or climate (E/H/C) linkages that could lead to the development of a mechanistic conceptual model and stock-specific report card similar to those produced in the Ecosystem Considerations report for LMEs. A communication feedback loop was suggested to coordinate the efforts between the individual stock assessment authors, the ecosystem considerations chapter authors, and PIs from projects such as the IERPs and other ecosystem research fishery projects (e.g. Fisheries and the Environment or FATE) that require coordination with stock assessment scientists. Feedback of the initial proposal from the NPFMC Plan Teams and Council encouraged the development of the framework particularly to evaluate the forecast skill of proposed ecosystem linkages while cautioning against overburdening stock assessment authors with a complicated ecosystem status assessment.

With the onset of operationalizing EAFM, the National Marine Fisheries Service (NMFS) has implemented a number of national initiatives over the past several years to advance stock assessments beyond the single-species context. These initiatives include (but are not limited to) stock assessment prioritization, habitat assessment prioritization, climate vulnerability analysis, and stock assessment categorization. In concert, these national initiatives pave the way for a stock assessment process that is prioritized, timely, efficient, innovative, and expanded in scope (SAIP, *In Review*). This next generation of stock assessments (NGSA) concept directly addresses our national standard guidelines as mandated by the MSA and includes integration of ecosystem information as one of the core framework elements for implementation. Here we adopt the information taken through these national initiatives to create new species profiles and ecosystem considerations (SPECs) that can be used to revamp the ecosystem consideration sections of the individual SAFE chapters for Alaska groundfish. Given a proper ecosystem feedback system and continued support and timeliness to the stock assessment community, the SPECs take a step toward the goal of next generation assessments.

Objectives

We propose a framework for the SPECs that take advantage of the large amount of data collected through the national initiatives and combines the responses in a stepwise and updateable set of elements. The primary goal of this framework is to establish a baseline SPEC for any stock or stock complex evaluated through the series of national initiatives. Data collected for any national initiative can be set to a relative scale and then serve as a baseline SPEC. Products from efforts like the IERPs can then be used to update the baseline SPECs with new ecological data or ecosystem indicators relevant to a particular stock or stock complex. Together the SPEC elements describe the ecosystem status for a given stock or stock complex. Specific objectives of this project are to 1) collect initiative data using standard protocol for stocks in a given fishery management plan (FMP), 2) conduct simple qualitative cost/benefit assessment based on initiative scores, 3) develop SPEC baseline elements from initiative dataset, 4) create stock-specific ecosystem-based terms of reference (eco-TOR) for future research planning. Baseline SPEC elements for objective 3 include an overall ecosystem status rating, a life history conceptual model, a stock profile, and a stock report card. We provide an example of these elements through a case study of Alaska sablefish which is managed within the NPFMC groundfish FMP. When considered together, the SPEC elements provide the necessary information for establishing the role of the stock in the ecosystem while identifying relevant indicators and setting priorities for potential future research.

Methods

In the following sections we first provide a summary of the national initiatives utilized to accomplish the objectives listed above. We then detail methods for initiative data collection and subsequent cost/benefit assessment that were used for Alaska groundfish managed under the NPFMC. Finally, we describe the development of four elements that form the SPEC baseline and options for identifying eco-TOR for a given stock or stock complex.

Summary of National Initiatives

The primary directive of NMFS to sustainably manage marine fish and associated habitat requires that assessments of fish and habitat be conducted. However, of the 470 managed stocks for our nation, NMFS only has the capacity to assess about 40% of those stocks each year (Methot 2015). NMFS strives to develop at least some baseline monitoring for all managed stocks and the national initiatives should allow for an objective approach to determining how to achieve the mandate goals.

Stock Assessment Prioritization: A main part of the NGSA framework is the development of a national standardized protocol for setting target assessment level and frequency for each stock or stock complex as not all stocks require the highest quality assessments or annual updating (Methot 2015). Factors for setting the targets include fishery importance, ecosystem importance, relative stock status, recruitment importance, and history of the assessment. Also considered are whether the stock was on a rebuilding plan, is at risk to overfishing, or seems to require caution or concern due to assessment results. Priority is based on the target level ranking and given to assessments that are overdue or which have new data to raise them to a higher level of assessment. The process is designed to be focused on region specific decision-making using factor weighting and regional scaling to adjust assessment levels and frequency. The Northwest region and the Alaska region began the stock assessment prioritization process in 2015. A stock or stock complex with a high stock assessment prioritization score would mean that it is a priority for conducting a stock assessment given the regional weighting.

Habitat Assessment Prioritization: A similar effort of prioritization has ensued to provide scoring criteria for determining which stocks would likely benefit the most from habitat assessment (NMFS, 2011). This process is somewhat similar to the stock assessment prioritization process described above but also considers stocks for which habitat assessment will most advance the essential fish habitat (EFH) priorities. Criteria include fishery status, habitat disturbance, vulnerability, rarity, habitat dependence, ecological importance, economic/social value. The process is also designed to be region specific and each NMFS region organizes a regional working group to conduct this process. In 2012, the Southwest region provided a pilot study for habitat assessment prioritization (NMFS, 2012). This first pass at designating high, medium, and low priority stocks for habitat assessment provides a useful guideline for determining metrics of ecosystem importance and effects. A stock or stock complex with a high habitat prioritization score implies that there is great potential for using the habitat information in the stock assessment process or for EFH, while a low score implies that habitat information was not relevant to this stock.

Productivity and Susceptibility Analysis (PSA): In 2008, a working group of scientists from NMFS developed a process for estimating the vulnerability of marine fish stocks (Patrick et al., 2010). This semi-quantitative approach was termed productivity–susceptibility analysis (PSA). The objective of a PSA is to combine attributes of productivity (e.g., life-history traits such as natural mortality and growth rate), with attributes of susceptibility to fishing impacts (e.g., spatial overlap with fisheries and discard mortality). The combined vulnerability score was indicative of the likelihood that a stock may be overfished in the absence of conservation measures and included some measure of uncertainty in the data quality to support that score (Ormseth and Spencer 2011). Orsmeth and Spencer (2011) calculated PSA scores for a total of 90 stocks and stock complexes in the Bering Sea, Aleutian Islands and Gulf of Alaska. The PSA is a traditional calculation of the stock vulnerability and summarizes the current conditions. A high score would imply that the stock is vulnerable to fishing and ecological pressures while a low score suggests the stock is resilient to these pressures.

Fish Stock Climate Vulnerability Assessment (CVA): Over the past several years, NOAA scientists have developed a new methodology to rapidly assess the vulnerability of fish stocks to expected changes in climate and ocean conditions. The CVA methodology can be viewed as a corollary to the PSA because it uses species life history characteristics to assess vulnerability but with the added component of comparing species distributions to projections of future climate change variables (e.g., mean ocean surface temperature) (Morrison et al., 2015). Groups of climate and ecological experts generate climate exposure and biological sensitivity scores by reviewing maps of climate variables with respect to maps of species distributions and life history traits. The overall CVA score for a given species was estimated by taking the weighted average of numerically converted scores (low=1, moderate=2, high=3, very high=4) applied to a logic rule over the range of biological sensitivity attributes and climate exposure factors (Morrison et al., 2015). The CVA methodology is also being applied to all regions in the United States. The Northeast region completed the CVA in 2015 for 82 species of fish and invertebrates (Hare et al., 2016). The method is currently being applied to stocks in the Southwest, Northwest, and Bering Sea. A high score would imply that the stock is vulnerable to future climate change while a low score would suggest that the stock is resilient to this change.

