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Managing Fisheries in a Changing Environment

Discussions from the 2017 Forum
May 1–2, 2017, Monterey, California

Editors

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SUMMARY

The 2017 Forum convened by the Fisheries Leadership & Sustainability Forum (Fisheries Forum) explored the challenges of managing fisheries in a changing environment. To meet the mandates of the Magnuson-Stevens Act and achieve management objectives, federal fishery managers need to understand and respond to changing fisheries and marine ecosystems. The Forum explored the causes and implications of change, focusing on climate-related ocean changes; emerging capabilities to understand, model, and project future changes; pathways for integrating this information into decision making; and the opportunities for and challenges to flexibility and responsiveness in the council process.

The Fisheries Forum convenes a series of forums for council members, council staff, and National Oceanic and Atmospheric Administration Fisheries staff. Each forum focuses on a topic with regional and national relevance. The forums are a unique opportunity for managers to explore emerging issues and questions and to share ideas and information across management regions.

INTRODUCTION AND FORUM OBJECTIVES

The ocean environment is dynamic and changing. To continue meeting the mandates of the Magnuson-Stevens Act (MSA) and achieve management objectives, federal fishery managers need to acknowledge and respond to changing conditions. The 2017 Forum convened regional fishery management council members and staff, National Oceanic and Atmospheric Administration (NOAA) Fisheries staff, and invited experts to explore the opportunities for and challenges of managing fisheries in a changing environment.

Managing under changing conditions is a timely and high-priority topic. Some management regions are experiencing changes to the ocean environment that are affecting managed stocks, fishery stakeholders, and the management process. The fisheries management community is taking important steps to build its capacity to understand and respond to change. At the council level, many regions are developing and implementing regional approaches to ecosystem-based fisheries management (EBFM), an effort that can provide a framework for understanding change and integrating ecosystem information into the management process. NOAA Fisheries recently developed the Climate Science Strategy and accompanying regional action plans, which aim to increase the production, delivery, and use of climate-related information at the national and regional levels. In addition, NOAA Fisheries scientists and the academic community are developing new capabilities to anticipate future changes to fisheries and marine ecosystems and to support the management community's ability to respond to change.

Managing fisheries in a changing environment involves a paradigm shift from the expectation that conditions will remain stable over time to the expectation that conditions are dynamic and likely to change. As such, managing for change is a responsibility shared by the entire fisheries management community, including scientists, decision makers, support staff, and the broader public. Within the council process, environmental changes factor into nearly every decision point and can affect councils' ability to meet management mandates and objectives. Managing for change is also a challenge that spans many topics, including ecosystem-based fisheries management, climate-related ocean change, and council process, and it builds on core needs of the management process, including stakeholder engagement and effective science-management communication.

The agenda for the 2017 Forum was designed to provide structure to a set of topics that can often feel overwhelming. The meeting adopted a broad interpretation of "change" that encompasses the different ways councils experience and talk about change, including ecosystem change, climate change, and variability. The Forum supported the following objectives:

- Share regional experiences and concerns related to changing fisheries and ocean conditions, and explore the management and governance challenges related to changing resource productivity and distribution.
- Examine regional approaches to ecosystem-based fisheries management (EBFM), and EBFM as a strategy for supporting ecosystem resilience in the face of change.
- Learn about emerging capabilities to anticipate potential changes to fish stocks and ecosystems, and consider the opportunities, challenges, and processes involved in planning for change in the near and long term.
- Explore the range of pathways for integrating climate-related information into the decision-making process, and identify opportunities for supporting effective communication between scientists and managers.
- Reflect on the institutional and operational challenges of making decisions under conditions of uncertainty and change.

- Share perspectives on the tools, skills, capabilities, and information councils need to manage fisheries effectively in a changing environment as well as on the role of goals and objectives in framing management decisions.

The Forum included presentations by participants and invited experts and opportunities for small and large group discussions. Day 1 sessions focused on the near-term challenges of managing fisheries *in* a changing environment. Day 2 sessions took a longer-term and more strategic view of managing fisheries *for* a changing environment.

This summary focuses on the prominent discussion themes and reflects the questions, concerns, and ideas Forum participants were most interested to discuss with their colleagues. Short summaries of regional examples and research presentations are provided as an appendix. Additional resources, including the final agenda, presentations, and videos are available at www.fisheriesforum.org.

MANAGING FISHERIES IN A CHANGING ENVIRONMENT

Participants explored the wide range of changes that management regions are experiencing and anticipating, and they focused in depth on changes to fishery productivity and availability. Participants explored how a changing environment affects fisheries management, the challenge of instilling the flexibility into the management process, and the tradeoffs involved in responding to change.

Management Regions Experience Change Differently, But Share Similar Concerns

Across management regions, managers are experiencing and perceiving change in different ways. Some regions are experiencing the impacts of change and variability, while other regions are not, and the impacts of change are likely to be more significant in some regions than in others. Forum discussions provided participants with valuable insight into current and potential changes and a more complete understanding of the intersection between fisheries management and a changing environment.

Forum participants shared their experience with change in terms of three related categories: (1) changes to **environmental conditions** (physical, chemical, and oceanographic), (2) the **biological and ecological** consequences of these changes (e.g., changes to fishery productivity and distribution), and (3) the **management implications** of these changes (e.g., social and economic impacts on fishery stakeholders). The group shared regional examples and concerns related to each category, including the following:

- **Environmental conditions**: Changes to temperature, salinity, ocean acidification, sea-level rise, cyclical fluctuations (i.e., El Niño/La Niña), and oceanographic features like upwellings and currents
- **Biological and ecological consequences**: Changes to survival, recruitment, and stock productivity and distribution; changes to fish behavior and catch condition; interspecies interactions and ecosystem function; and shifts and loss of suitable habitat
- **Management implications**: Social and economic impacts to stakeholders, shifting tradeoffs and interactions (e.g., between objectives, sectors/user groups, and fisheries), and increasing uncertainty and unpredictability in the decision-making process

Subsequent discussions focused more closely on the implications of change in the context of changing resource productivity and fishery availability. Although regions are experiencing change differently, they share many of the same concerns related to fishery conditions and fishing activity:

- **Access and opportunity**: Change can lead to a perceived mismatch between resource distribution and access.

