"fences" and "boxes." Some shared the concern that this rigidity will concentrate the impacts of climate-related disruptions among certain user groups and places. Others noted that there can also be benefits to inflexibility; in particular, they acknowledged that sideboards and other effort limitations can help limit shifts in effort and "spillover effects" related to changing resource conditions. Looking ahead, participants shared concerns about climate change that including the loss of access to fisheries, displacement of effort, and the possibility of communities experiencing tipping or "break" points. Participants reflected that the Council may need to consider how to introduce more flexibility and allow for adaptation.

Goals, objectives, and tradeoffs

Participants recognized the importance of establishing a shared understanding of the outcomes the Council is trying to achieve—and avoid—under changing environmental conditions. Goals, objectives, and metrics for success provide the guidance needed to consider tradeoffs and evaluate potential management options. The group noted that articulating preferences and performance metrics will be critical to leveraging the capacity of scientific tools, particularly the Alaska Integrated Climate Modeling Project (ACLIM).

Goals and objectives can derive from existing federal mandates and regional guidance. At the federal level the Council process is guided by the mandates of the Magnuson-Stevens Act, including the National Standards and the National Standard guidelines. At the regional level, participants pointed to the guidance provided by the Council's Groundfish Management Policy and the objectives specified by the Alaska Groundfish Fisheries Programmatic Supplemental Environmental Impact Statement.[1] In addition, the draft Bering Sea Fishery Ecosystem Plan includes six ecosystem goals.[2] This guidance reflects values that include sustaining fisheries and communities, maintaining ecosystem structure and function, and implementing robust and precautionary harvest strategies.

Workshop participants observed that the Council could identify additional objectives or preferences that specifically address responding to and planning for change. For example, participants suggested the Council could promote qualities such as resilience and diversity of opportunity, and consider specific outcomes such as maintaining stability in catch levels (or conversely, reducing variability) and optimizing revenue. The development of goals and objectives can also be an iterative process. Scientific investigators noted it will be valuable to have additional insight from the Council community regarding the relative performance of different simulations explored through ACLIM; in other words, why one scenario is perceived as "better" than another.

Changing environmental conditions will also impact the Council's consideration of tradeoffs between goals and objectives. In particular, the group discussed tradeoffs related to the allocation of allowable biological catches (ABCs) among groundfish stocks within the 2 million mt cap on optimum yield (OY) from Bering Sea groundfish stocks. Participants questioned whether the Council might revisit and potentially increase this aggregate limit. Some also commented on the challenge of understanding the tradeoffs that result from apportioning ABCs among groundfish stocks, given the possibility of changes to stock productivity and distribution, and changing interactions between species. The group suggested that ACLIM could support the Council's ability to explore these tradeoffs.

[1] www.npfmc.org/wp-content/PDFdocuments/meetings/Management_FMP.pdf
[2] www.npfmc.org/wp-content/PDFdocuments/membership/EcosystemCommittee/Meetings2018/DRAFT_BSFEP.pdf

Risk

Workshop discussions frequently touched on the topic of risk, which is a function of the likelihood and the consequences of particular outcomes. The concept of risk is foundational to the tools and information products that are being developed to help frame the range of possible climate change scenarios, and the consequences for stocks, ecosystems, and people. In particular, ACLIM and the approach of management strategy evaluation (MSE) are intended to help frame options, risks, and tradeoffs associated with different management options relative to management goals and objectives.

Workshop discussions often addressed risk implicitly in terms of tolerance for different outcomes and the perception of "what's at stake." Participants observed that individuals perceive risks differently, and that risk perception shapes the decisions people make in response to changing conditions. The group also reflected on risk tolerance at the Council level. In general, the Council adopts a precautionary management approach that is articulated and implemented through Council policies (e.g., the Council's Ecosystem Policy and the Bering Sea OY cap). Risk was particularly prevalent in the group's discussion of identifying and responding to early warnings. The group considered the consequences of failing to identify and respond to a potential problem, and conversely, incorrectly determining that a problem exists.

Time frames

Planning for change will challenge the Council community to look beyond the typical planning horizon of the management process. Workshop presentations highlighted the wide array of products supported by the NOAA Integrated Ecosystem Assessment (IEA) program, including models, ecosystem indicators, and risk assessments. These information products can support Council decision-making within different time frames. For example, ecosystem models can provide short-term projections (e.g., 9-month forecasts) that provide insight into ecosystem conditions on an intra-annual basis. At the other end of the spectrum, ACLIM will project longer-term physical, biological, and socioeconomic changes from the present to the year 2100. Participants noted the importance of understanding how the time frames of different information inputs can support management needs, including areas of strength as well as challenges.

Participants felt that the Council process is well equipped to address short-term planning but that longer-term planning is more challenging. The group observed that the Council process is highly effective for planning in the one- to two-year time frame. This time frame reflects the predictable annual cycle of major Council processes, and information inputs that are designed to support decision making on an annual and species-specific basis (e.g. surveys, stock assessments, harvest specifications, and Ecosystem Status Reports). In contrast, participants felt that it is difficult to envision and plan for the range of scenarios that might occur in the distant future (e.g., 100 years).

The group described the medium term of three to five years as a particular "blind spot." Within this time frame, the population dynamics of stocks are affected by climate variability more than by directional trends. The three- to five-year time horizon is far enough into the future that scientists can't make assumptions based on current conditions and population structures, yet not far enough into the future that predictions of directional trends can frame the range of possible scenarios. Speakers suggested that scientists can explore the use of mechanistic approaches and ensemble modeling to determine which approach performs best for projecting outcomes within this time frame.

Resources

Workshop discussions emphasized the value of maintaining and building upon existing information foundations including fishery-independent surveys, stock assessments, and monitoring. However, the group noted that there are limited and potentially declining resources available to invest in fisheries science and data collection. The group acknowledged the need to prioritize and consider tradeoffs. For example, participants perceived that there are tradeoffs between investing in fishery-independent data collection (particularly surveys) and investing in other ecosystem information and modeling. Participants often emphasized the value of fishery-independent surveys for identifying early warning signs, including in the Gulf of Alaska and the northern Bering Sea. Some also expressed concern that information limitations will contribute to uncertainty and result in additional precaution. Participants noted that cooperative research and industry observations can help supplement limited resources (Section 3.3).