Stock Assessment Classification: This is a new national data tracking system to be implemented with the updated Stock Assessment Improvement Plan (SAIP, In Review). Five categories of input data (e.g catch, size/age composition, abundance, life history, ecosystem) for a given stock assessment are scored on a 0 to 5 scale. These scores along with information on the assessment model type and number of years since the assessment was conducted will for the overall classification score. This score effectively relates to the amount of data available for each assessment of the stock or stock complex and would be considered a benefit. An overall low score would mean that the stock was data-limited while an overall high score would mean the stock was data-rich.

Standard Protocol Data Collection

In order to collect the information for the national initiatives listed above, numerous data calls around the nation were implemented to generate profiles on the ecological status for a given stock or stock complex. However, since each initiative had a slightly different goal, the resultant data collected for any given FMP were difficult to assimilate for potential use within a current stock assessment framework. For Alaska groundfish managed under the NPFMC, the requests for numerous initiatives occurred nearly all at the same time. Therefore, we created an all-initiative-encompassing Google form (AK super form) to collect the required information for all groundfish stocks to satisfy requests from multiple initiatives at the same time. This method allowed for the stock data to be collected in a standardized fashion that could be subset for any given request and available for potential future applications.

The AK super form contained questions regarding stock status, stock assessment parameters, distribution and biology, early life history, movement, habitat, prey, predators, ecosystem status, and economic status for a given stock or stock complex. Ranking options for data quality were also included for many of the form questions and were based on the climate vulnerability analysis categories (Morrison et al. 2015) with the addition of a fifth category (4 = Complete Data. The score is based on very complete data which have been observed, modeled, or empirically measured for the stock in question and are unlikely to be greatly improved or modified with more research or analysis). The form ended with a section on stock assessment classification based on the most recent SAIP update and an area for relevant references.

Many of the forms were pre-filled with information gathered from the Species Information System (SIS) which is a national database that supports the stock assessment program. Also, due to the nature of these large-scale forms, some sections of a few initiatives had already been completed for a subset of groundfish stocks. For example, climate vulnerability analysis species profiles had already been created for several of the Bering Sea Aleutian Islands (BSAI) stocks at the onset of the AK super form. This information was pre-filled for the BSAI forms. Habitat assessment prioritization also occurred on a separate time schedule, but the questions for the HAP were also included in the AK super form. Each groundfish stock assessment author was responsible for checking pre-filled data within their forms and for filling in the remaining information for their assigned stock or stock complex.

Qualitative Cost/Benefit Assessment

Once all the data was collected through the AK super forms, we subset the data for use in calculating ranking, frequency, and scores for various initiatives as needed. Upon completion of the initiative exercise, we collected initiative output where available for a given factor or attribute for each stock or stock complex. If the output was a score range (e.g., between 0 and 5), the value was converted to be within a quarter score following the climate vulnerability analysis scoring categories of 1 = low, 2 = moderate, 3 = high, and 4 = very high (Morrison et al. 2015). If the factor or attribute was not scored but a continuous variable was used for estimating frequencies or for ecological context (e.g. mean age, recruitment variability, depth range), then quartiles were calculated over the range of values of all Alaska groundfish stocks and then converted to the quarter score range above. A value of 0 was available for unknown status of a given factor or attribute.

The set of stock-specific factor scores set on a quarter scale was then categorized as a cost or benefit to the stock (Table 1). Generally, ecological attributes (e.g. biology, ecosystem, and habitat) were considered a cost due to the scoring set up through the climate vulnerability analysis. A low score usually implied that the stock was a generalist for that particular attribute while a high score would mean the stock was a specialist (e.g. prey or habitat specificity). Economic factors were considered benefits to the stock as a high score suggested high economic value for a given fisheries sector such as commercial, recreational, or subsistence. Climate and stock status factors were a mix of cost and benefits and usually related to the resilience of the stock. For example, high recruitment variability was considered a cost as it implies the stock was less resilient to ecosystem shifts, while high growth rate or mean age was considered a benefit as the stock could monopolize on good feeding condition or weather long periods of poor environmental conditions through longevity. Table 1 provides the different factors or attributes considered across the initiatives with a short description, the range of scores or values for Alaska groundfish, and the cost/benefit designation. Some descriptions were taken from the prioritization plan (Methot 2015) and a summary of the climate vulnerability assessment for the northeast U.S. Fisheries (Hare et al. 2016).

The cost/benefit assessment along with the qualitative scores for each factor or attribute can be used in concert to develop metrics for the SPEC. We used the information to develop an overall stock ecosystem status ranking and stock profile as detailed below. These metrics can be used in a stepwise fashion to identify priority research areas and potential relevant indicators to monitor for a given stock.

Species Profile and Ecosystem Considerations (SPEC) Elements

For Alaska groundfish in the North Pacific Region, we propose a baseline SPEC that consists of four elements: 1) an overall stock ecosystem status ranking, 2) a stock life history conceptual model, 3) a stock profile, and 4) a stock report card. Together these elements assist with identifying mechanisms for understanding the influence of the ecosystem on the stock or stock complex and highlighting data gaps which can be used for setting research priorities and terms of reference. The proposed methodology for each element is provided below.

Stock Ecosystem Status Rating: This first element provides a metric for specifying a simple ecosystem rating that effectively communicates the status of the stock or stock complex with respect to the overall ecosystem scores. We took final scores generated for a given initiative (e.g., stock prioritization ranking) and modified the logic rule applied for the Northeast Region climate vulnerability analysis (Hare et al., 2016) to estimate an overall qualitative score for a given stock or stock complex. If three or more scores of the five overall initiative scores (described in the Summary of National Initiatives section above) were greater than or equal to 3.5, we characterized the stock as having an overall ecosystem status rank of very high. If two or more scores were greater than or equal to 3.0, the ecosystem status rank was high. If two or more scores were greater than or equal 2.5, the status was moderate. All other scores were considered to have an overall ecosystem status of low.

This first element can be thought of as an ecosynthesis and can be used to identify which stocks can benefit the most from inclusion of E/H/C linkages in reference to the assessment capabilities and stock limitations. Also the individual initiative final scores can be considered as reference to understand the general cost and benefit level for a given stock or stock complex. A comparison of these ecosynthesis scores across stocks within a given FMP can be useful for survey planning and setting research goals.

Stock Life History Conceptual Model: When attempting to understand the interconnections between a variety of physical and biological elements, a holistic approach is often employed to realize the broader scope of system functioning (e.g., Spencer et al., 2010). Generally as more linkages are simultaneously evaluated a conceptual model is useful to organize the relationship between entities. Pictographs or diagrams can also be valuable to visualize the synthetic product (e.g., Mundy et al., 2005, Figure 1). Determining the most appropriate indicators for a given stock and if, or when to use them is not a straight-forward process, even though a variety of E/H/C indicators exist as well as the guidelines for how to incorporate them into an assessment model. The expertise of a multi-disciplinary team may be required to adequately develop a representative conceptual model.

As a first pass, we utilized the responses from the stock assessment authors within the Alaska super form to create a life history conceptual model for a stock or stock complex. The models were as detailed as we could make given the available life history information. At minimum, simple life history stage location and duration could be included on the picture with potential environmental drivers at the hypothesized choke points within the life history (e.g. cross-shelf transport influencing dispersal during the pelagic larval life stage). Often a guild (e.g. flatfish) may be the extent of the conceptual model detail. Regardless, the conceptual model is a clear and efficient way to convey the basic life history for a stock and also highlight previously explored mechanisms influencing stock population dynamics.

