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February 5, 2021

Mr. Marc Gorelnik, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, #101
Portland, OR 97220

RE: •Agenda Item I.2: Climate and Communities Initiative Workshop Report

Dear Chair Gorelnik and Council Members:

Changing ocean ecosystems are altering the distribution and abundance of fish populations and impacting the people whose health, well-being and livelihoods depend on them. While general trends are clear, the exact spatial and temporal scales of impacts are unknown and difficult to predict. Adaptable and flexible management regulations are often considered a key aspect of climate ready fisheries, but what is flexible management?

To help answer this question, The Nature Conservancy conducted a review of the available literature and all of the federally adopted Fishery Management Plans in the United States, to identify areas of fishery management and monitoring that may provide points of flexibility. Incorporating flexibility into fishing regulations requires a multifaceted process that enables pre-approved, responsive decision making with public oversight. Preparation and long-term planning, such as the Climate and Communities Initiative's (CCI) Scenario Planning Project, are the backbone of management flexibility. Full, stakeholder engaged planning processes enable a fishery to consider the range of possible future scenarios and develop actions that would address them. Monitoring and analysis then provide the means to track the different components of a fishery (e.g. ecology, economics, social) to understand the current and trending situation and determine if alternative actions are needed.

The range of potential options to respond to a situation coming out of the planning process should be developed for both the industry and managers. An essential part of flexible fisheries management is providing the necessary tools, such as around gear and permits, that allow the industry the ability to rapidly adapt to the current challenges with the proper oversight. Similarly, managers must utilize their range of tools and develop pre-approved actions from the planning process to initiate once certain threshold are triggered that provide timely responses with public oversight. Even in the most data rich fisheries, we cannot predict the future, but we can plan to be responsive to the current and emerging oceanic, economic, and social conditions.

Incorporating flexibility in fishery management is it much more complicated than what is summarized in this letter. Our more detailed findings are included in the attached white paper *Flexibility in the Pacific Fisheries Management Council's Fishery Management Plans: What is Flexible Fisheries Management?* I will be attending the ecosystem agenda items at the March Council meeting and am available to answer any questions related to this letter or the white paper. Additionally, please do not hesitate to contact me at gway.kirchner@tnc.org. Thank you.

Sincerely,

Gway R Kirchner

Gway Kirchner
Marine Fisheries Project Director, Oregon Chapter
The Nature Conservancy

Flexibility in the Pacific Fisheries Management Council's Fishery Management Plans: *What is Flexible Fisheries Management?*

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The Nature Conservancy
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List of Abbreviations

ABC	acceptable biological catch
ACL	annual catch limit
C-HARM	California Harmful Algae Risk Mapping
CCI	Climate and Communities Initiative
CPS	coastal pelagic species
DPIPWE	Department of Primary Industries, Parks, Water, and Environment (Tasmanian Government)
EEZ	exclusive economic zone
EFP	exempted fishing permit
FMP	fishery management plan
GMT	Groundfish Monitoring Team
Gulf Council	Gulf of Mexico Fishery Management Council
HMS	highly migratory species
IATTC	Inter-American Tropical Tuna Commission
MAFMC	Mid-Atlantic Fishery Management Council
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council
OFL	overfishing limit
PFMC	Pacific Fishery Management Council
RAMP	Risk Assessment and Mitigation Program
SAFE	Stock Assessment and Fishery Evaluation
TAC	total allowable catch
TNC	The Nature Conservancy
WCPFC	Western and Central Pacific Fisheries Commission
WPRFMC	Western Pacific Regional Fishery Management Council

Introduction

Many facets of society must adapt to a changing climate, including commercial, recreational, and tribal marine fisheries. The nature of fishing already requires flexibility to adapt to the ever-changing realities of running a business, a dynamic ocean, and regulations. However, uncertainties related to shorter-term climate shifts (e.g., extreme weather events) and longer-term climate change (e.g., ocean temperatures and acidification) have triggered a need for fishery managers to examine their ability to manage in the face of these changing ocean conditions.

Two years ago, the Pacific Fishery Management Council (PFMC) launched its Climate and Communities Initiative (CCI; PFMC, 2020). This initiative uses informed science and integrated policy considerations in a focused effort to develop strategies to mitigate climate change impacts on West Coast fisheries and their dependent communities. A primary CCI activity is a collaborative effort between PFMC and The Nature Conservancy (TNC) on scenario planning. Scenario planning is a process where a variety of plausible future conditions are created and then evaluated for possible impacts and the identification of potential challenges and opportunities. Following this type of exercise, decision-making bodies may evaluate existing policies and practices to determine where changes are needed now or in the future.

One of the major themes running across all studies on developing climate-ready fisheries management is the need to integrate flexibility and adaptability to create a more responsive management process (Barange et al., 2018; Johnson et al., 2019; Karp et al., 2018). Fisheries management requires collecting information, analyzing that information to develop regulations, and successfully implementing those regulations (Quinn & Deriso, 1999). The process has been designed to continuously update management as new information becomes available. Adaptive decision-making abilities at certain scales, therefore, are already written into federal and international fishery management plans (FMPs) and may be applied to future climate change scenarios. The U.S. fishery management system, however, is generally designed to adapt on long time scales with the aid of extensive oversight and public review. Substantial changes in regulations, like the amendment processes, can take years, allowing management actions to remain consistent over longer time periods. Other aspects, however, such as harvest levels, are consistently updated as new information becomes available.