- **Fishery encounters and interactions**: Change can affect catch and bycatch composition, increase interactions between fisheries, and result in encounters with new species as distributions shift.
- **Social and economic impacts**: Changes create social and economic impacts felt at different levels (individuals, businesses, communities, states) and by different sectors (including commercial, recreational, subsistence, harvesting, and processing). The resilience and ability of these groups to adapt to change varies, resulting in "winners" and "losers."
- **Management performance**: Change can potentially undermine the credibility and performance of all management decisions, including achievement of sustainability mandates.

Change Has Profound Impacts for the Council Process

Change holds significant consequences for the management process and the responsibilities of council members. Participants discussed several specific concerns about the decision-making process.

Change Can Undermine the Effectiveness of Management Decisions

A changing environment can disrupt the relationship between management actions and intended outcomes. Participants were concerned about the potential for environmental change to affect the success of management decisions, including achievement of sustainability mandates (i.e., setting annual catch limits, ending and preventing overfishing, and rebuilding), balancing of competing interests and tradeoffs, and effectiveness of specific tools and strategies such as area closures and bycatch management. The group was also concerned about disentangling the effects of management decisions and environmental change—that is, determining whether observed outcomes are the result of management decisions, environmental factors, or both.

Change Can Intensify Existing Tradeoffs and Create New Ones

Management always involves tradeoffs between user groups and objectives, but these tradeoffs can become more difficult to balance under conditions of uncertainty and change. The group was particularly concerned about tradeoffs and interactions between (1) directed fisheries (e.g., bycatch management and constraining stocks), (2) directed harvest of a stock and forage needs, and (3) fisheries and protected species. Some expressed frustration that, given the limited tools and jurisdiction of managers, balancing these tradeoffs often involves limiting fishing mortality, restricting fishing activity, or both.

Change Contributes to Uncertainty and Unpredictability

Although the causes and short-term consequences of change are becoming more apparent to fishery managers, there is considerable uncertainty about how these changes will interact and unfold over the longer term. Participants were concerned about the challenges of managing under conditions of increasing unpredictability and uncertainty and about the ability of fishery managers and scientists to recognize the signals of change and to anticipate how changes will affect management.

Change Demands Bigger-Picture Thinking

The marine environment is affected by a wide range of human activities that are outside the direct control of fishery managers. The group noted concerns such as coastal development, stormwater runoff, shoreline hardening, loss of estuarine habitat, and the introduction of plastics and chemical pollutants. Activities that impact the coastal and marine environment can serve as additional stressors to fisheries and habitat in a changing environment, but they also present opportunities for engaging a wider network of stakeholders to mitigate adverse impacts and build ecosystem resilience.

Change Creates New Demands on the Entire Management Process

The group agreed that a changing environment adds to the existing demands of council members and the management process. Participants identified specific needs, including adapting management measures to changing conditions, engaging effectively with stakeholders and management partners, confronting difficult decisions and tradeoffs, and being proactive by preparing for change, learning from experience, and encouraging resilience.

Managing in a Changing Environment Requires Flexibility

Managers must respond to change to continue meeting management mandates and objectives. Participants agreed that a changing environment enhances the need for flexibility and responsiveness in the management process. The group reflected on the opportunities, challenges, and difficult questions involved in putting flexibility into practice, and it considered whether existing tools provide fishery managers with the flexibility needed to respond to change.

Many participants felt that managers do have the procedural tools and framework to consider potential scenarios and respond effectively to change. The group identified several specific examples of how flexibility is supported by the management process.

- **Legal requirements**: Within the federal fisheries management process, the National Environmental Policy Act (NEPA) requires managers to consider a range of alternative actions and evaluate their impacts to the natural and human environment.
- **Procedural mechanisms**: The NOAA Fisheries Operational Guidelines provide guidance on mechanisms designed to support responsive management, including framework adjustments.
- **Responsive management**: There are multiple regional examples of real-time information collection and response, including in-season quota management and bycatch monitoring. Co-management arrangements that delegate some management responsibilities to industry can be another way to facilitate additional flexibility and responsiveness.
- **Allocation**: Though often contentious, the allocation of harvest privileges among user groups is an important tool for aligning access with resource availability.

Some participants felt that managers do lack flexibility, but many also felt that this lack is due to the specific decisions made within the management process rather than the available tools and underlying process and framework. Participants also observed that there are tradeoffs among different forms of flexibility. For example, allocating quota to states, regions, or sectors can increase flexibility to set regulations (e.g., seasons, trip, or possession limits), but fixed allocations make it challenging to adapt as the fishery changes. The pace of the council process can also impede flexibility and rapid response to change. Participants noted the value of thorough deliberation, particularly regarding controversial issues, but they also observed that the difficulty of building consensus can create inertia. Others pointed out that even when the decision-making process can move forward quickly, the regulatory process is time consuming.

Putting Flexibility into Practice Is Challenging

The group agreed that while flexibility and responsiveness are needed to manage in a changing environment, putting these qualities into practice can be extremely difficult. Forum participants identified several challenges and needs related to flexibility.

Flexibility Requires Tradeoffs among Competing Values

The group felt that the need for flexibility in the management process creates conflict with other deeply held values, particularly stability. The tools used by fishery managers to manage fishing effort (e.g., limited entry, catch shares, allocations) are also intended to create predictability and reflect historical investment and participation. These decisions can encourage specialization and reliance on particular fisheries, create barriers to entry, and make it more difficult for fishery participants to adapt as conditions change. Flexibility also intersects with the decisions fishery managers make to support social and economic objectives and to balance the needs of different user groups. Forum participants considered whether flexibility is compatible with stability, or whether responding to change means accepting tradeoffs between these two competing values. To align access with changing resources, fishery managers will also have to confront difficult decisions and manage stakeholder expectations related to access, allocation, and the duration of harvest privileges. Managers will also have to address underlying and ongoing challenges to managing catch and effort (e.g., latent capacity, recreational discard mortality).