Stock Profile: A more in depth look at the factors and attributes making up the overall initiative scores reveals a surprising plethora of stock-specific information that can be utilized to create a baseline profile for a given stock or stock complex. The quarter scores can be evaluated along with the cost/benefit assessment to understand the relative influence on a particular stock or stock complex. We also classified the variety of factors or attributes (Table 1) into types to assist with this evaluation. The resultant profile can be used to identify the important vulnerable and resilient traits for a stock and assist with narrowing the playing field of potential E/H/C indicators to monitor. When combined with the life history conceptual model, potential mechanisms that influence the stock should emerge.

Stock Report Card: The region-wide report cards from the Ecosystem Considerations chapter identify the top ten indicators for understanding change in the four Alaska LMEs (Zador 2015). In general, one to two indicators were selected by a group of experts to represent broad categories of the different trophic levels of the LME (e.g. physical processes, human dimensions). Along with the indices, overall mean and variance are shown with successive high and low periods highlighted by color code. The most recent five year mean and trend are provided using symbol indicators. Finally the regime shifts and current year are also delineated (Zador et al., 2016). If a series of E/H/C indicators can be identified for a given stock or stock complex using the stock life history conceptual model, stock profile, and/or auxiliary knowledge from current ecosystem research projects, then a stock-specific report card should be developed following the same format as the Ecosystem Considerations report. In this way the stock-specific report cards use an established and consistent format for viewing in the SPEC that is easily related to the LME report cards in the Ecosystem Considerations report.

We suggest an organization for a SPEC report card that first includes the relevant spatial or temporally trending stock assessment indices (e.g. recruitment estimates, spawning stock biomass) for comparison with other indicators. Following this, general categories of ecosystem, habitat, and climate (E/C/H) indicators should be selected that represent potential mechanisms identified through the assessment of the life history conceptual model and stock profile. Ecosystem indicators for use in the SPEC report card would typically refer to estimates of the population status (e.g. recruitment, total biomass), consumption (e.g. diet, stomach fullness), condition (e.g. mass, energy density), and diversity (e.g. evenness, spatial distribution). Habitat data includes the indices of the physical environment (e.g. bottom temperature) or biological environment (e.g. chlorophyll *a*) as well as what is typically considered essential fish habitat data (e.g. rocky substrate). Climate data refers to the large scale indicators (e.g. El Nino Southern Oscillation, Pacific Decadal Oscillation) and any climate/ecosystem model results (e.g. ROMS indices, IBM trajectories). Additional indicators (e.g., economic time series) may also be included that represent the stock profile factors of interest for a given stock or stock complex. A description of the indicators and justification for selection should also accompany the report card.

Where applicable, we used the conceptual model to organize the report card indicators by life history stage so that a hypothesized mechanism may be easier to track through the proxy indicators. One example of this is the Ocean Domain Dynamic Synergy or ODDS conceptual model put forward by Shotwell et al. (2014) for sablefish. They propose that a strong year class of sablefish relies on the compounding effects of three separate mechanisms operating from offshore pelagic to the nearshore settlement life stages. This type of sequential development could be used to organize the relevant indicators generated for many stocks and the associated report card may serve as a useful tracking system for top proxies.

Ecosystem Terms of Reference (Eco-TOR)

Once the baseline SPEC has been created for a stock or stock complex, the elements may be used in concert to identify ecosystem-based terms of reference for future research. The overall ecosynthesis rating and the stock profile may be used to identify clear vulnerabilities for the stock and/or data gaps that require further investigation. Additionally, the Annual Guidance Memo and/or Science Plan for a given science center as well the council and regional office research priorities are also areas for identifying potential eco-TOR. For the North Pacific Region, groundfish stocks are on a five-year center of independent experts (CIE) review schedule where a large variety of TOR are presented for a given stock, stock complex, or stock guild. The CIE reviews may provide useful suggestions for developing eco-TOR that could be presented at the end of the SPEC within the SAFE report. The eco-TOR could be thought of as a set of ecosystem priorities for a particular stock or stock complex and can be used as a primary communication device for coordinating future research projects between the ecosystem and stock assessment communities.

Results: Example SPEC of Alaska Sablefish

We provide an example SPEC for Alaska sablefish using the data gathered from the national initiatives for Alaska groundfish. This sablefish example is in draft form as not all the initiatives have been completed and reviewed for Alaska groundfish. It should be considered solely for soliciting feedback on this proposed baseline SPEC process rather than a peer-reviewed investigation for sablefish. We will attempt a complete example for sablefish in the 2016 November assessment cycle following acceptable review of this document and agreement on the best SPEC process. We first provide background on previously identified E/H/C linkages for sablefish based on current research and then summarize the results of the baseline SPEC. Eco-TOR have recently been identified for sablefish through the more recent CIE and results of that review are listed.

E/H/C Linkages Background: Until recently E/H/C data was not specifically explored to be integrated into the stock assessment model. Rather the information has been contextual and useful for explaining recent trends in recruitment and growth. Previous reports on temporal changes in growth (Echave et al. 2012) and factors affecting sablefish recruitment in Alaska (MESA 2010) were submitted to various Plan Teams for discussing topical issues such as a sablefish EFH amendment. Recently, several projects have been completed and initiated exploring temporal trends in sablefish recruitment. A mechanistic ODDS model was proposed by Shotwell et al. (2014) that included indicators for three stages of early life history to potentially influence recruitment. Colder than average wintertime sea surface temperatures in the central north pacific associated with the path of the North Pacific polar front were suggested to create positive recruitment events for sablefish. Covariates were integrated into the recruitment deviations of the assessment model and a multistage hypothesis testing procedure combined with cross-validation and retrospective analysis were used for model selection. The impact on future projections in terms of recruitment precision and changes in female spawning biomass was also explored. Large-scale climate indices, regional upwelling, and freshwater discharge were investigated by Coffin et al. (2014), which suggested that July upwelling and eastern GOA discharge are potentially important to sablefish recruitment. Yasumiishi et al. (2015) considered biophysical nearshore influences on recruitment and found that warmer sea surface temperatures, higher chlorophyll *a*, and higher pink salmon productivity were all positively associated with sablefish recruitment estimates.

SPEC Elements Summary: The overall ecosynthesis rating for Alaska sablefish was High (Figure 1). This was based on two final scores above 3.0 for stock classification and stock prioritization. Alaska sablefish was classified as a data-rich stock with high quality data. Preliminary results of the climate vulnerability analysis suggested that this stock was in the Moderate to High category for overall sensitivity and future climate exposure scores likely due to rapid growth requirements, temperature sensitivity, and early life survival. Habitat prioritization did not show large benefits for using habitat information within the stock assessment since sablefish are generalists for habitat use. The PSA score was in the moderate range of all groundfish scores implying high productivity and low susceptibility. Stock prioritization was very high due to high commercial importance and high recruitment variability making the target frequency of the assessment set at an annual level.