Roles and responsibilities

Workshop discussions considered how managers and stakeholders (including communities, industry, and individuals) can or should share responsibility for responding and adapting to change. The group reflected on how, where, and by whom qualities such as flexibility and resilience can be instilled, and whether this is more a function of management decisions or adaptation by stakeholders. Managers can address flexibility directly through management strategies that guide or constrain the decisions stakeholders can make in response to change. Flexibility can also be provided in other ways. For example, cooperative structures, Community Development Quota (CDQ) entities, and third-party monitoring services can support organization and information-sharing that help fleets adapt to change.

2.2 Looking ahead

Workshop participants shared their broader reflections on the challenges facing the Council and steps the Council community can take to develop capacity to manage fisheries in a changing environment. These themes of discussion include observations shared by speakers and Council leadership, in addition to the ideas explored through workshop discussions. These themes also build on the later sections of this summary that address specific topics in more depth, including learning from experience (Section 3.1), developing early warning capacity (Section 3.2), and supporting communication and information-sharing (Section 3.3). While these reflections are not intended as recommendations or consensus statements, they reflect sentiments broadly shared by the group that could help inform the Council's considerations of next steps.

Recognize that the Council is building on a solid foundation.

Participants emphasized that while climate change will introduce new challenges, the Council is building on a foundation of successful and sustainable management policies. These observations expand on the observations of "what worked well" regarding the Council's response to the decline of GOA Pacific cod.

- Biological sustainability: Participants recognized that the biological sustainability of the Council's managed stocks provides a strong advantage. While changing environmental conditions will impact managed stocks, the Council approaches these impacts with the objective of maintaining its track record of sustainable management and does not have the added burden of correcting for past overfishing.

- Ecosystem-based management: The Council and the Alaska region have more than 20 years of experience implementing ecosystem-based fisheries management. Participants felt that Alaska's marine ecosystems are healthy, and recognized the leadership exhibited by the Council and region and the steps that have been taken to maintain ecosystem productivity and function.

- Information foundations: The Council process is strengthened by information inputs that support robust harvest strategies. Participants noted that the region benefits from frequent stock assessments and consistent monitoring and fishery-independent data collection. The group also felt that the Council process is supported by cutting-edge science and tools, including sophisticated ecosystem modeling capabilities.

- People and relationships: The Council process benefits from strong working relationships, effective communication, and a high level of trust and transparency. Participants noted that the collective experience of the Council community, including managers, scientists, and the public, is an asset and that this group has shared experience working through difficult decisions. The group also commented on the inclusiveness of the Council process, particularly the Council's efforts to integrate local and traditional knowledge through the Bering Sea FEP process (Section 3.3).

Consider that adapting to change may not be a linear process.

Participants recognized that in order to adapt to changing ecosystem conditions, the Council may need to revisit past decisions. Management strategies that are based on historical access and past conditions are likely to constrain flexibility under changing ecosystem conditions. Participants reiterated the importance of learning from experience and hindsight, including the decline in abundance of GOA Pacific cod. These experiences can provide a vantage point to identify where the management framework provides or lacks flexibility, consider how to avoid or mitigate future impacts, and reflect on goals and objectives for responding to change.

Changing ecosystem conditions may also prompt the Council to re-examine broader questions and tradeoffs related to longstanding policies. Participants noted that ACLIM will provide the capability to explore the performance of different management strategies under a range of possible climate scenarios. Specifically, the group noted the potential to explore harvest control rules, as well as Council policies regarding the Bering Sea OY cap and forage fish management. Participants noted that adapting to change may involve examining the rationale for past decisions and re-evaluating whether they are fundamental to the Council's conservation and management strategies.

Anticipate that change will require confronting difficult decisions and conversations.

Responding and adapting to change will require the Council to tackle challenging conversations, particularly related to access, allocation, and impacts to subsistence. Participants emphasized the need to prepare for these difficult conversations by maintaining open dialogue and trust. The group also emphasized that the Council community needs to be willing and invested in working through these conversations. While the Council community has many shared interests, individuals also have their own preferences and priorities that may make it difficult to grapple with "big picture" conversations.

Participants also reflected on the challenge of revisiting past decisions, and the observation above that adaptation is not necessarily a linear process. The Council process is evolutionary and tends to build on previous decisions. The group observed that in a region where management strategies have performed successfully, it may be particularly challenging to accept that progress may involve stepping back from past decisions to consider new ideas and strategies.

Recognize and maintain what works well.

The Council will continue to encounter new and unexpected challenges. Participants recognized that surprises will test the management system and that no system can be perfectly equipped to handle the unexpected. The group suggested that the Council could take a measured approach to responding to change and considering ideas for adaptation. Participants reiterated that the Council process has many strengths including strong scientific foundations, a deliberate decision-making process, and robust harvest strategies. Many stated that while it is important to learn from experience, the Council process is well equipped to handle change and the Council should be cautious of making adjustments to the management process and framework. Participants also questioned whether learning from experience means making changes to current management strategies or considering this experience when making future decisions.

The group also recognized that new management challenges will continue to unfold over time. Participants noted that the Council may encounter new challenges as the abundance of GOA Pacific cod increases; for example, abundance may increase more quickly in some areas than others. Some suggested a precautionary approach to allowing access as the stock rebuilds. The group noted the potential for the Council to learn from the experiences of other regions that have managed rebuilding stocks (e.g., Gulf of Mexico red snapper) and faced shifting distributions (e.g., many east coast stocks).

Expect that climate change will introduce surprises and big questions.

Climate change will continue to impact the productivity and distribution of fishery resources. Workshop discussions focused primarily on changes in productivity, in light of the Council's recent experience with GOA Pacific cod. The group did not focus as much attention on the challenges posed by shifting distributions, though participants questioned how the Council could monitor changes and support new harvest opportunities.