Participants also questioned the nature of flexibility over the long term. For example, does flexibility mean continually responding to change, or moving from one stable management regime to another? Should managers aim to catch up or keep up with the pace of change, or should they prepare and plan for changes before they occur? Finally, the group recognized that there will be "winners" and "losers" among stakeholders who are affected differently by change depending on attributes such as resilience, dependence, and adaptive capacity. Participants questioned the extent to which fishery managers can and should mitigate social and economic impacts as well as the appropriate balance between mitigating negative impacts and creating new opportunities.

Flexibility Requires Information

Timely and accurate and information is critical for capturing the signals of change, meeting MSA mandates and management objectives, and supporting a credible management response. The group emphasized the importance of aligning fishery-independent and fishery-dependent data collection with the spatial and temporal distribution of a changing resource. Ongoing data challenges, including data-limited stocks and accurate catch and effort reporting (particularly in recreational fisheries) become even more significant in a changing environment. Another challenge is data credibility, particularly given the lengthy feedback loop between on-the-water observations, science, and the management process. The group felt that involving industry in cooperative research can help generate timely information to inform decision making as well as generate buy-in and cooperation.

Flexibility Requires Coordination

A changing environment enhances the need for coordination among fishery management partners, agencies, and other entities with intersecting interests in the marine environment. Coordination across council and council-state jurisdictions is particularly important as fisheries change; for example, changing patterns of fishing activity in state waters can have implications such as annual catch limit overages for federally managed species. Environmental change can also intensify the need for coordination with interests closely linked with the council process, including groups such as Native American tribes and subsistence-based communities, and area-based designations including marine national monuments. The group also agreed that change will require enhanced coordination at the watershed and ecosystem level, particularly related to coastal development and offshore energy.

Coordinating and sharing responsibilities with a widening circle of interests is challenging. The group identified several elements of effective coordination—beginning with mutual willingness to coordinate. Other ingredients of successful coordination include engaging in regular communication and involvement, developing strong interpersonal and working relationships, sharing information, developing

a common frame of reference for issues, and leveraging both formal and informal pathways for collaboration.

Flexibility Requires Creativity

Responding to change demands that fishery managers and stakeholders be willing to think in new ways and engage in new types of conversations. The group felt that change reinforces the value of learning and incorporating information gained through experience, including information gained through structured approaches such as adaptive management and the ongoing reflection and evaluation of past actions. Similarly, it's important to look ahead to consider how future changes may affect management, and how management decisions might perform under changing conditions. Finally, participants noted the value of engaging in planning and discussion outside of the immediate decision-making process, for example, through visioning and strategic planning conversations.

Flexibility Requires Buy-in

A final theme during the first day of discussions was the importance of credibility and buy-in. Responding to change requires information and management flexibility, but it also involves navigating different perspectives and preferences within the stakeholder-driven fisheries management process. First, managers and stakeholders must have the motivation to recognize that conditions have changed, and they must reach the conclusion that changes require a management response. Participants highlighted the difficulty of establishing climate as a clear driver of change and of determining when environmental change merits management change. Second, the involved parties need sufficient motivation to depart from the status quo, recognizing and accepting that a management response will result in costs and benefits to fishery stakeholders. This response is particularly challenging given that change involves making decisions under conditions of increased uncertainty. The group also noted that those who are most invested in the status quo are often the least willing to change. Forum discussions suggested that these two aspects of motivation may be the most significant barrier to recognizing and responding to change. Participants described this duality as "we want flexibility, but we don't want to change."

MANAGING FISHERIES FOR A CHANGING ENVIRONMENT

The second day of the Forum focused on regional approaches to ecosystem-based management, advances in research to understand and anticipate the impacts of climate change on fisheries and marine ecosystems, and pathways for integrating climate and ecosystem-related information into the management process. Discussions emphasized that preparing for and responding to change is a shared responsibility that requires effective communication among managers, scientists, and stakeholders.

Effective Communication between Managers and Scientists Is Critical

Collaboration and communication between scientists and managers is essential for integrating climate and ecosystem-related information into management. Change is happening quickly. To leverage new climate-related information and utilize limited resources effectively, managers need to be aware of scientific advances as they occur. Managers need to understand the utility of these advances to the management process as well as the relation of different projects, initiatives, and information sources to one another. Meanwhile, scientists rely on managers to articulate their needs to ensure scientific efforts are relevant to management.

Forum participants explored opportunities to forge a strong link between science and management and to ensure that managers' capability to use new information evolves in step with advances by the scientific community. Participants reflected on their own experiences with communication between the science and

management communities, including construction of linkages between science and management capacity. The group's discussion led to several suggestions.

Build and Maintain Opportunities for Collaboration

The council process creates many opportunities for interdisciplinary collaboration among managers, scientists, support staff, and, in some cases, the public. These opportunities include standing working groups and plan teams and project- or issue-specific groups as well as stakeholder initiatives such as exploring new tools or approaches through exempted fishing permits. Convening teams that include different perspectives to work through a shared challenge or task is an effective way to build strong working relationships and support ongoing communication.

Communicate Management Questions and Needs

Scientists need feedback from the management community to develop useful tools and information products. Managers can help provide focus by articulating key questions, needs, and objectives; by identifying priorities; and by providing feedback on how information can most effectively support council decision making. For example, managers can provide insight into questions such as: What spatial and temporal scale is helpful for illustrating potential changes? What information do councils need to understand shifting fishery distributions? What kind of forecasts and early warning are valuable? Scientists can look to council feedback to ensure that they are communicating their work effectively and are developing products that can be incorporated into the management process.

Create Consistent Opportunities for Discussion and Interaction

Councils are busy, and big-picture, ecosystem-related initiatives may be challenging to prioritize amid the mandatory and time-sensitive decisions councils are charged with making. Councils can build a stronger sense of ownership and investment in ecosystem-related initiatives by creating dedicated time and consistent opportunities for these conversations, for example, through fishery ecosystem plan development and review of ecosystem status reports. Consistent interactions among scientists and managers are also important to relationship building. Participants felt that council meetings are a valuable opportunity for scientists to understand how their work is used to inform management.

Recognize Good Communicators and Boundary Crossers

Managers and scientists both benefit from the participation of skilled science communicators. Good communicators can be found in a variety of roles, including council and agency staff, advisors, and council members. Traits shared by effective communicators include accessibility, familiarity with scientific methods and the management process, and ability to translate information effectively. Support staff who interface with councils and scientists can be valuable in this role.