Adult sablefish in Alaska are typically encountered between 200-1000 m along the continental slope, shelf gullies, and deep-sea canyons (Wolotira et al., 1993). The species is oviparous with high fecundity and spawning takes place in early spring (at depth >300 m) with a peak in March. Egg size is large with optimal temperature/salinity conditions between 4-6^{o}C and 34-35 ppt. Following hatch, larvae begin to feed and immediately swim to the surface (Mason et al., 1983) where they develop as neustonic residents. Larvae have been sampled in surface waters far from shore (160 km in southeast Alaska to 240 km in the Aleutians) and grow very quickly from 1.2 to 2 mm per day (Wing, 1997; Kendall and Matarese, 1987; Sigler et al., 2001). There is no clear transition from larvae to young-of-the-year (YOY) or age-0 sablefish. However, large, pigmented pectoral fins are a diagnostic feature of larvae as they grow and both stages appear to be obligate surface dwellers as they drift to inshore (Kendall and Matarese, 1987). Typically, by the end of the summer YOY sablefish reach nearshore fjords or bays, which serve as overwinter habitat until the following summer when juveniles begin movement to their adult habitat on the continental slope, arriving within four to five years (Rutecki and Varosi, 1997). The life history conceptual model (Figure 2) highlights the extended neustonic early life exposure period where YOY would be influenced by surface currents and cross-shelf transport as well as the rapid early growth rate and high prey specificity of the early juveniles for euphausiids.

The stock profile (Figure 3) developed for sablefish provides clear areas for concentrating development of relevant ecosystem indicators. Very high scores were calculated for recruitment variability, growth rate, commercial value, constituent demand, exposure to ocean currents, early life dispersal, movement, depth, and range. High scores occurred for mean age, juvenile prey specificity, exposure to dissolved oxygen, exposure to precipitation, exposure to sea surface temperature, temperature sensitivity, and early life survival. Habitat factors were generally low for this stock supporting the overall low habitat prioritization score. Given this profile, it seems clear that ecological indicators that may help explain high recruitment variability or influence the movement rates would be particularly relevant. Also potential indicators relating to the economic value of the stock over time could be interesting to examine. High temperature sensitivity and a subsequent high exposure to sea surface temperature changes during early life may warrant an investigation regarding thermal indicators of the ocean surface. This was in fact the main findings of Shotwell et al. (2014). High prey requirements for YOY and early juveniles as well as exposure to freshwater inputs may imply an investigation of nearshore indicators that could influence the early life survival, dispersal, and settlement. This confirms the results from Coffin and Mueter (2015), and Yasumiishi et al. (2015) and the relationships with freshwater discharge and chlorophyll *a* in the nearshore environment. Investigation on the influence of exposure to diminishing levels of dissolved oxygen could highlight an area for potential future research as shoaling of the oxygen minimum zone could influence adult movement, depth, range, and potentially the spawning cycle.

A draft report card (Figure 4) was developed for sablefish during the most recent CIE using relevant available long-term indicators that represented pressures during the different life stages. A description of each indicator is provided in Table 2. We chose to present the time series of both the recruitment estimates and the spawning stock biomass from the most recent stock assessment (Hanselman et al.,

2015) because the comparison between the two show an obvious lack of a stock-recruitment relationship for this species as periods of low spawning biomass coincide with periods of high recruitment and vice versa. This implies that environmental pressures are highly influential on sablefish recruitment rather than the level of spawning biomass. We then considered the stock profile and results of current investigations regarding sablefish recruitment to select indicators related to regional climate and early life history. The indicators for offshore sea surface temperature, Gulf-wide freshwater discharge, chlorophyll *a* in southeast Alaska nearshore, and adult pink salmon returns were all selected because they were significantly related to sablefish recruitment through various investigations (Shotwell et al., 2014; Coffin and Mueter, 2015; and Yasumiishi et al., 2015). Size of the copepod community was an indicator included in the draft Gulf of Alaska report card and provides a measure of the zooplankton community composition. In recent years, the copepod community size has been declining which often results from warming temperatures and implies that less lipid rich prey are available for the upper trophic levels. This may be a useful indicator for sablefish given their high prey specificity during their early life history stages. Coho marine survival at Auke Creek in southeast Alaska and percent sablefish in rhinoceros auklets indicators were selected because they represent two predation pressures on early juvenile sablefish. Since sablefish are relatively rare in predator diets, we consider these indicators of good feeding conditions that would also benefit sablefish rather than an indicator of targeted predation pressure. On the other hand, we also include number of sets with sperm whale depredation on the longline survey as the incidence of sperm whale predation on adult sablefish is an active area of current research and interest to the stakeholder community. This report card is a first pass at potential indicators to monitor for sablefish given what we could find in the available literature and by inspecting the Ecosystem Considerations report. The list could be adjusted to reflect the other higher scores from the stock profile when more relevant indicators are made available through future ecosystem surveys and research projects.

Ecosystem Terms of Reference: Following the evaluation of the baseline SPEC, ecosystem terms of reference or eco-TOR can be developed for future survey planning and research efforts. For sablefish, it is clear that the conceptual model, stock profile, report card and current research all put the high recruitment variability at the forefront of research priorities. Other eco-TOR topics could include developing a better understanding of the fluctuations of migration patterns and spawning timing. Depredation of sablefish by whales on longlines is also a particular area of interest from the stakeholder community as the increase in whales has made these interactions with gear more frequent. In addition to these potential topics gleaned from the SPEC elements and current research projects, a TOR for the 2016 sablefish CIE focused on understanding recruitment fluctuations within the topic of recommendations for further improvements to the sablefish assessment. Reviewer's responses addressing this TOR have just recently been received and several recommendations for future research on recruitment can be gleaned from these reviews. The following is a list of potential eco-TOR for future sablefish research:

- Using a spatially-explicit model, investigate whether certain areas disproportionately contribute to recruitment (e.g. higher recruits per spawner).
- Continue to research predictors of recruitment including oceanographic conditions and early life survival such as lipid density and isotope analysis.
- Continue to conduct ecosystem research that may be used to provide improved tactical fisheries management advice (e.g. definition of regimes, improved precision of short term recruitment forecasts, incorporation of environmental variables in long term recruitment forecasts, essential fish habitat).
- Continue research to improve understanding of spawning dynamics of sablefish (e.g. timing, location, its relationship with spatial distribution of recruitment).

Discussion and Conclusions

The concurrent nature of the national initiatives in the North Pacific Region provided a unique opportunity to develop an efficient data collection protocol. This method satisfied the data call requests for several initiatives and allowed for developing the SPEC baseline framework. The standardized SPEC elements are easy to evaluate and can be generated for any stock or stock-complex included in the national initiative analysis. For the North Pacific Region, we can use the SPEC baselines to revamp the ecosystem considerations sections of the individual stock or stock complex SAFE reports. When considered in a stepwise fashion, the SPEC elements provide a clear avenue for identifying mechanisms that influence the population dynamics of a given stock or stock complex. The overall ecosynthesis rating identifies the potential for a stock to include E/H/C data, while the life history conceptual model and profile highlight important aspects of the stock ecology and status for eventual selection of relevant indicators for the report card. Additionally, the ecosynthesis rating and the stock profile assist with identifying obvious data gaps and can be used to construct research priorities for the future.

The organization of the indicators section in the Ecosystem Considerations chapter along with the associated data access links and summary reports from the Alaska Marine Ecosystem Considerations web site (http://access.afsc.noaa.gov/reem/ecoweb/index.php) provide a valuable resource for locating potential indicators for inclusion in the SPEC report card. Other efforts from the wide variety of ecosystem surveys and research projects (e.g., IERPs, FATE) may also identify new or revised environmental indices that may be useful indicators for a given stock. Once indicators have been monitored and show consistently strong relationships with the trending assessment indices, the E/H/C indicators may be directly incorporated into the stock assessment model which is the goal of NGSA. A collection of ecosystem linkage guidelines from efforts such as the National Ecosystem Modeling Workshops (NEMoWs) are available and can assist with linking this data directly within a stock assessment model should that become feasible.