Workshop speakers emphasized that under climate change scenarios, scientists and managers will be operating outside the realm of historical conditions and assumptions. While scientists can provide projections and help frame possible future scenarios, the Council community should also expect surprises. For example, speakers posed the possibility of regime shift and "tipping points," resulting in fundamental changes to the carrying capacity and structure of marine ecosystems. Sudden or dramatic changes would raise challenging questions, such as when to acknowledge that an ecosystem has changed or that a stock is not rebuilding. Speakers noted that it will be challenging to model how the Council might respond to unforeseen outcomes, and that this is an opportunity for ongoing discussion between managers and scientists. The group also noted the importance of learning from experience and conducting retrospective analyses of surprises and unexpected outcomes.

Participants noted other questions for consideration. For example, participants questioned whether it could be justifiable to increase harvest in a situation when environmental conditions are expected to increase the rate of natural mortality (as in the case of GOA Pacific cod). Participants also questioned

whether and how the Council may move from a single-species management approach toward managing at the species complex or ecosystem level.

Leverage the science and tools developed for the region.

Participants emphasized the need to utilize the ecosystem information and modeling capabilities developed by AFSC to support the Council's work. In addition to the group's focused discussion of early warnings and indicators, discussions also highlighted opportunities to leverage the emerging capabilities of ACLIM. Participants noted that ACLIM will provide the capability to further examine many of the questions, concerns and tradeoffs raised in discussion. The group emphasized the need for ongoing communication between the Council and scientific communities to further develop and refine the use of these tools. Workshop speakers emphasized that input from the Council community is critical to "getting fishing right" and modeling the interplay between ecosystem conditions, stock dynamics, management strategies, and fishing behavior. Speakers further noted that "our science is only as good as the questions we ask," and that a diversity of ideas and perspectives is important.

The group also recognized that leveraging these capabilities will enhance and expand the Council's implementation of ecosystem-based management. Participants noted that Ecosystem Status Reports are primarily used to inform the ABC-setting process and to justify additional precaution, but that the incorporation of ecosystem information into stock assessments could potentially support increases in catch levels. Looking ahead, developing the capacity to leverage new information and tools can help inform a broader range of decisions and illustrate the utility of practicing EBFM.

The Alaska Climate Integrated Modeling Project (ACLIM)

The Alaska Climate Change Integrated Modeling (ACLIM) project represents a comprehensive, collaborative effort to characterize and project climate-driven changes to the Bering Sea ecosystem, from physics to fishing communities, and to understand how different fisheries management approaches might help promote adaptation to climate-driven changes and long-term sustainability in fish and shellfish populations. Results will include projections of the future ecosystem state of the Bering Sea, risk of changes in catch under different management tools, and spatial and temporal schedules of expected change. A core component of the work is to evaluate alternative management strategies to adapt to changing conditions. ACLIM would like feedback from the council and stakeholders about potential strategies and metrics to evaluate during the next phase of the project.
Excerpted from workshop abstract

Develop strategies for making big challenges manageable.

Participants emphasized the need to frame big challenges in manageable ways, and to identify specific opportunities for gaining traction on next steps and workshop discussions. For example, workshop discussions highlighted effective "storytelling" as a strategy for helping managers and stakeholders understand the causes and potential consequences of change. Participants often commended scientists for providing a clear and cohesive explanation of factors that contributed to the decline of GOA Pacific cod. The group suggested that framing change in terms of possible scenarios and stories can enable the Council community grapple with future challenges and possible long-term outcomes in a more accessible way. Workshop participants also commented on the value of breaking down big next steps into actionable, "bite-sized" pieces. In addition, they noted the importance of clearly identifying opportunities for the Council community to participate and contribute their ideas and perspectives.

3. Managing in a changing environment: Issues in focus

3.1 Lessons learned from Gulf of Alaska Pacific cod

The Ecosystem Research Workshop provided participants with a timely opportunity to reflect on the Council's experience with Gulf of Alaska (GOA) Pacific cod, which experienced a sharp decline in abundance linked to changing environmental conditions. In December 2017 the Council approved a 2018 catch limit recommendation of 18,000 mt for GOA Pacific cod. This represents an 80% reduction in catch level compared to 2017. The decline in GOA Pacific cod was linked with anomalous warm conditions in the Gulf of Alaska from 2014-2016, which contributed to an increase in natural mortality and low recruitment.

GOA Pacific cod: What happened, and how do we know?

The Pacific cod stock in the Gulf of Alaska experienced a drastic decline in biomass and abundance since 2015. The decline was most obvious in a sharp reduction in the 2017 bottom trawl survey biomass, which had a very tight confidence interval because Pacific cod were consistently encountered in very low abundances throughout the survey region. The 2017 survey estimates were a 71% decrease in abundance and a 58% decrease in biomass compared to the 2015 estimates. Low densities in much of the survey region were corroborated by reduced catch rates in the fishery in 2017. Three other fishery independent surveys in 2018 also support the decline in abundance and biomass (Alaska Fishery Science Center longline survey, International Pacific Halibut Commission longline survey, and the State of Alaska Department of Fish and Game small mesh trawl survey).

Evidence from National Oceanic and Atmospheric Administration (NOAA) research suggests unfavorable ocean conditions are a natural cause of the disaster. The Gulf of Alaska experienced anomalous warm conditions throughout the water column starting in 2014 through the beginning of 2017. The marine heat wave affected the entire ecosystem and, in particular, affected prey availability for upper trophic level predators as was evident in a number of ecosystem indicators (groundfish condition, seabird die-offs, and other unusual marine mammal mortality events), including the poor condition of Pacific cod (negative weight-at-length anomalies). It is believed that the warm water throughout the time period, including winters, increased the metabolism of Pacific cod and reduced available forage resulting in poor body condition and increased mortality. The warm water also impacted Pacific cod egg production and larval survival, greatly reducing recruitment during these years. These factors suggest the Pacific cod decline is due to reduced survival and new recruitment because of the anomalous environmental conditions.
Summary provided by Steve Barbeaux, NMFS AFSC

Workshop participants identified several reasons why the decline in abundance of GOA Pacific cod provides an opportunity for the Council community to learn from experience. First, this scenario offers a preview of the types of climate-related impacts and disruptions that the region may experience in the future. This experience provides a starting point and a shared frame of reference to reflect on the capacity of scientists, managers, and stakeholders to identify and respond to changes. GOA Pacific cod is also viewed by managers and stakeholders as a cohesive story due to the efforts by stock assessment and ecosystem scientists to communicate the implications of ecosystem factors for the population dynamics of the stock. Finally, participants shared mixed perspectives on whether the region's response to GOA Pacific cod should be considered a success. They felt that this example illustrates many positive attributes and strengths of the management system, but also highlights perceived weaknesses,

challenges, and opportunities for improvement. Participants identified the following lessons learned. These reflect prominent themes of discussion, though do not necessarily indicate consensus among the group.