Approach Communication as a Long-Term Investment

Effective communication is an ongoing need that requires time, patience, and dedication to produce benefits. Communication also involves a learning curve; it takes time for managers and scientists to learn new terminology and "speak the same language." Council members can also benefit from having time to absorb and reflect on new information and thereby provide constructive feedback, for example, advance preparation such as a webinar before a presentation can help equip council members to engage in a productive discussion.

Identify Institutional Opportunities and Challenges

Communication also depends on fostering a culture of collaboration and good will at an institutional level. The group identified many positive examples of collaborations but also described challenges, such as barriers to communication across research programs and divisions and varying levels of willingness

among scientists to engage with councils. Successful collaboration can also depend on the willingness of leadership to dedicate the needed time, funding, and staff resources.

Managers Need to Communicate with Stakeholders about Change

Preparing for change is a shared responsibility that also includes the public. Forum participants felt that communicating with stakeholders about change is critical to leveraging new information and predictive capabilities and to generating the awareness and buy-in to support a management response. The group raised several points related to stakeholder communication and buy-in, which they identified as an opportunity for councils to continue learning from one another.

Providing Information Is a Management Responsibility

Managers bear part of the responsibility of understanding how fisheries are changing and of considering the impacts of the decisions they make in response. However, fishery stakeholders share the responsibility of adapting to change and must make their own decisions in response to changing fishery and management conditions. The group emphasized the need to equip fishery stakeholders with information about future changes and future scenarios so that they can determine how to respond. Information-sharing can also be a two-way conversation, and stakeholders can provide feedback on the information that is useful to them.

Managers Can Build Awareness of Tradeoffs and Opportunities

Managers can help stakeholders understand that failure to acknowledge change in the short term can lead to tradeoffs, costs, and constrained options over the long term. Managers can also help frame adaptation to change in a positive way. The group felt that responding to change is often framed in terms of constraining opportunity; however, managers can emphasize that awareness of future changes benefits stakeholders by empowering them to prepare. Engaging the industry to provide on-the-water insight, including through cooperative research, is another positive opportunity to generate buy-in.

Opportunities for Engagement Extend Beyond the Council Process

Many of the strategies for supporting effective science-management communication—particularly consistent and dedicated opportunities for discussion—can also support stakeholder buy-in. Participants felt the conversation about preparing for and responding to change needs to extend beyond the council table, for example, through workshops and other outreach opportunities. They also noted that engaging stakeholders on climate and ecosystem-related topics is particularly difficult when stakeholder relationships are already strained, but that investing in outreach and relationship-building generally can help the build capacity to address challenging topics.

Conclusion

The 2017 Forum was a valuable opportunity for fishery managers to share their experiences and concerns related to a changing environment. In addition, the Forum provided managers with new insight into the advances in research and modeling to understand the mechanisms and potential outcomes of change. Forum presentations and discussions illustrated the opportunity for managers to leverage these scientific gains by developing the commensurate capacity to plan for change and integrate environmental information into decision making.

Forum discussions emphasized that managing fisheries under changing conditions will place new demands on managers and the decision-making process. Change will enhance the need for flexibility and responsiveness, and it will introduce additional complexity and uncertainty into an already complicated management process. Change also requires adopting a longer-term, ecosystem-level frame of reference for decision making. For managers accustomed to a familiar and highly structured decision-making

process, it will be important to develop strategies for approaching "big picture" challenges in a structured and accessible manner.

Change also increases the need for managers to strengthen relationships with the scientific community and with fishery stakeholders. Strong working relationships and clear communication pathways can provide a foundation for addressing the new set of challenges that a changing environment will bring to fisheries management. Finally, participants recognized the value of continuing to share ideas and experience across regions, while also investigating next steps and specific solutions in the context of each region's fisheries and stakeholders.

APPENDIX: PRESENTATION SUMMARIES

Changes to Resource Productivity

Forum participants from the Pacific region shared three examples of the causes and consequences of changing resource productivity in the California Current Ecosystem (CCE). Speakers explored the steps that fishery managers and scientists are taking to link harvests with variable or changing abundance, and they reflected on the management implications of responding to change.

California Current Context

Steven Bograd, Oceanographer, NOAA Fisheries Southwest Fisheries Science Center

Steven Bograd described the highly anomalous environmental conditions experienced in the California Current Ecosystem from 2013 to present. The drivers for these conditions included a weather-driven mass of unusually warm water in the northeast Pacific, referred to as "the Blob," and a strong El Niño event in 2015–2016 that also contributed to warm surface temperatures. CCE impacts, which researchers attributed primarily to the influence of the Blob, included algal blooms; salmon, marine mammal, and bird mortality; and fisheries impacts due to changes in distribution, productivity, and interactions with protected species. Some marine species were negatively affected while others responded positively, for example, through increased recruitment or range expansion. Bograd described these conditions as a "stress test" that offers insight into future challenges under changing conditions. He concluded by emphasizing the need for ecosystem-based fisheries management tools, including integrated ecosystem assessments, climate-ready management strategies, and dynamic ocean management.

Pacific Sablefish Example

Michele Culver, Washington Department of Fish & Wildlife; Member, Pacific Fishery Management Council

Michele Culver described efforts by fishery managers and scientists on the West Coast to improve their understanding of the environmental factors influencing sablefish productivity. Sablefish is a valuable and relatively data-rich stock that spans the Pacific Coast from California to Alaska and that is managed on the U.S. West Coast by the Pacific Fishery Management Council. Since 1999, the stock has shown a persistent downward trend in biomass despite increasingly precautionary management by the Council. Scientists and managers in Canada and in the Alaska region of the United States have experienced the same trend. Culver described recent steps by scientists to improve the sablefish assessment model to understand the cause of this decline and to improve understanding of the sablefish stock throughout its range. In 2016, in response to a request by the Council, NOAA Fisheries scientists conducted an in-depth examination of the relationship between environmental factors and recruitment. Scientists and managers are now considering management strategy evaluation (MSE) as a way to evaluate the performance of harvest control rules under conditions of changing productivity.