Although this work may help contribute to the AFSC mission to move toward next generation stock assessments, it is also useful to contribute to stakeholder interest/trust/buy-in. Most stakeholders are very unlikely to peruse the Ecosystem Considerations report or be able to synthesize that information into how that affects their stock of interest. Often due to time constraints for estimating stock assessment models and producing large SAFE reports, recommended low quotas are given a vague justification of "recruitment failure" or some other unknown environmental driver. The standardized format of the baseline SPEC allows for a clear and consistent assessment of potential influential ecosystem drivers using data that is collected similarly across the nation. Placing this analysis within the individual SAFE reports would put information regarding potential explanations for variable quotas into one place for stakeholders to review and think about their future investments into their stock of interest.

Our example baseline SPEC using information on sablefish highlights how the different SPEC elements support many of the results of the current investigations regarding mechanisms influencing sablefish recruitment. However, the nature of a baseline, is just that, a beginning. A wide-variety of auxiliary E/H/C data are available that could supplement and enhance this baseline. A life history table organized by life stage and biological traits would be a very useful companion to the life history conceptual model picture and provide more detail than can be illustrated. Although habitat prioritization was not high for sablefish, other stocks (e.g. rockfish) with a higher HAP score may benefit from including information on EFH and associated habitat suitability models to start the process of integrating habitat information into the stock assessment. Output from trophic models and individual based models may also be useful for highlighting the connectivity of a species within the food web and across their range and depths. The report card may also be updated as new indicators become available from longer-term surveys. One example for sablefish is a new proposal to gather samples through the sablefish life history and determine energetic choke points from lipid analyses. Once a baseline energy curve can be established, samples from any survey in any given year can be compared to the standard curve to determine if the stock was healthy in that year at that life stage. Over time, this could be turned into an indicator that could be evaluated in the sablefish report card. The fluid nature of the SPEC report card allows for qualitative assessment of the indicators as they mature. This allows the stock assessment scientist time to monitor the indicator and eventually determine when/if it may be used in an extended stock assessment model (ESAM) format or for developing projections of future climate change for a management strategy evaluations (MSE).

We suggest that a feedback loop also be established between the ecosystem and assessment communities so that as indicators are developed, they are used appropriately. Avenues for this type of feedback system are available through the variety of RFP initiatives and fully integrative programs like the IERPs. However, products from these projects often do not reach the general stock assessment community and stock-specific indices are somewhat lost during the production of whole ecosystem indicators. An alternative might be to provide a forum for communication that is associated with the list of available indicators and associated best practices for the indicators guideline. One model for this is the CAPAM technical workshops that are designed to understand how best to model particular elements of population assessments. An example of implementation for the SPEC feedback workshop would be to pick a specific assessment input such as recruitment, and setup a workshop to provide examples and guidance on E/H/C indicators particular to that input. Another forum might be to setup an E/H/C indicators database on a data portal such as AKFIN where most of our stock assessment data currently resides. Contributors would also provide a short detail of the indicator that would be useful background for the assessment scientists. To some extent, contributors to the Ecosystem Considerations chapter already do this and the current descriptions could be tailored to include a section on implications for single-species assessment rather than the ecosystem wide implications.

Regardless of implementation of the feedback loop, the baseline SPEC framework starts the conversation of whether a stock or stock complex should include E/H/C linkages and takes the first steps toward integrating that information into the stock assessment process. This is essentially a bottom-up EAFM from the perspective of the individual SAFE reports, while the Ecosystem Considerations report would be the top-down representation of EAFM. The baseline SPEC elements and eco-TOR set the stage for future collaboration and research projects that can be tailored to fit the stock needs. Additionally, since the SPECs would be consistent between stocks or stock complexes, similar linkages may be identified between stocks and allow for more efficient allocation of resources to fund process studies that support the proposed extended E/H/C aspects of the stock assessment.

Acknowledgements

We would like to thank Chris Lunsford for his careful edits and suggestions on this draft SPEC report and Mandy Lindeberg for her assistance with the life history conceptual model. This is a new baseline that may potentially be applied across regions and we welcome continued discussion to make this a useful section for both the stock assessment and ecosystem communities.

References

Coffin, B., and F. Mueter. 2015. Environmental covariates of sablefish (Anoplopoma fimbria) and Pacific ocean perch (Sebastes alutus) recruitment in the Gulf of Alaska. Deep Sea Res. II. Special Issue. http://dx.doi.org/10.1016/j.dsr2.2015.02.016.

Echave, K.B., Hanselman, D.H., Adkison, M.D., Sigler, M.F. 2012. Inter-decadal changes in sablefish,Anoplopoma fimbria, growth in the northeast Pacific Ocean. Fish. Bull. 210: 361-374.

Hanselman, D.H., Lunsford, C.R., and Rodgveller, C.J. 2015. Assessment of the sablefish stock in Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA and

BS/AI. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. pp. 283-424.

Hare JA, Morrison WE, Nelson MW, Stachura MM, Teeters EJ, Griffis RB, et al. 2016/ A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLoS ONE 11(2): e0146756. doi:10.1371/journal.pone.0146756

Kendall, A.W., and Matarese, A.C. 1987. Biology of eggs, larvae, and epipelagic juveniles of sablefish, Anoplopoma fimbria, in relation to their potential use in management. Marine Fisheries Review 49(1): 1-13.

Levin, P.S., M.J. Fogarty, S.A. Murawski, and D. Fluharty. 2009. Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. PLOS Biology 7(1): 23-28.

Livingston, P. (ed.). 1999. Ecosystem Considerations for 2000, Appendix D. *In* Stock Assessment and Fishery Evaluation Report, North Pacific Fisheries Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. 140 pp.

Mason, J.C., Beamish, R. J., and McFarlane, G.A. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (Anoplopoma fimbria) off the Pacific coast of Canada. Can. J. Fish.Aquat. Sci. 40: 2126-2134.

MESA. 2010. Factors affecting sablefish recruitment in Alaska. Report submitted to North Pacific Fishery Management Council, November, 2010. 16 pp

Methot Jr., R. D. (editor). 2015. Prioritizing fish stock assessments. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-152, 31 p.

Morrison, W.E., M. W. Nelson, J. F. Howard, E. J. Teeters, J. A. Hare, R. B. Griffis, J.D. Scott, and M.A. Alexander. 2015. Methodology for Assessing the Vulnerability of Marine Fish and Shellfish Species to a Changing Climate. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OSF-3, 48 p.

Mundy, P.R. (ed.). 2005. The Gulf of Alaska: biology and oceanography. Alaska Sea Grant College Program report. University of Alaska Fairbanks. AK-SG-05-01. 214 p/

NMFS. 2010. Marine fisheries habitat assessment improvement plan. Report of the National Marine Fisheries Service Habitat Assessment Improvement Plan Team. U.S. Dep. Commer., NOAA Tech Memo. NMFS-F/SPO-180, 115 p.

NMFS. 2011. Habitat Assessment Prioritization. Report by the Habitat Assessment Prioritization Working Group. Internal report, NMFS White Paper. Office of Science and Technology, NMFS, NOAA. Silver Spring, MD. 41 p.

NMFS. 2012. Regional habitat assessment prioritization for California stocks. Report of the Southwest Regional Habitat Assessment Prioritization Working Group. Internal report, NMFS White paper. Office of Science and Technology, NMFS, NOAA. Silver Spring, MD. 20 p.

Ormseth, O.A. and Spencer, P.D. (2011) An assessment of vulnerability in Alaska groundfish. Fish. Res.112:127–133.