GOA Pacific cod highlights strengths of the Council process and foundations.

Participants identified many attributes of the Council process that performed well and enabled scientists and managers to identify and respond to change.

- Attributes of the system: Participants felt that the Council's response to GOA Pacific cod reflects a management process that is working as intended. Specifically, participants felt that the process provides the flexibility to respond to new information and challenges, and that the Council's harvest strategies are robust to changing conditions. Participants also emphasized the value of investing in consistent, high-quality information inputs including surveys, observer coverage, and stock assessments.

- Attributes of people and relationships**:** Participants felt that a high level of trust and strong working relationships among managers, scientists, and stakeholders supported broad acceptance of the science and the Council's decision to reduce harvest levels in 2018. The group also commented on the effectiveness of communication and outreach by scientists and managers. For example, participants commented on the value of the AP and Council receiving a presentation on the status of GOA Pacific cod in October 2017, well in advance of the Council's final action on groundfish harvest specifications, and expressed support for continuing this approach. Participants also commented on the value of early and ongoing communication between the GOA Pacific cod stock assessment author, the GOA Groundfish Plan Team, and the Council's SSC.

- Attributes of the scenario**:** Participants felt that their own observations and experience corroborated and aligned with other information inputs. For example, participants described seeing changes in fishing effort and the availability of Pacific cod, and the impact of changing environmental conditions to other species (e.g., increased mortality of birds and marine mammals).

The group noted that strengths and weaknesses are closely related, and that a strength of the process can also become a weakness if these attributes are not maintained over time. In particular, participants expressed concern about the frequency and availability of funding for fishery-independent surveys. Some felt that the Gulf of Alaska bottom trawl survey should be conducted annually.

Early warnings are valuable, but the implications are unclear.

Participants felt that the warning signs of ecosystem change, and the potential impacts to GOA Pacific cod, could have been identified and more explicitly considered prior to the fall of 2017. However, many observed that earlier identification of the problem would not necessarily have translated to a different outcome. The group also recognized the tendency for information to take on added significance in hindsight ("hindsight is 20/20."). Participants raised a number of questions and considerations with regard to early warnings, including what advice the SSC could have provided to the Council, what steps the Council could have taken in response, and whether managers and stakeholders would have been willing to take proactive measures, for example by reducing harvest.

Participants also questioned whether any these steps would have altered the trajectory of the stock. Many felt that an early warning may not have resulted in a different outcome, though it could have provided stakeholders, the industry, and communities with more time to plan ahead. Some also questioned whether an early warning could have triggered other measures such as an additional survey or a phase-in of quota reductions over multiple years. Another suggestion was to look to the decline of GOA Pacific cod as a form of early warning and consider the impacts this might have to the Gulf of Alaska ecosystem in the near future. The topic of early warnings is addressed further in Section 3.2.

The impacts and outcomes are still to be determined.

Participants emphasized that the decline in productivity of GOA Pacific cod, and the Council's response, are only a starting point and that this will be an ongoing learning experience. The GOA groundfish fishery is very complex and involves many gear types, sectors, and seasons. The group observed that biological outcomes, and the social, economic, and management implications of this scenario for individuals, businesses, and communities will continue to develop over time. These longer-term outcomes will frame whether the response to GOA Pacific cod it is ultimately considered a successful response to change.

The group identified possible short-term management implications including changing patterns of effort, displacement, impacts to other fisheries (including Bering Sea Pacific cod and fisheries in Alaska state waters), bycatch constraints, the loss of other landings associated with Pacific cod, impacts to observer coverage, and changes to catch deliveries and processor openings. They also noted that there are constraints in place that limit spillover effects to other fisheries. Participants felt that the Council's ability to manage the fishery inseason in 2018 and constrain catch within the annual catch limit will be an important metric for success. The group observed that it will take more time to assess whether scientists correctly interpreted the decline of Pacific cod. It will also take time to evaluate whether managers took the appropriate steps to rebuild the stock, though it was noted that cause and effect cannot be conclusively determined. Finally, participants recognized that the Council will encounter new challenges related to providing opportunity as the stock increases in abundance. For example, there may be a perceived mismatch between localized observations of abundance, and stock abundance at an ecosystem scale.

Future climate-related changes and disruptions may play out differently.

Participants observed that future climate-related impacts to the Council's managed fisheries may be different than the impacts to GOA Pacific cod, and that the experience gained from this scenario may not be directly translatable. For example, the group questioned whether similar "warm blob" conditions in the future would result in similar impacts. They also noted that some of the attributes of GOA Pacific cod and the management process that performed well in this scenario may not hold true in the future. For example, the alignment between ecosystem indicators, fishery-independent surveys, and personal observations of change that helped foster trust in the case of Pacific cod may not be apply in other scenarios. Participants noted that impacts to data-poor and constraining stocks would be particularly challenging. Looking ahead, the group observed that other changes, such as changes to council composition or economic conditions, could influence how the Council responds to changing conditions.

3.2 Early warnings and red flags

Workshop discussions emphasized the value of early warnings and "red flags" for alerting the Council community to changing ecosystem conditions and potential impacts to managed stocks. These discussions built on presentations about ecosystem indicators and the GOA Pacific cod stock assessment and were also framed by the group's reflection on lessons learned from GOA Pacific cod. Many participants felt that in hindsight, the ecosystem changes and resulting impacts to GOA Pacific cod could have been identified earlier.

The concept of early warnings can be interpreted in multiple ways. Workshop discussions focused primarily on early warnings in the context of observations, Ecosystem Status Reports, and stock assessment information. Participants identified several benefits of an effective early warning process.

- Providing additional response time: Participants emphasized that early warnings provide all participants in the Council process, including scientists, managers, and stakeholders, with more time to consider information and determine how to respond.

- Distributing responsibility: Participants suggested that strengthening the use of early warnings could vest the responsibility for reviewing and considering ecosystem information with more people and at multiple points in the process.