Pacific Sardine Example

David Crabbe, Member, Pacific Fishery Management Council

David Crabbe shared his experience participating in, and later helping to manage, the Pacific sardine fishery. Pacific sardines, which are managed by the Pacific Fishery Management Council as part of the Coastal Migratory Pelagics complex, fluctuate in abundance in response to environmental conditions. The stock is assessed annually. The Council utilizes a precautionary harvest control rule that links allowable harvest with environmental conditions and that includes a provision to close the directed fishery when biomass falls below a threshold of 150,000 metric tons. The fishery has been closed for the past two

years. Crabbe reflected on opportunities to continue managing the fishery in a responsive way that benefits fishermen and the stock.

Changes to Fishery Availability

Fishery managers from the east and west coasts shared three regional examples of changes to fishery availability. Changes in fishery availability are often associated with shifts in stock distribution caused by changing environmental conditions. Availability can also be influenced by other factors, such as range expansion, the rebuilding of an overfished stock, and changes in migration patterns. These three examples supported a multi-part discussion that explored the management implications of changing fishery availability, focusing first on the topics of allocation, access, and infrastructure and second on coordination and governance challenges.

Mid-Atlantic Summer Flounder Example

Mike Luisi, Maryland Department of Natural Resources; Chair, Mid-Atlantic Fishery Management Council

Mike Luisi provided a two-part overview of the Mid-Atlantic summer flounder fishery, illustrating the interaction between a complex management and governance framework and a changing resource. Summer flounder is jointly managed by the Mid-Atlantic Fishery Management Council and the Atlantic States Marine Fisheries Commission, which coordinates management of fisheries in state waters. The fishery extends from North Carolina to Massachusetts, and the center of the stock's distribution is shifting north. For the first part of his talk, Luisi focused on the topics of access and allocation. The summer flounder fishery is allocated between commercial and recreational sectors. Within sectors, each state's access to the fishery is linked to historical landings. In the commercial fishery, the quota is allocated among states on the basis of 1980–1989 landings. Recreational harvest targets are based on the proportional distribution of 1998 recreational landings among states, and from 2001 to 2013, they were managed using regulations determined at the state level. In 2014, the Council moved toward a more regional approach to managing recreational harvest targets to provide more flexibility. Luisi described the challenges related to access and allocation that are arising in each sector, noting the perception that allocations based on historical landings are not aligned with the current distribution of the stock. The Council is developing a comprehensive amendment to the fishery management plan that will address commercial and recreational management issues and that will consider important questions about the basis and process for revising allocations.

For the second part of his talk, Luisi explored the governance and coordination needs of fisheries that span or expand into multiple management jurisdictions. For example, New England states are interested in increasing their participation in the management process for summer flounder and other Mid-Atlantic species like black sea bass that are shifting north. Luisi reflected on the opportunities for management partners to work together through joint management and other mechanisms (e.g., providing adjacent councils with seats on species-specific management committees) as well as described some of the challenges of coordinating efforts among management partners with different legal requirements, processes, and priorities.

Atlantic Coast Blueline Tilefish Example

Chip Collier, Fishery Biologist, South Atlantic Fishery Management Council
Brandon Muffley, Fishery Management Specialist, Mid-Atlantic Fishery Management Council

Chip Collier and Brandon Muffley shared two regional perspectives on the management of blueline tilefish, a stock that spans the jurisdiction of the three east coast councils, thereby illustrating the challenges of managing fisheries that shift across council jurisdictions and potential responses. Blueline tilefish is managed by the South Atlantic Council in federal waters from Florida to North Carolina as part

of the multispecies snapper grouper complex. Until recently, there were no federal regulations for blueline tilefish in Mid-Atlantic federal waters, and only two states, Virginia and Maryland, set state regulations. Landings outside of this range increased substantially in recent years, creating the potential for unregulated landings. Concerns about sustainability and access to this stock led both councils to consider approaches for ensuring permanent federal management of the stock throughout federal waters. The Mid-Atlantic Council developed an amendment that will establish federal management of blueline tilefish north of the North Carolina/Virginia border by incorporating blueline tilefish as a managed stock into a combined Golden and Blueline Tilefish Fishery Management Plan. Both speakers emphasized the value of a short-term response to address unregulated landings as well as longer-term efforts in both council regions to improve scientific understanding and management of the stock.

Pacific Dungeness Crab Example

Michele Culver, Washington Department of Fish & Wildlife; Member, Pacific Fishery Management Council

Michele Culver described a climate-related coordination challenge that involves public health as well as concerns about fishery access: reducing the risk of human exposure to domoic acid through consumption of Dungeness crab.

The Pacific Dungeness crab fishery is a valuable state-managed fishery in Washington, Oregon, and California. Under certain conditions, harmful algal blooms can result in elevated levels of domoic acid, a toxin that can accumulate in shellfish and that is harmful if consumed. Since experiencing outbreaks in 2015, the three states (including their respective fisheries management and public health agencies) have worked together to establish consistent testing protocols and to coordinate fishery openings before the season begins. Culver reflected on additional opportunities for states to work together, such as through in-season coordination. She concluded by sharing lessons and noted the value of states communicating early and often and considering how climate-related impacts to one fishery can affect landings and participation in other state and federal fisheries.

NOAA Fisheries Climate Science Strategy

Advancing Climate-ready Risheries Management

Roger Griffis, Climate Coordinator, NOAA Fisheries

Roger Griffis described the origins and purpose of the NOAA Fisheries Climate Science Strategy, which was adopted in 2015 to increase the production, delivery, and use of climate-related information in support of NOAA Fisheries mandates. Climate change is already affecting the ocean environment, causing physical and chemical changes that impact species, marine ecosystems, and ultimately fisheries and fishing communities. These impacts are expected to increase over time. Climate-related changes create a growing demand for information to support sustainable resource management under conditions of change. The Climate Science Strategy is a way for managers and scientists to identify and prioritize information needs to reduce impacts and support resilience.