Patrick, W.S., P. Spencer, J. Link, J. Cope, J. Field, D. Kobayashi, P. Lawson, T. Gedamke, E. Cortés, O.A. Ormseth, K. Bigelow, W. Overholtz. 2010. Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. Fish. Bull., 108: 305–322.

Rutecki, T.L. and Varosi, E.R. 1997. Distribution, age, and growth of juvenile sablefish, Anoplopoma fimbria, in Southeast Alaska. In M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 45-54. NOAA Tech.Rep. 130.26.

Shotwell, S.K., D.H. Hanselman, and I.M. Belkin. 2014. Toward biophysical synergy: Investigating advection along the Polar Front to identify factors influencing Alaska sablefish recruitment. Deep-Sea Res. II, 107:40-53. http://dx.doi.org/10.1016/j.dsr2.2012.08.024.

Sigler, M.F., Rutecki, T.L., Courtney, D.L., Karinen, J.F., and Yang, M.S. 2001. Young of the year sablefish abundance, growth, and diet in the Gulf of Alaska. Alaska Fishery Research Bulletin 8(1): 57-70.

Spencer, P., M. Canino, J. DiCosimo, M. Dorn, A.J. Gharrett, D. Hanselman, K. Palof, and M. Sigler. 2010. Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans. 40 p.

Townsend, H. M., J. S. Link, K. E. Osgood, T. Gedamke, G. M. Watters, J. J. Polovina, P. S. Levin, N. Cyr, and K. Y. Aydin (editors). 2008. National Marine Fisheries Service Report of the National Ecosystem Modeling Workshop (NEMoW). U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-87, 93 p.

Wing, B.L. 1997. Distribution of sablefish, Anoplopoma fimbria, larvae in the Eastern Gulf of Alaska. In M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 13-26. NOAA Tech. Rep. 130.

Wolotira, R. J. J., T. M. Sample, S. F. Noel, and C. R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-1984. NOAA Tech. Memo. NMFS-AFSC-6. 184 pp.

Yasumiishi, E.M., S.K. Shotwell, D.H. Hanselman, J.A. Orsi, and E.A. Fergusson. 2015. Using salmon survey and commercial fishery data to index nearshore rearing conditions and recruitment of Alaskan Sablefish. Marine and Coastal Fisheries. 7 (1): 316-324.

Zador, S. (ed.), 2015. Ecosystem Considerations 2015, *In* Stock Assessment and Fishery Evaluation Report, North Pacific Fisheries Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Zador, S., Holsman, K., Aydin, K., Gaichas, S., 2016. Ecosystem Considerations in Alaska: the value of qualitative assessment. ICES Journal of Marine Science, published online August 22, 2016, doi:10.1093/icesjms/fsw144.

Table 1: Draft profile table, SAP = stock assessment prioritization, HAP = habitat assessment prioritization, CVA = climate vulnerability analysis, PSA = productivity/susceptibility analysis

Type	Factor/Attribute	Description	Value	Cost/Benefit
Stock Status	Fishing Mortality	Based on fishing mortality rates and limits, scored in SP	0 to 5	Cost – reduce stock size
Stock Status	Recruitment Variability	Estimated in stock assessment model, continuous in SP	0.3 to 1.6	Cost – unstable population
Stock Status	Growth Rate	To estimate the relative productivity of the stock, continuous in SP and CVA.	0.02 to 0.45	Benefit – avoid predation
Stock Status	Mean Age	To determine the resilience of a stock to changes in recruitment and develop target assessment frequency, continuous in SP.	2 to 31	Benefit – more resilient
Stock Status	Total Mortality	To determine the resilience of a stock due to natural and fishing pressures that diminish older age groups, continuous in SP.	0.04 to 1.9	Cost – less resilient
Stock Status	Stock Abundance	Based on the most recent spawning biomass, targets and limits, scored in SP.	0 to 5	Cost – higher is overfished
Habitat	Habitat Specificity – Adult	To determine, on a relative scale, if the adult stock is a habitat generalist or a habitat specialist while incorporating information on the type and abundance of key habitats, scored in CVA, HAP.	0 to 4	Cost – more requirements for specialist
Habitat	Habitat Specificity – Juvenile	To determine, on a relative scale, if the juvenile stock is a habitat generalist or a habitat specialist while incorporating information on the type and abundance of key habitats, used in CVA, HAP.	0 to 4	Cost – more requirements for specialist
Habitat	Direct Habitat Degradation	To determine if the habitat on which the stock depends has degraded due to anthropogenic or direct effects, scored in CVA, HAP.	0 to 4	Cost – loss of habitat
Habitat	Habitat Vulnerability	To determine if the stock is dependent on vulnerable habitats for a critical life stage, scored in CVA, HAP.	0 to 4	Cost – more requirements
Ecosystem	Predation – Adult	To determine, on a relative scale, if the adult stock has a wide variety of predators or few, used in CVA.	0 to 4	Cost – high predation
Ecosystem	Predation – Juvenile	To determine, on a relative scale, if the juvenile stock has a wide variety of predators or few, used in CVA.	0 to 4	Cost – high predation
Ecosystem	Prey Specificity – Adult	To determine, on a relative scale, if the adult stock is a prey generalist or a prey specialist, scored in CVA.	0 to 4	Cost – specific food needs
Ecosystem	Prey Specificity – Juvenile	To determine, on a relative scale, if the juvenile stock is a prey generalist or a prey specialist, used in CVA.	0 to 4	Cost – specific food needs
Economics	Commercial Index	To measure a stock's commercial importance with a non-linear ranking based on landed catch, scored in SP.	0 to 5	Benefit – worth more to sustain
Economics	Recreational Index	To measure a stock's recreational importance using supplemental data on the	0 to 5	Benefit – worth more to sustain

Type	Factor/Attribute	Description	Value	Cost/Benefit
		estimated recreational harvest where available, scored in SP.		
Economics	Subsistence Index	To measure a stock's subsistence importance using supplemental data on estimated subsistence harvest, where available, scored in SP.	0 to 5	Benefit – worth more to sustain
Economics	Non-catch Value Index	To measure value placed on the stock that is not associated with harvest (e.g., public sentiment for protection), scored in SP.	0 to 5	Benefit – worth more to sustain
Economics	Constituent Demand Index	To measure constituent demand for excellence in assessment of stock (e.g., choke stock), scored in SP.	0 to 5	Benefit – worth more to sustain
Climate	Ocean Currents	To evaluate changes in large-scale circulation, scored in CVA.	0 to 4	Benefit
Climate	Dissolved Oxygen	To evaluate the shoaling of the oxygen minimum zone.		Cost
Climate	Ocean pH	To determine if there are changes in mean ocean pH comparing the 1956–2005 to 2006–2055 periods. pH represents ocean acidification, scored in CVA.	0 to 4	Cost
Climate	Precipitation	To determine if there are changes in mean precipitation comparing the 1956–2005 to 2006–2055 periods. Precipitation is a proxy for streamflow, scored in CVA.	0 to 4	Benefit
Climate	Sea Surface Temperature	To determine if there are changes in mean ocean surface temperature comparing the 1956–2005 to 2006–2055 periods, scored in CVA.	0 to 4	Cost
Climate	Sea Surface Salinity	To determine if there are changes in mean ocean surface salinity comparing the 1956–2005 to 2006–2055 periods, scored in CVA.	0 to 4	Cost
Biology	Depth Index	To estimate the stock utilization of varies depths within the water column, continuous in CVA.	0 to 1000	Benefit – deep is safe
Biology	Range Index	To estimate the latitudinal limits of the stock range, continuous in CVA.		Benefit – wide range resilient
Biology	Movement Index	To estimate the ability of the stock to move to a new location if their current location changes and is no longer favorable for growth and/or survival, scored in CVA.	0 to 4	Benefit – move more resilient
Biology	Spawning Cycle	To determine if the duration of the spawning cycle for the stock could limit the ability of the stock to successfully reproduce if necessary conditions are disrupted by climate change, scored in CVA.	0 to 4	Cost, more time periods to spawn resilient
Biology	Early Life Survival	To determine the relative importance of early life history requirements for a stock, scored in CVA.	0 to 4	Cost – more requirements
Biology	Early Life Dispersal	To estimate the ability of the stock to colonize new habitats when/if their current	0 to 4	Benefit – move more resilient