- Leveraging available information: Participants observed that strengthening the use of early warnings could improve utilization of existing information, and also provide the opportunity to consider other types of information, such as local and traditional knowledge (LTK) and industry observations (Section 3.3).

Participants explored how the Council community could build upon the use of ecosystem indicators to enhance the region's ability to identify and respond to early warnings. The group primarily focused on opportunities to strengthen the indicator review process and to support coordination between ecosystem and stock assessment scientists. Many viewed strengthening the indicator review process as improving an existing process, though some expressed concern that this would introduce more complexity.

3.2.1 Strengthening the review of ecosystem indicators

Scientific review

Participants felt that strengthening or formalizing the ecosystem indicator review process could improve the region's ability to detect early warnings by supporting a methodical examination of ecosystem information. Ecosystem information that is not directly incorporated into stock assessment or ecosystem models is considered in a qualitative and contextual way. Participants observed that a more systematic and structured process for considering this information could improve its utility to the management process and provide stronger justification for determining whether or not a response is warranted.

In particular, workshop participants reflected on the challenge of reconciling signals from different information sources. For example, ecosystem indicators pointed to anomalous conditions in the Gulf of

Alaska from 2014 to 2016, but the impacts to the productivity of GOA Pacific cod were not recognized until the 2017 GOA bottom trawl survey and Pacific cod stock assessment. Participants observed that a more systematic approach to evaluating ecosystem indicators relative to stock assessments might enable scientists to identify red flags sooner.

Workshop speakers[3] introduced a conceptual "okay/not okay" framework (Figure 1) for evaluating ecosystem and stock assessment information relative to one another (Zador and Harvey, in prep.). This framework would prompt scientists to consider for each stock whether ecosystem and stock assessment information indicate favorable or unfavorable conditions and trends. The determination of "okay" and "not okay" is complex and nuanced for stock assessments as well as for ecosystem information. The Magnuson-Stevens Act provides the broad parameters for what is "not okay" through the mandates to end and avoid overfishing and rebuild overfished stocks. However, a stock assessment can indicate concerning trends, such as a large drop in ABC, even if a stock is not found to be overfished or undergoing overfishing. By taking a consistent and systematic rather than an ad hoc approach to evaluating ecosystem and stock assessment information, scientists can proactively identify potential issues of concern. The SSC has requested that AFSC provide guidance to inform the determination of "okay" or "not okay," in particular for ecosystem status with respect to a given stock. This will be an evolutionary process rather than a one-size-fits all approach. The ongoing development of Ecosystem and Socioeconomic Profiles (ESPs, more detail provided below) will eventually provide stock-specific ecosystem indicators as an appendix to each stock assessment, facilitating coordinated evaluation of ecosystem and stock information.

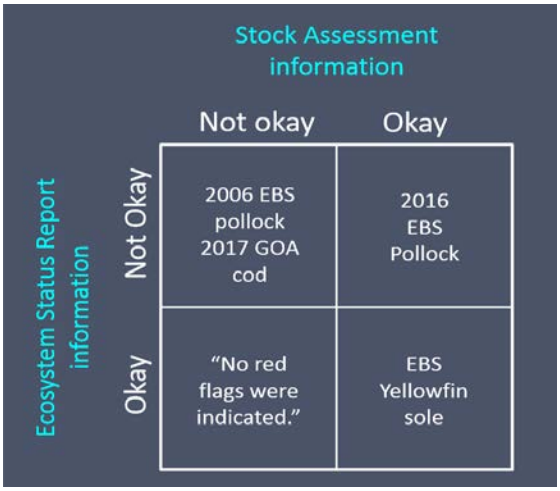

Figure 1: Conceptual okay/not okay framework

Strengthening the ecosystem indicator review process could also include reviewing this information sooner. Participants noted that there can be a narrow window of opportunity for identifying and responding to red flags. For example, there is a short turnaround time between completion of the biannual Gulf of Alaska bottom trawl survey in late summer, stock assessments conducted in the fall, and the Council's December groundfish specifications process. In the case of GOA Pacific cod, ecosystem and stock assessment scientists had only a few weeks to draw linkages between ecosystem and stock assessment information and identify the factors that contributed to declining productivity. Participants suggested that by reviewing ecosystem information earlier in the year, scientists could identify "yellow flags" or ecosystem points of concern. AFSC is currently considering establishing a routine spring review of ecosystem and economic data. Participants proposed that in response to identifying yellow flags or concerns, scientists could convene a working group or team to take a closer look. Identifying these concerns early would allow more time for scientists to generate ideas and hypotheses to explore and would also provide managers and stakeholders with advance notice of emerging concerns.

[3] From presentation by Stephani Zador, NMFS Alaska Fisheries Science Center, February 7, 2018. PDF and abstract available on the Council's Ecosystem Research Workshop page.
http://www.npfmc.org/ecosystem-research-workshop/

Management response

Workshop discussions considered how ecosystem indicators currently translate into management advice, and the potential implications of strengthening the indicator review process. The group observed that formalizing this process could involve establishing thresholds or triggers leading directly to a management response. However, participants primarily discussed a formalized indicator review in terms of supporting the coordination and communication that worked well in the case of GOA Pacific cod. The group also questioned how the Council might respond to early warnings and recognized that the adoption of precautionary catch limits is the most likely response.

Workshop discussions illustrated a number of considerations related to the interpretation of and response to early warnings. The group recognized the need to be responsive to early warnings while exercising caution given the possibility of error. An error could involve incorrectly determining that ecosystem indicators suggest a problem and responding accordingly, or conversely, failing to recognize when ecosystem indicators suggest that a problem exists (referred to statistically as Type I and Type II error, respectively). Some noted that such errors could undermine the credibility of scientists and managers, but some also stated that the possibility of error does not mean the process is flawed.

The group also reflected on the relationship between environmental indicators and fishery outcomes. They observed that there is ideally some understanding of the mechanism linking environmental conditions with stock dynamics, but that it is also important to make use of available information even if these mechanisms are not well understood. The group noted the importance of distinguishing between correlation (an ecosystem indicator is associated with a fishery outcome) and causation (an indicator represents an ecosystem component that directly contributes to a fishery outcome). Participants also noted that mechanisms can change or break down over time with changing environmental conditions. Some suggested managing expectations and exercising caution in relying on indicators and models to predict future ecosystem changes.