The Climate Science Strategy is organized according to seven objectives that describe information needs related to monitoring, research, and forecasting as well as strategies for using this information effectively for management purposes. Each NOAA Fisheries management region has developed a regional action plan to customize and guide the implementation of the strategy at a regional level. The regional action plans identify specific actions and priorities that can be undertaken in the next three to five years. Looking across regions, key actions and next steps include strengthening the use of ecosystem status reports and potentially enhancing forecasting and early warning capabilities, providing information about shifting

species distributions, completing fish stock climate vulnerability assessments, building regional capacity for management strategy evaluation, and developing risk assessment tools.

Regional Ecosystem-Based Fisheries Management Frameworks

Ecosystem-based fisheries management (EBFM) can strengthen councils' ability to manage fisheries in a changing environment by supporting ecosystem resilience and productivity and providing the framework for integrating environmental information into decision making. Three Forum participants shared their regions' approaches to EBFM, including the drivers for transitioning toward EBFM, the structure of each region's plan or approach, and the process for implementing specific actions. Participants also described how their region's EBFM approach helps frame consideration of climate change, and they reflected on their challenges and lessons learned.

Pacific Coast Fishery Ecosystem Plan

Rich Lincoln, Council Member, Pacific Fishery Management Council

Rich Lincoln provided an overview of the Pacific Coast Fishery Ecosystem Plan (FEP) for the U.S. Portion of the California Current Large Marine Ecosystem. The FEP process was initiated by the Pacific Fishery Management Council in 2009, and the plan was adopted in 2013. The stated purpose of the FEP is "to enhance the Council's species-specific programs with more ecosystem science, broader ecosystem considerations, and management policies that coordinate Council management across its Fishery Management Plans and the California Current Ecosystem." Lincoln described increasing environmental variability and the Council's interest in integrating more environmental information into stock assessments as motivations for developing the FEP.

The FEP is an informational document with objectives that are supported through the implementation of ecosystem initiatives. These initiatives are included as an appendix to the FEP and can be reviewed and updated in response to emerging challenges and changing conditions. The Council reviews the California Current Ecosystem Status Report (ESR) and the Ecosystem Initiatives Appendix to the FEP on an annual basis and adopts a new initiative every two years. The first initiative, selected in 2013, focused on protecting unfished and unmanaged forage species; the second initiative, advanced in 2015, involved a review of the ecosystem indicators presented in the annual ESR. In early 2017, the Council identified two initiatives for further scoping, one of which would examine the cross-fishery management plan effects of climate shift.

Lincoln concluded by reflecting on the need to invest in both information and decision-making tools as strategies for managing effectively under changing conditions. Although additional science is needed to understand a changing environment, managers would also benefit from a decision framework to help make decisions in the face of uncertainty.

Ecosystem Approach to Fisheries Management in a Changing Environment

Warren Elliott, Vice Chair, Mid-Atlantic Fishery Management Council

Warren Elliott described the Mid-Atlantic Fishery Management Council's Ecosystem Approach to Fisheries Management (EAFM) and the process of developing the council's EAFM Guidance Document. The Council defines EAFM as "a fishery management approach that recognizes the biological, economic, social, and physical interactions among the components of ecosystems and attempts to manage fisheries to achieve optimum yield taking those interactions into account." The Council first initiated development of the EAFM Guidance Document in 2011 in response to a visioning and strategic planning process that identified broad support for EBFM.

The EAFM Guidance Document is a non-regulatory umbrella document that supports a transitional approach to incorporating ecosystem considerations into the Council's species-based management programs. The Council developed the document by focusing on four topic areas in turn (forage, habitat, climate, interactions) through a series of workshops that included scientists, managers, and stakeholders. The final document was adopted in 2016, and the Council is developing a risk assessment approach (described in a later presentation by Sarah Gaichas) to help identify priorities and next steps. Elliott emphasized the value of the Mid-Atlantic's collaborative process as well as the systematic, stepwise approach that made the task of developing the EAFM Guidance Document more manageable.

Developing a Bering Sea FEP

Diana Evans, Fishery Analyst, North Pacific Fishery Management Council

Diana Evans described the North Pacific Fishery Management Council's development of a Fishery Ecosystem Plan (FEP) for the Bering Sea. The Council developed its first FEP for the Aleutian Islands region in 2007, a process that provided the Council with a valuable opportunity to explore the utility of FEPs. The Council voted in 2015 to proceed with the development of an FEP for the Bering Sea, a region that supports abundant fisheries and fishing activity and that is also the focus of extensive ecosystem research.

The Council already supports EBFM through a variety of actions, and it considered whether and how an FEP could add value to existing processes while using time and resources efficiently. The Council identified several benefits to developing an FEP, including (1) providing increased transparency and accessibility to show how ecosystem considerations are reflected in council decision making, and (2) facilitating communication between scientists and managers to strengthen the connection between scientific research and management questions and needs. The FEP will be an action-informing document implemented through modules, similar to the use of ecosystem initiatives in the Pacific region. One proposed module would focus on providing feedback on the information and products that would help support the Council's response to climate change and that would complement the Alaska Integrated Climate Modeling Project (ACLIM) (described in a later presentation by Kirstin Holsman; see below).

Evans shared some of the challenges and questions the Council continues to work through during the FEP development process, including aligning the FEP with existing processes (such as the Council's annual review of ecosystem status reports), managing stakeholder expectations and concerns, and setting goals and objectives. Another unique challenge facing the Council is balancing the desire to make the EBFM process transparent and accessible, while also developing the tools to process and utilize complex ecosystem information.

Indicators and Ecosystem Status Reports

The NOAA Fisheries Climate Science strategy identifies establishing and strengthening ecosystem indicators and ecosystem status reports (ESRs) as a high priority in all regions. Indicators and ecosystem status reports are tools for providing fishery managers with timely ecosystem-level context to inform decision making.

Indicators represent a component of an ecosystem over time, and they can provide insight into changes and trends related to ocean conditions, primary productivity, specific species, fishing behavior, and other elements of marine ecosystems. Ecosystem status reports summarize and synthesize information about the state of marine ecosystems at the regional or large marine ecosystem (LME) level. These tools track changes and trends in marine ecosystems and can provide timely information about current conditions as well as insight into potential future changes, including changing climate conditions.