Type	Factor/Attribute	Description	Value	Cost/Benefit
		habitat becomes less suitable, scored in CVA.		
Biology	Settlement Requirements	To determine the relative importance of juvenile settlement requirements, used in CVA.	0 to 4	Cost – more requirements
Biology	Temperature Sensitivity	To use the distribution of the species as a proxy for its sensitivity to temperature, scored in CVA.	0 to 4	Cost – more is sensitive
Biology	Acidification Sensitivity	To estimate a stock's sensitivity to ocean acidification based on its relationship with"shelled species."(followed Kroeker et al. 2012.), scored in CVA.	0 to 4	Cost – more is sensitive

Table 2: Draft indicator descriptions – Alaska Sablefish (*in progress*, not peer-reviewed)

Indicator	Description
Trending Stock Assessment Time Series	
Recruitment	Estimates based on the most current sablefish stock assessment model for age 2 recruits lagged to cohort
Spawning Stock Biomass	Estimates based on the most current sablefish stock assessment, in metric tons.
Regional Climate Indicators	
Sea Surface Temperature	Surface temperature index along the North Pacific Polar Front in the central North Pacific, derived in Shotwell et al. 2014
Gulf of Alaska Freshwater Discharge	Freshwater index taken from Ecosystem Considerations GOA Report Card (Zador, 2015), similar to index from Coffin et al. 2014
Early Life History Indicators	
Chlorophyll a (Icy Strait)	In situ measurements of chlorophyll a taken from SECM survey in Southeast Alaska, from Yasumiishi et al. 2015
Copepod Community Size (CPR Transect)	Index taken from Ecosystem Considerations GOA Report Card (Zador, 2015), related to food web complexity
Adult Pink Salmon Returns	From Yasumiishi et al. 2015
Auke Creek Coho Marine Survival	Measure of predation influence on juvenile sablefish
Percent sablefish in Rhinocerous Auklet Diet	Seabird forage index useful as ecosystem indicator
Adult Indicators	
Proportion sets with sperm whales	Index from AFSC longline survey, depredation influence on adult sablefish is an area of active research