The group considered the rationale for initiating a management response, and how ecosystem information is evaluated relative to stock assessments and other information sources. They generally felt that ecosystem information is more actionable when corroborated by other information. In the case of GOA Pacific cod, participants acknowledged that the results of the GOA bottom trawl survey had a strong influence on the SSC's recommendation and the Council's decision to reduce catch levels in 2018. The group felt it was unlikely that the Council would have made this decision based solely on ecosystem information and observed that there may be more receptiveness to ecosystem indicators when this information aligns with the perception of a problem. Participants also commented on the role of hindsight in evaluating lessons learned from GOA Pacific cod and managing expectations regarding early warnings. While this experience underscores the value of early warnings, it also demonstrates how information can have added significance with the advantage of hindsight.

Looking ahead

Workshop participants questioned how the ecosystem indicator review process would be formalized, and in particular the roles of the Council, SSC, and plan teams in determining which indicators would be used. Discussions also highlighted longer-term considerations, including tracking the performance of indicators over time.

3.2.2 Additional considerations

Workshop discussions also explored the role of industry observations as a form of early warning, the interpretation of contextual data, and the development of Ecosystem and Socioeconomic Profiles (ESPs). This portion of the summary reflects workshop discussions as well as additional input and context provided by workshop speakers.

Industry observations

Participants observed that industry-based metrics, such as catch per unit effort (CPUE) and the rate at which an industry is achieving catch limits, could serve as an early warning. This information could supplement the limited spatial and temporal coverage of fishery-independent sampling. For example, participants noted that there was a rapid decrease in participation by the GOA jig fleet as catch rates of Pacific cod declined. While these observations may be shared anecdotally (e.g., through communication between industry and stock assessment authors), there is not a formal process for reviewing catch rates in-season. However, this information is continually processed through the observer program and could be made available to stock assessment and ecosystem scientists. As previously noted, AFSC is considering a spring review of ecosystem and economic information, which could include a review of catch rates.

Participants also emphasized that on-the-water observations of change can be a valuable source of information. For example, stakeholders may observe changes to target species (e.g., disease, fish condition), as well as indirect signs of change (e.g., changes in prey base, seabird and marine mammal mortality). These observations are also shared informally with stock assessment scientists, and some suggested this process could be strengthened and improved (see section 3.3).

Hard data, squishy application

Workshop discussions occasionally used the term “squishy data” in reference to ecosystem information, including the information provided in Ecosystem Status Reports, that is external to stock assessments and ecosystem models. Workshop speakers clarified that it is the application of these data to particular stocks—rather than the data themselves—that might be described informally as squishy. While these data are quantitative, their use requires interpretation by scientists who can consider the intersection between ecosystem conditions and stock dynamics.

Ecosystem information that lacks a defined entry point is used in a qualitative manner to provide ecosystem context for Council decision-making, primarily through the annual groundfish specifications process. Workshop speakers emphasized that the qualitative use of ecosystem information can complement stock assessments and ecosystem models and plays an important role in the Council’s implementation of EBFM. The use of contextual information allows for the timely and flexible incorporation of new information and diversifies the information inputs that can inform Council decision-making. For example, this information could provide insight into how the factors of predation, food availability, and temperature can influence stock dynamics through natural mortality and recruitment.

The use of contextual information also facilitates learning and adaptation and can encourage communication between stock assessment and ecosystem scientists. Over time, ecosystem data may be incorporated directly into stock assessments and ecosystem models as scientists study the mechanisms relating these data to the population dynamics of fish stocks. Workshop participants noted the

importance of investing in research to understand these relationships. For example, the Council and SSC's annual review of research priorities is an opportunity to communicate these priorities to NMFS and other research and funding partners such as the North Pacific Research Board (NPRB).

The group's discussion of "squishy data" also considered how other sources of quantitative and qualitative information (e.g., LTK, citizen science, industry observations, economic conditions) could be utilized as model inputs or contextual information.

Ecosystem and socioeconomic profiles

ESPs are a newly developed framework[4] for providing stock-specific ecosystem information as an appendix to stock assessments. While stock assessments produced by AFSC already include an ecosystem considerations section, this section is typically limited and not regularly updated. The Ecosystem Status Reports use indicators to provide an overview of the ecosystem as a whole, but the same indicators can suggest different implications for different stocks. For example, an indicator that is "good" for one stock (e.g., indicates conditions that are favorable for recruitment) may be "bad" for another.

ESPs will interpret ecosystem information in the context of a particular stock, complementing the more general ecosystem information provided by the annual Ecosystem Status Reports. The process of developing ESPs will also enable scientists to identify strong relationships between ecosystem conditions and the population dynamics of a stock. Over time, ESPs can help increase the potential to incorporate environmental information directly into stock assessment models and therefore into the catch level recommendations provided by the SSC. While ESPs were not a focus of workshop discussions, speakers noted that ESPs may strengthen the region's ability to identify early warnings.

3.3 Communication and information-sharing

Workshop participants emphasized that ecosystem change enhances the need for communication and information-sharing among managers, scientists, and stakeholders. The group focused in particular on the value of diversifying information inputs and fostering two-way communication with stakeholders. The group discussed the following ways in which communication and information-sharing can strengthen the region's ability to understand, anticipate, and respond to change.

- Building shared knowledge: Participants observed that a diversity of information inputs, knowledge, and perspectives can help enhance understanding of ecosystem function and change, and also provide insight into fishing behavior that can help inform management decisions and scientific efforts, particularly the ongoing development of ACLIM.

- Supporting mutual interests: Participants recognized that the Council community, scientific community, and stakeholders have a shared stake in understanding how marine ecosystems and fisheries are changing and how stakeholders may respond to these changes, identifying and

[4] The first prototype ESP produced by AFSC is included with the 2017 BSAI sablefish stock assessment and includes three information products: a species profile, a conceptual model, and a report card. www.afsc.noaa.gov/refm/stocks/plan_team/2017/BSAIsablefish.pdf

addressing information gaps, and supporting successful fisheries management decisions. Each group also possesses capacity and infrastructure that can be leveraged to help share information effectively. The group felt that ecosystem information should be available and accessible to everyone who can utilize this knowledge.