The development and use of indicators and ESRs within in each management region provides a valuable opportunity for managers and scientists to share experience across regions. At the Forum, three NOAA Fisheries scientists described the evolution and use of three regions' indicators and ESRs. Although the suite of indicators and resulting information products are different in each region, the three speakers emphasized several important similarities:

- Timing: Timing of the provision of ESRs and indicators is important for informing decision making, particularly the process for setting annual catch limits.
- Accessibility: Managers often request that ESRs and indicators be presented in a concise, digestible format that helps support discussion and facilitate the uptake of information.
- Iteration and evolution: Scientists and managers can work together in an iterative process to develop useful information products and visuals, and to identify the indicators that are most informative to management.
- Goals and objectives: The development of ecosystem-level goals and objectives is an important step for enhancing the utility of indicators and ESRs to decision making.

Ecosystem Considerations Reports for Alaska's Groundfish Management

Stephanie Zador, Research Biologist, NOAA Fisheries Alaska Fisheries Science Center

Stephani Zador described the evolution and use of annual ESRs to support groundfish management in the Alaska region. The Alaska Fisheries Science Center (AFSC) has produced ESRs annually since 1995, and the reports are one of many avenues through which the region and the North Pacific Fishery Management Council support ecosystem-based fisheries management (EBFM). ESRs are linked with the stock assessment process and directly support groundfish management by informing discussion during the Council's annual quota setting process each December.

The AFSC develops separate ESRs for three large marine ecosystems within the Alaska Region: the Eastern Bering Sea, the Gulf of Alaska, and the Aleutian Islands. It will develop a report for the Arctic in the future. Each ESR includes multiple information products, including (1) a two-page report card that provides a snapshot of current trends and selected indicators; (2) an ecosystem assessment describing the state of the ecosystem each year; (3) a detailed report on ecosystem and ecosystem-based management indicators, including a description of the indicator, status and trends, and potential fishery management implications; and (4) short briefs highlighting "hot topics" in each region. These information products are revised annually in response to input from scientists and questions from managers and advisors.

ESRs are presented sequentially each year to plan teams, the Council's Scientific and Statistical Committee (SSC), and finally the Council and its Advisory Panel. Each body considers this ecosystem context when developing recommendations throughout the quota-setting process. Zador shared two recent examples in which ecosystem indicators were used to justify an adjustment to the acceptable biological catch (ABC) for groundfish species. In conclusion, Zador reflected on the region's use of ESRs as an opportunity to facilitate discussion and the rapid uptake of ecosystem-related information and to enhance transparency and trust between scientists and managers.

Mid-Atlantic State of the Ecosystem Report

Sarah Gaichas, Research Fishery Biologist, NOAA Fisheries Northeast Fisheries Science Center

Sarah Gaichas introduced the recent draft Mid-Atlantic State of the Ecosystem Report. The Northeast Fisheries Science Center (NEFSC) provides a concise state of the ecosystem report and a more detailed ESR for Northeast Continental Shelf Ecosystem, an area that includes the jurisdictions of both the New England and Mid-Atlantic Fishery Management Councils. The 2017 draft Mid-Atlantic State of the Ecosystem Report is a separate report that focuses specifically on the Mid-Atlantic Bight ecological production unit. The Mid-Atlantic ESR evolved from discussions with the Mid-Atlantic Fishery Management Council's Scientific and Statistical Committee (SSC). Gaichas described the report as an effort by NEFSC to provide ecosystem information and indicators specific to the Mid-Atlantic region and organized in a way that are useful to management and that support the Council's recently adopted Ecosystem Approach to Fishery Management (EAFM) Guidance Document.

Gaichas highlighted several distinctive features of the draft report. The report begins with a conceptual model, which is a visual depiction of the ecosystem-level context for the Council's managed species. The model characterizes relationships among focal species groups, human activities, environmental drivers, habitats, ecological links, and ecosystem-level management objectives (e.g., food production, recreational opportunities) derived from the Magnuson-Stevens Act and Council practices. The report is organized according to these objectives and their associated indicators, and it begins with the human dimensions of management (followed by sections on other topics, including resource species and the physical environment) to help make this information accessible.

Gaichas concluded by explaining how the information presented in the Mid-Atlantic ESR can support the Council's EAFM. The Council's EAFM Guidance Document proposes a risk assessment approach that evaluates each of the Council's FMPs by level of risk (low, moderate, high, very high) according to categories that include stock status, assessment type, climate vulnerability, and social and economic factors. This approach could be used to identify and prioritize questions to examine through a management strategy evaluation process.

Emerging Trends, Trials, and Triumphs in the California Current Ecosystem Status Report

Elliott Hazen, Research Ecologist, NOAA Fisheries Southwest Fisheries Science Center

Elliott Hazen provided an overview of the annual California Current Ecosystem Status Report, developed through NOAA Fisheries' California Current Integrated Ecosystem Assessment (CCIEA) program. The CCIEA program helps coordinate and advance ecosystem science to inform the management of multiple ocean uses, including fisheries. The annual ESR is a concise document that was first initiated in 2014 at the request of the Pacific Fishery Management Council. Hazen described the purpose of this document as "to inform the Council of the status, trends, and variability of key physical, chemical, biological, and social indicators in support of ecosystem-based fisheries management (EBFM)."

The broad conceptual model for the California Current Ecosystem includes focal ecosystem components (e.g., ecological integrity, human wellbeing), mediating components (e.g. habitat, governance and institutions), and drivers and pressures (e.g. human activities, climate drivers). The CCIEA program has developed a large set of indicators for these components, and it focuses on a smaller subset of these indicators for the ESR. The program also utilizes narratives and conceptual models to help convey ecosystem information to fishery managers and other information users.

Hazen concluded by sharing some of the challenges and opportunities of providing the Council with information about the California Current Ecosystem. The inherent variability of the ecosystem can make

it challenging to distinguish between decadal patterns and signals of directional change. The amount of information provided can also be overwhelming. Hazen described the opportunity to move toward a web-based ESR approach that would allow users to explore information in a more timely, interactive, and customizable way. Finally, managers and scientists are exploring how the ESR could be used to provide more formal decision support.

Advances in Research, Tools, and Modeling

The scientific community is making exciting advances in understanding the impacts of climate change on fisheries and the ocean environment and in developing tools that can help inform management strategies. Forum speakers highlighted three very different approaches for providing managers with insight into likely changes, including the consequences, sources of uncertainty, and opportunities for response.