Figure 1: Draft Overall Ecosystem Rating – Alaska sablefish

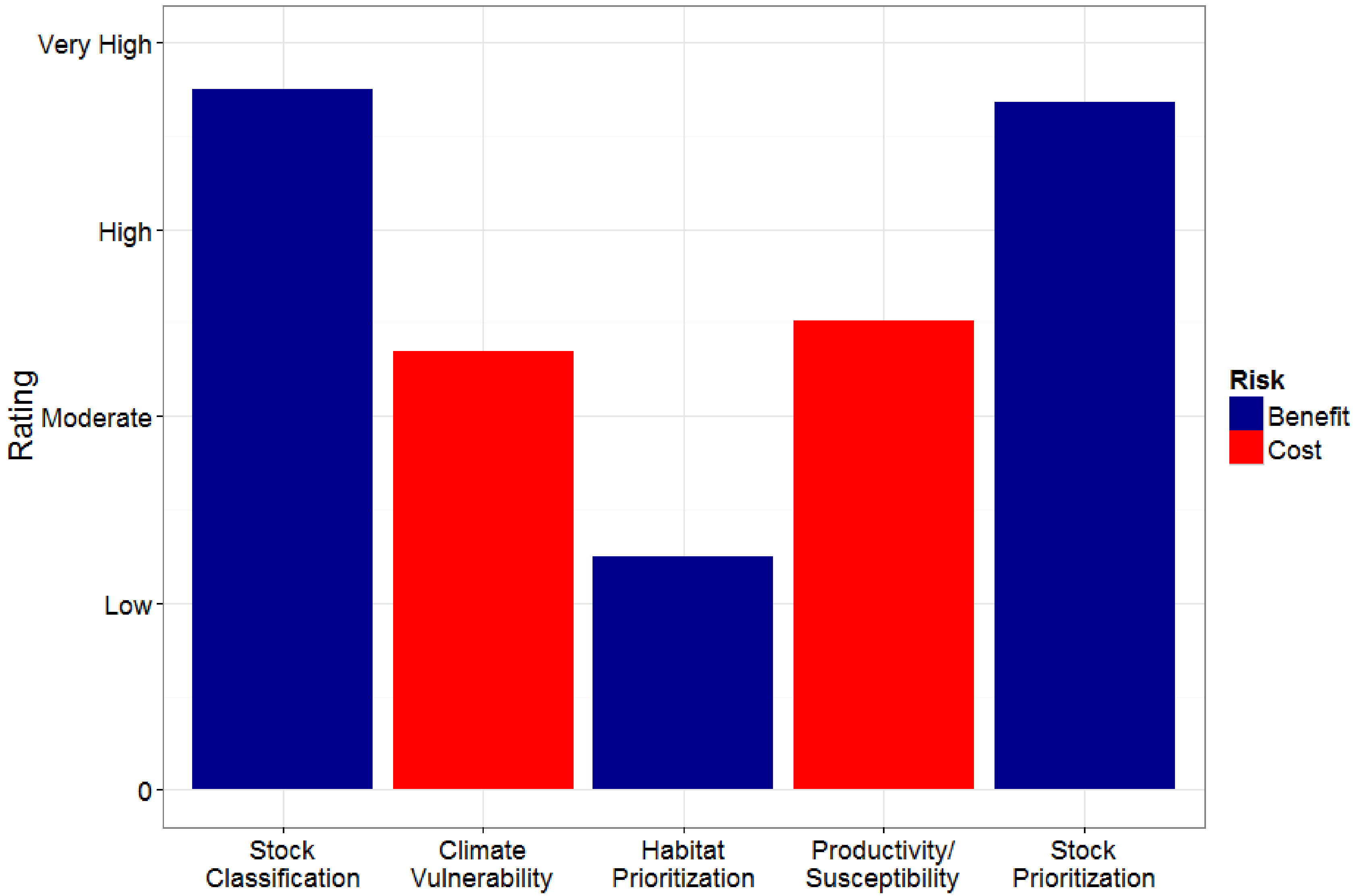

Figure 2: Draft Life History Conceptual Model – Alaska sablefish

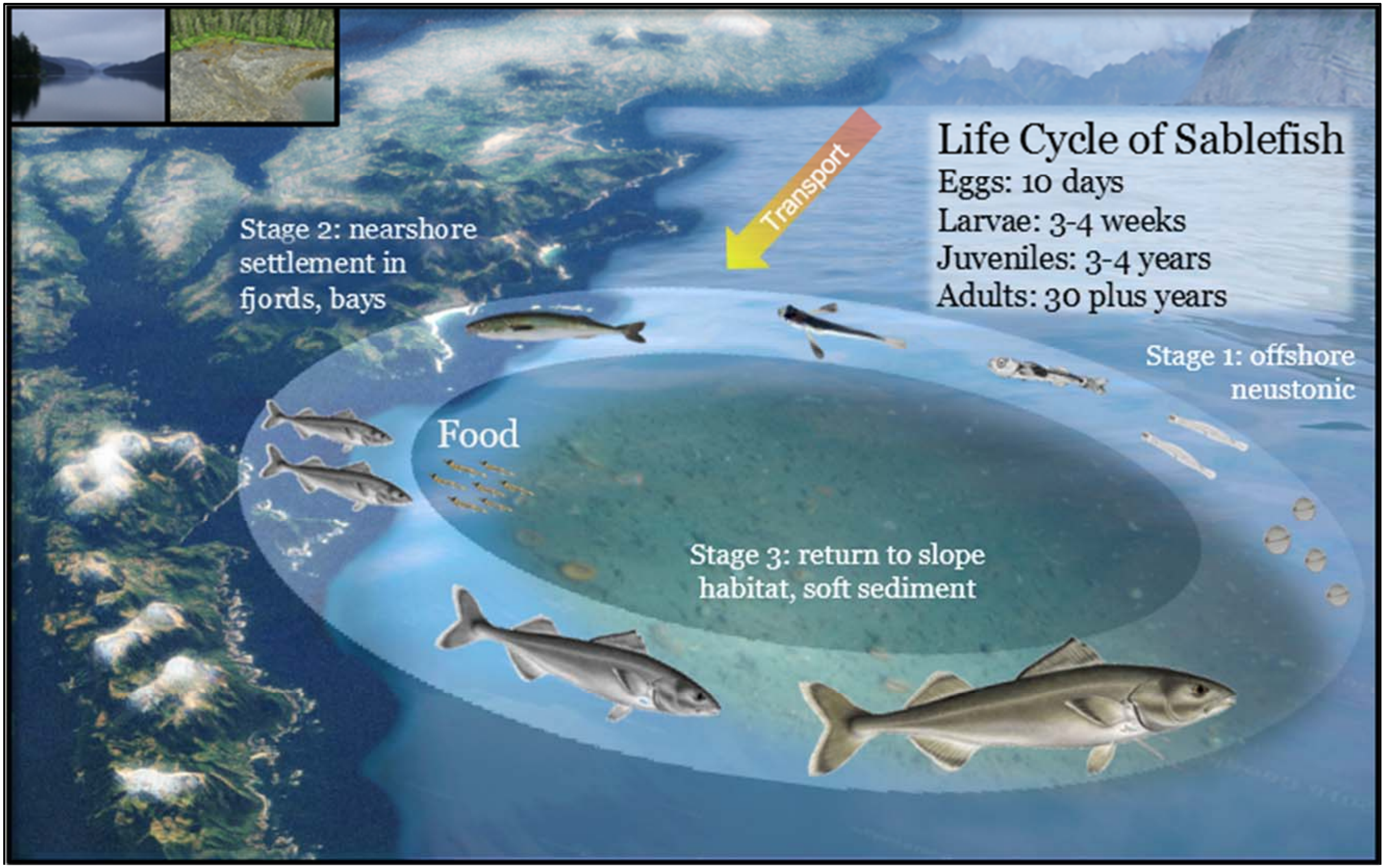

Figure 3: Draft Stock Profile – Alaska sablefish, positive sign at the end of the bar equals a benefit or opportunity for the stock while negative sign equals a cost to the stock. Colors relate to a data type.

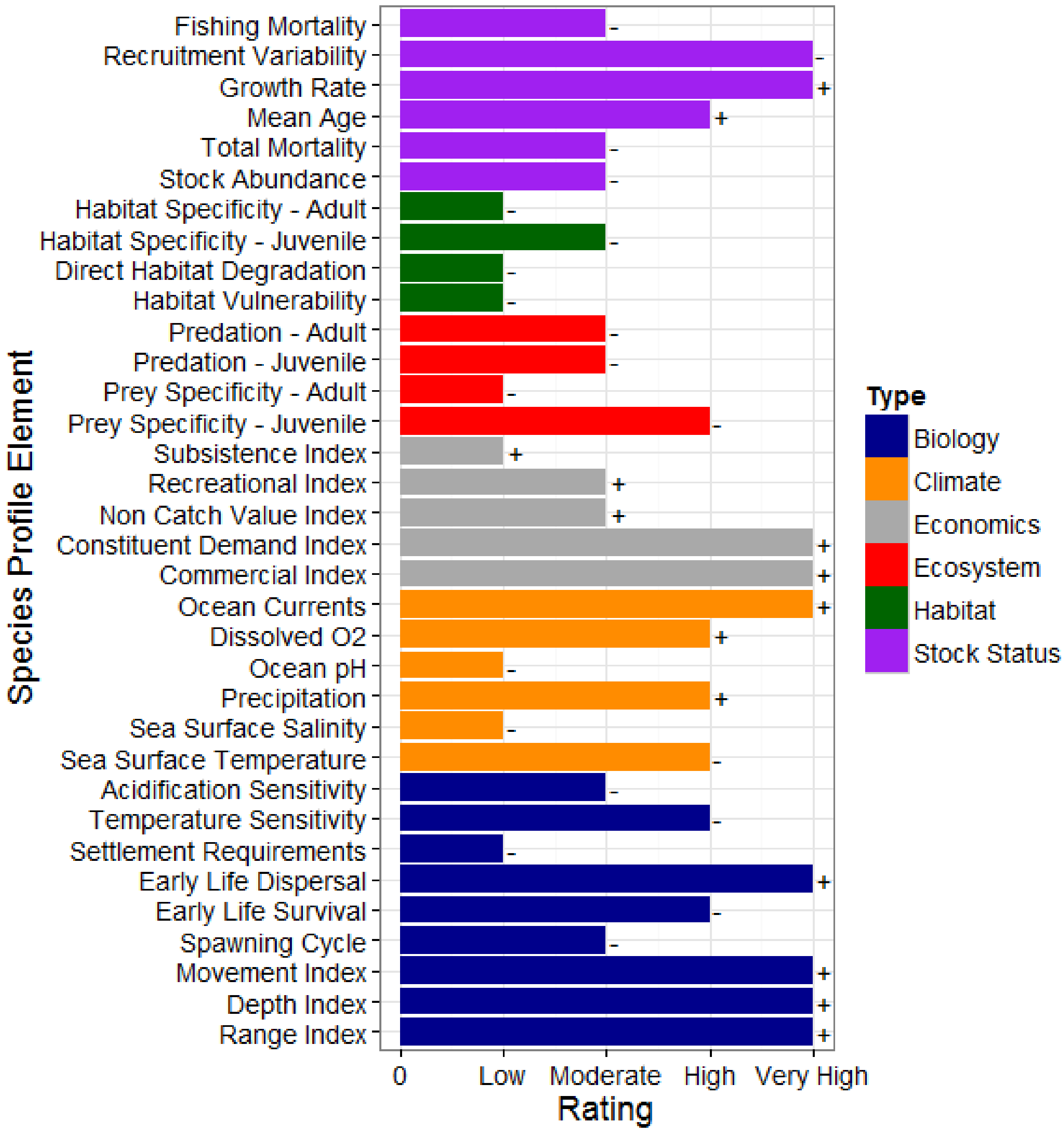

Figure 4: Draft report card based on conceptual model and SPEC profile – Alaska sablefish (indicators are not peer-reviewed and are subject to change).