- Strengthening relationships: Participants felt that communication and information-sharing can promote trust, transparency, and a sense of shared investment among managers, scientists, and stakeholders. The group noted that strong working relationships are already a strength of the Council process, and ongoing dialogue will be critical as the Council encounters new challenges and difficult conversations.

- Identifying and responding to change: Participants felt that communication and information-sharing can support the early identification of red flags and signals of change, providing managers and stakeholders with more time to respond.

3.3.1 Opportunities for information-sharing

Workshop discussions explored specific opportunities to enhance information-sharing through the incorporation of local and traditional knowledge (LTK), industry-generated knowledge, and communication within the scientific community. Participants perceived that information generated by stakeholders is an underutilized resource that could be leveraged more effectively to help identify early warnings, build ecosystem knowledge, and respond to change.

Local and traditional knowledge

Workshop discussions included a strong emphasis on the value of LTK for enhancing ecosystem knowledge. The integration of LTK is a focal area of the draft Bering Sea Fishery Ecosystem Plan and the work of the Council's Ecosystem Committee.

LTK and the Bering Sea FEP

The Bering Sea FEP aims to improve the Council's understanding and utilization of local and traditional knowledge, support the co-production of knowledge, and improve communication with rural and Alaska Native communities. Traditional knowledge is defined as traditional indigenous knowledge that spans generations and is acquired through long-term resource use and environmental engagement. Local knowledge includes the lifetime observations and experience of local participants who may be (but are not necessarily) indigenous. [5] Traditional knowledge and local knowledge, referred to collectively as LTK, are two different types of information that both provide a different form of evidence than typical scientific research methods. The integration of LTK can be facilitated through a process termed "co-production of knowledge," which involves leveraging traditional knowledge and conventional scientific research to share information, values, and ideas.

[5] Raymond-Yakoubian and Raymond-Yakoubian 2015 in the Bering Sea Fishery Ecosystem Plan, Pre-Draft for NPFMC Ecosystem Committee (February 2, 2018). http://www.npfmc.org/wp-content/PDFdocuments/membership/EcosystemCommittee/Meetings2018/DRAFT_BSFEP.pdf

The Council is continuing to refine the definitions of LTK and co-production of knowledge in the context of the Bering Sea FEP and the Council process. The FEP will be implemented through targeted projects and research efforts—termed "action modules"—that support the objectives of the FEP. The draft FEP specifically proposes the development of an action module to develop a formalized process for analysts to include and consider LTK and subsistence information in the Council process. The Council recently established a Social Science Planning Team (SSPT), tasked with improving the quality and application of social science data to inform fisheries management and program evaluation. The SSPT will play an important role in considering how LTK can be integrated into the Council process and will partner with the BS FEP team on the LTK and subsistence action module.

LTK can provide valuable insight into past and present changes in ecosystem conditions. Workshop participants shared specific examples of how they felt LTK could illustrate current changes, for example in terms of shifting weather patterns, unusual mortality events, and changes in the behavior of marine mammals. Participants also shared historical examples of change. The group also emphasized the mutual benefit of information-sharing between the Council community and holders of LTK and felt that information-sharing should to be a "two-way street." Participants noted that information generated by the scientific and Council communities does necessarily reach local communities. Participants stated that the impacts of climate change will be felt particularly acutely by western Alaska and Bering Sea communities that rely on the Bering Sea ecosystem for subsistence and survival. These communities have a critical stake in understanding how the environment is changing, including impacts to fisheries and marine mammals targeted for subsistence hunting, as well as other coastal impacts associated with climate change such as coastal erosion and changing sea ice cover.

Participants expressed their desire for LTK holders to "have a seat at the table," and to leverage the full value of LTK by integrating knowledge in a structured and possibly quantitative way. The group also reflected more broadly on opportunities and challenges to incorporating LTK into Council processes. For example, some participants described LTK as broad, encompassing knowledge that people depend on in their daily lives, and felt that science has a comparatively narrow focus. Some felt that it can be challenging for scientists, LTK holders, and other participants in the Council process to understand one another's perspectives.

Workshop discussions also considered specific mechanisms that could help facilitate information sharing and the input of LTK. Participants suggested community school systems as a potential outreach pathway and discussed outreach methods such as newsletters and in-person engagement. The group also suggested providing ecosystem information in a way that is targeted toward specific communities and concerns. Workshop discussions also highlighted the following existing outreach mechanisms for facilitating the exchange of information and integration of LTK.

- Tribal consultations: Executive Order 13175[6] establishes a process through which federal agencies consult with tribal officials regarding the development of regulations, legislation, and other actions that have tribal implications. The NMFS Alaska Regional Office coordinates consultations with tribes and Native corporations in the Alaska region.

[6] www.federalregister.gov/documents/2000/11/09/00-29003/consultation-and-coordination-with-indian-tribal-governments

- NPFMC Rural Outreach Committee (ROC):[7] The Council recently revisited the role of the ROC, which is currently inactive. In 2009, The Council convened a standing ROC tasked with providing input to the Council on opportunities to improve outreach to rural communities and Alaska Native entities in support of the Council policy[8] of increasing Alaska Native consultation. In response to discussions and public input at the Council's February 2018 meeting, the Council requested that staff review existing protocols and consider additional steps for supporting outreach to rural Alaskan communities and Alaska Native populations.

- Local Environmental Observer (LEO) Network[9]: Workshop participants questioned whether NMFS could make use of information provided through the LEO Network. The LEO Network provides a platform for members to share and view observations of unusual events related to wildlife, environmental conditions, and weather, and connect with other members and topic experts. The LEO Network was developed by the Alaska Native Tribal Health Consortium as part of its Community Environment & Health program. AFSC included a summary of LEO Network observations as a "hot topic" in the 2017 Ecosystem Status Reports for the Eastern Bering Sea[10] and Gulf of Alaska[11] regions, and noted that the LEO Network could serve as a platform for gathering citizen science observations to present in future reports.