Assessing the Vulnerability of Fish Stocks in a Changing Climate

Roger Griffis, Climate Coordinator, NOAA Fisheries

Roger Griffis introduced the NOAA Fisheries Climate Vulnerability Assessment Methodology, which provides a framework for leveraging existing information and expert knowledge to assess the vulnerability of fish stocks under changing climate conditions. NOAA Fisheries is developing regional vulnerability assessments that apply this methodology at a regional scale to identify vulnerable species, to provide insight into the fisheries and fishing communities at risk, and to help focus science and management to reduce risks and increase resilience. The NOAA Fisheries Climate Science Strategy identifies conducting climate vulnerability assessments in all regions and for all large marine ecosystems as a short-term priority.

The climate vulnerability assessment methodology focuses on two variables: exposure and vulnerability. Exposure characterizes the environmental change a species is likely to experience, and it is evaluated in terms of physical and chemical attributes such as sea surface temperature and salinity under future climate and ocean projections. Sensitivity characterizes the ability of a species to tolerate change, respond to change, or both, and it is evaluated using expert opinion based on attributes such as habitat specificity and sensitivity to temperature. NOAA Fisheries experts rank species in terms of their exposure and sensitivity to generate relative vulnerability scores of low, moderate, high, or very high. Each species also receives a directional score indicating whether the overall impacts of change are likely to be negative, neutral, or positive. Experts develop a vulnerability narrative for each species to provide additional insight into the characteristics that cause a species to be vulnerable to changing conditions.

An assessment of the northeast region was completed in 2016, and assessments are underway or near completion in several other regions. Griffis emphasized that climate vulnerability assessments are not an endpoint; they are a starting point to initiate conversation, to identify information gaps and research needs, and to help prioritize management challenges and questions.

Predicting Geographic Range Shifts of Marine Species and Understanding Sources of Uncertainty

Jim Morley, Postdoctoral Researcher, Rutgers University

Jim Morley described his research with colleagues at Rutgers University to predict geographic range shifts for several hundred fish species across U.S. management regions. These predictions can provide fishery managers and stakeholders with valuable insight into how species are likely to respond to climate-related changes in ocean temperatures.

Morley began by describing the foundations of this research in thermal biology. Marine fish species are very responsive to environmental changes because they are ectothermic, and processes such as digestion,

growth, and reproduction are influenced by temperature and oxygen availability. Each species has an optimal thermal range, termed the "thermal envelope." A species is most productive in the habitat where conditions match its thermal envelope. Changing ocean temperatures lead to a shift in the geographical location of this preferred habitat and, therefore, to a shift in a species' likely distribution.

Morley and his colleagues are predicting range shifts by modeling each species' preferred habitat and how it is likely to shift based on environmental conditions. The resulting projections predict where a species' biomass will be located in the future. The magnitude of the shift predicted for each species is influenced by two important sources of uncertainty: the level of warming experienced and the trajectory of greenhouse gas emissions. For this project, researchers are using 16 climate projection models and two future emissions scenarios (status quo or reduced) to generate 32 possible scenarios that capture the range of possible range-shift scenarios for each species. The magnitude of range shifts predictions and the uncertainty associated with these predictions can help managers anticipate future changes and identify priorities for a management response.

The Alaska Integrated Climate Change Modeling Project (ACLIM)

Kirstin Holsman, Research Fishery Biologist, NOAA Fisheries Alaska Fisheries Science Center

Kirstin Holsman provided an overview of the Alaska Integrated Climate Change Modeling Project (ACLIM), an interdisciplinary collaboration among scientists at the NOAA Fisheries Alaska Fisheries Science Center and the University of Washington. The project aims to identify impacts and management solutions for Eastern Bering Sea fisheries. The Bering Sea ecosystem is strongly influenced by winter sea ice conditions and is likely to experience significant climate-related changes in the future.

The first phase of the ACLIM project involves understanding how and when the Bering Sea ecosystem will change. The Bering Sea is a highly productive and well-studied ecosystem. The recently concluded Bering Sea Project, a collaboration between the North Pacific Research Board and the National Science Foundation, led to major advances in the scientific understanding of Bering Sea ecosystem dynamics and processes. ACLIM builds on this progress by coupling physical, biological, and socioeconomic models to frame the range of possible future climate scenarios.

The second phase of ACLIM will test the performance of new and existing management tools under changing conditions, and it will explore how management could adapt and minimize the impacts of change. ACLIM provides the unique capability to consider adaptation in the long term, for example, by testing management tools in advance to assess how well they perform and by identifying management strategies that would need to be initiated proactively in advance of change. The final phase of the project will aim to provide insight into the sources of uncertainty and to identify which can and cannot be managed or reduced. Holsman emphasized the value of input from the management community to develop information products that are valuable for decision making.

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Fisheries Leadership & Sustainability Forum

The Fisheries Leadership & Sustainability Forum (Fisheries Forum) provides policy-neutral support to the federal fisheries management community, including National Oceanic and Atmospheric Administration (NOAA) Fisheries, regional fishery management councils, and management partners. The Fisheries Forum convenes a series of forums for council members, council staff, and NOAA Fisheries staff. Each forum focuses on a timely topic with regional and national relevance. The forums are a unique opportunity for managers to explore emerging issues and questions, build their professional networks, and share ideas and information across management regions. For more information and to view materials from past forums, forums, please visit the Fisheries Forum Information Network (www.fisheriesforum.org).

Nicholas Institute for Environmental Policy Solutions

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in government, the private sector, and the nonprofit community address critical environmental challenges. The Nicholas Institute responds to the demand for high-quality and timely data and acts as an "honest broker" in policy debates by convening and fostering open, ongoing dialogue between stakeholders on all sides of the issues and providing policy-relevant analysis based on academic research. The Nicholas Institute's leadership and staff leverage the broad expertise of Duke University as well as public and private partners worldwide. Since its inception, the Nicholas Institute has earned a distinguished reputation for its innovative approach to developing multilateral, nonpartisan, and economically viable solutions to pressing environmental challenges.

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