Industry-generated knowledge

Workshop discussions explored opportunities for the fishing industry to provide information and observations and engage in research partnerships. The industry can provide research platforms, gear, and capacity that could be utilized to address gaps and collect information efficiently. Participants emphasized that industry-supported knowledge is particularly valuable given that there are limited resources to support data collection, and that there will be increasing and competing demands for information in a changing environment. The group discussed several pathways for sharing information.

- Opportunistic information sharing: Communication between the industry and NMFS can occur on an opportunistic and informal basis. For example, some stock assessment authors adopt an "open door" policy by actively encouraging the industry to share their observations and questions. Similarly, industry participants may proactively reach out to stock assessment authors to provide input and stay informed. Workshop participants noted that both scientists and industry can initiate these conversations, and that the contextual information contributed by industry is valuable to stock assessment authors, ecosystem scientists, and plan teams. Participants added that NMFS maintains direct contact with segments of industry, for example to coordinate openings and closings in open access fisheries, and that this routine communication contributes to an understanding of fishing behavior.

- Cooperative research: Cooperative research can leverage the experience and resources of scientists, managers, and stakeholders to generate information and explore research questions. Participants emphasized that collaboration between industry and NMFS could help supplement existing data collection methods, improve coverage and address information gaps, and enhance

[7] www.npfmc.org/committees/rural-outreach-committee/
[8] From the 2004 Alaska Groundfish Fisheries Programmatic Supplemental Environmental Impact Statement.
[9] www.leonetwork.org
[10] https://access.afsc.noaa.gov/reem/ecoweb/index.php?ID=15
[11] https://access.afsc.noaa.gov/reem/ecoweb/index.php?ID=18

the potential to identify early warnings. For example, participants suggested that the fishing fleet could record temperature measurements.

- Citizen science: Citizen science provides a platform for members of the public to collect data and share information with researchers. Participants noted that a wide range of stakeholders in the fishing industry, including the processing sector, could potentially contribute information and observations.

Workshop participants also commented broadly on the value of collaboration and industry-generated information that may not fit within one of these categories. In general, the group felt that there are opportunities to strengthen, formalize, and provide additional structure to support the integration of this knowledge into Council processes. Some also questioned whether fishery observers could collect additional biological data, for example related to fish condition.

Information-sharing within the scientific community

Workshop participants also recognized the value of communication among different groups and scientific disciplines with shared interests. The group commented on the potential to enhance communication among the different offices and divisions within NMFS, as well as with the broader academic community, as a way to share knowledge and address information gaps. For example, participants suggested that closer communication with NMFS physical oceanographers and with the observer program could provide stock assessment and ecosystem scientists with valuable insight. Participants also noted that there are other segments of the scientific community that are engaged in studying climate phenomena (e.g., the "blob") but do not necessarily intersect with the Council process. More dialogue within the scientific community, including the fisheries management realm, could help illustrate the human impacts associated with climate events.

3.3.2 Additional considerations

Workshop discussions explored several questions and considerations related to communication and information-sharing. The group observed that while LTK and industry-generated knowledge are distinct and different sources of information, some questions and considerations may pertain to both.

Pathways for information-sharing

The Council process provides a number of existing and potential pathways for stakeholders to provide and receive information. Participants considered whether these pathways are effective for sharing information related to ecosystem change. Discussions highlighted several considerations, including whether these opportunities and pathways are formal or informal, periodic or ongoing, accessible to stakeholders, supportive of two-way dialogue, and specific to sharing ecosystem information (as opposed to more general Council process information). The group questioned whether existing opportunities for the public to share observations and information could be strengthened or formalized to provide more value. For example, one suggestion was to consider a formal comment period for ecosystem observations. Participants also suggested the use of online forms or apps for submitting information and observations, and organizing this information into a database.

Roles and responsibilities

Participants felt that information-sharing and communication is a shared responsibility, and that managers, scientists, and stakeholders can each take steps to initiate and support two-way dialogue. The group shared different perspectives on whether existing pathways are adequate for communicating about ecosystem-related information. Many felt that the Council and scientific community could consider new strategies to facilitate two-way communication. Some participants observed that existing opportunities, such as public comment, are not accessible to all stakeholders and may not create the perception that input is wanted and valued. Others felt that the Council process already provides opportunities for engagement, and that stakeholders should take the initiative to share information and stay informed. Participants also commented on the value of scientists engaging directly with stakeholders and communities to gain firsthand experience.

Integrating information

Participants expressed strong interest in identifying how and when LTK and industry observations can be integrated into Council processes, specifying how different information sources complement one another, and articulating the information needs and gaps that this information could help address. The group emphasized that if LTK and industry input are collected, this information needs to be used in a timely and meaningful way or there is a risk of eroding rather than building trust.

The group questioned whether LTK and industry input is primarily contextual or could be integrated quantitatively, for example as a modeling input, and expressed their desire to see this information utilized to its full potential. Participants also reflected on whether this information aligns with the time frame and scale of information used to support fishery management decisions. Many felt that LTK and industry input is most valuable as a scientific input early in the process, rather than as input during the management process. Participants also noted that given the size of the Alaska region and the potential scope of ecosystem information, it is important to identify focused opportunities for stakeholder input to inform Council processes. For example, some suggested that observations of fish condition could serve as a useful indication of changing conditions.

Effective communication

Participants felt that effective two-way communication and opportunities for information-sharing should be respectful, straightforward and accessible to all stakeholders, regardless of their background or fluency in scientific terms. Participants commented that information should be provided in clear terms for a non-scientific audience, and that communicating in the form of “stories” and scenarios is an effective strategy for helping stakeholders and managers envision potential changes.

4. Conclusion

Introductory and concluding remarks by Council leadership acknowledged the value of engaging the Council community in discussion, and the need to continue these conversations. The prospect of planning and responding to ecosystem change is daunting. However, Council leadership emphasized the region’s strong history of leadership with regard to ecosystem science and EBFM, and the capacity and collective knowledge contributed by the Council community and the Council’s science and management partners. Workshop discussions identified many potential next steps, including continuing to learn from the experience of GOA Pacific cod, advancing the use of indicators and early warnings, supporting

effective communication and the two-way exchange of information, and providing input to make use of the tools developed by the scientific community to explore potential changes and management options. This summary identifies a number of pathways the Council can consider for continuing to strengthen the region's ability to prepare for and respond to change.