The nature of recreational and commercial fishing already requires flexibility and adaptation in response to constantly shifting weather, social, economic, and regulatory conditions. However, uncertainties related to shorter-term climate shifts and longer-term climate change have triggered a need for regional Councils to further strengthen their ability to manage in the face of climate change. The three-part goal for climate-ready fisheries are to (1) develop management plans that incorporate the projected, but still uncertain, changes in the ecosystem and (2) ensure sufficient oversight and public review of decisions while (3) reducing the amount of time needed to recognize a situation on the water and implement an appropriate response. (In this paper, the term “Council” means any Council governed by the National Marine Fisheries Service [NMFS], including PFMC.)

But what is flexibility? This white paper aims to define what flexibility means for fisheries and its application to fisheries management and explore existing tools that can be brought to bear to increase management flexibility for West Coast fisheries. These tools include those documented in federal FMPs throughout the U.S. and international fishery management processes. Lastly, the paper examines the points of flexibility in management plans from PFMC and beyond. This information is intended to serve as a resource for stakeholders and provide context to the PFMC's scenario planning process.

What Is Flexibility?

The ability to quickly change regulations and fishing strategies is a commonly accepted definition for flexibility in the context of fisheries management. However, this definition fails to capture vital components of successful fisheries management in a time of uncertainty. A more complete definition would explain that flexibility entails

- a management system that integrates a range of potential scenarios,
- indicator tracking that allows recognition of the scenarios when they occur, and
- the ability to formulate and apply an appropriate, preapproved, and timely response.

A definition that integrates these components could provide managers and fishers with information necessary for successful fishery operations while creating space for stakeholder involvement in decision-making. This type of structure would include preapproved, vetted formal management plans (e.g., FMPs) with adequate oversight that allow the alteration of rules and regulations as well as the creation of a range of future scenarios with preapproved actions detailing how to approach them.

Although U.S. fishery management structures already integrate some of these components, explicit consideration of potential climate impacts is lacking, as are the tools needed to approach rapidly evolving situations.

Flexibility in a Changing Climate

Managers already use regulatory tools that may be transferrable to future situations, such as

- regulating time, space, and gear;
- defining who gets to harvest; and
- setting the total allowable catch (TAC).

Flexibility in fisheries management requires a regulatory structure that enables decision-making at a scale and pace necessary to address the unexpected challenges related to climate change. Appropriate and timely responses will be needed when conditions deviate from predictions or the initial management decision proves unsuccessful. Flexibility relates to both management and industry decisions and applies to everything from daily actions to long-term projections—from gear selection in a given location on a given day to harvest guidelines for future seasons.

The following factors can improve flexibility in U.S. fishery management frameworks:

- knowledge of the current environmental conditions and resource status
- tools to track conditions and determine when a threshold or decision point has been reached
- prespecified stakeholder responses to modifications once the threshold is reached (e.g., season, area fished, gear, the total amount removed)
- a fishery management process that ensures public input and oversight

Because it is easier to identify climate events after they have occurred, these factors can be challenging to achieve. An important first step is a fundamental ability to recognize changes in conditions as they are happening. Scientists and managers must understand and be able to answer key questions such as: Is the event a short-term variation or a long-term trend? What is the status of the resource? And what factors influence the resource (e.g., static and dynamic habitat, predators, prey, fishing)?

Elements That Enable Flexibility

Unpredictable and rapid regulatory changes can be problematic to both the resource and resource users, limit businesses' ability to plan for fishing seasons, and limit public participation in decision-making. An FMP with built-in flexibility, which is preapproved through a vetted public process, can foresee the different regulatory pathways that may be activated if the data warrants and help alleviate some of the challenges of operating in uncertain times. This section provides detail about specific development decisions, management processes, and FMP components that could be deployed to increase the PFMC's ability to be flexible and responsive to future climate-related changes.

1. Long-Term Planning and Strategy Development

Long-term planning and strategy development are tools that can be used for sustainable fisheries management. To do so, managers must ask the following questions:

- What are the projected future challenges?
- What are the expected impacts?
- What are the goals of the fishery?
- What actions are required to address the fishery's challenges and achieve specified goals? Should a suite of alternative actions be included to address uncertainties?
- What resources are needed to take those actions?

Many of these questions are addressed during an FMP's development phase or when changes are made to the plan. Planning should include a range of topics, from permitting and quota transfers to stock assessments, harvest control rules, and in-season actions.

2. Collaborative Preseason Planning

Preseason or near-term planning meetings with stakeholders allow for the collaborative evaluation of current conditions, regulations, and risks for both target and nontarget species (e.g., protected species). Depending on the structure of these meetings, the collective group has the potential to inform ways of mitigating the coming season's risks (e.g., whale entanglements) using management or industry actions while still complying with regulations.

3. Framework Adjustments

Framework adjustments are tools present in all FMPs. They are intended to provide a means to change regulations without going through the full amendment process (e.g., at a single Council meeting) and determine the amount of flexibility available to the decision-making body. They are typically developed for regulations that need routine adjustments, such as annual harvest specifications or in-season modifications.

However, framework adjustments require that potential regulatory changes be included proactively in an FMP amendment. To ensure that a broad suite of actions is available when an issue presents itself, officials must write the necessary tools into a management framework, often before that issue arises. Long-term planning and strategy development provide a platform to develop potential scenarios and appropriate responses. Framework adjustments can then serve as the tools to implement the responses as needed.

4. Exempted Fishing Permits

Exempted fishing permits (EFPs) provide another means to create alternative rules that could go into effect quicker than amendments. These permits, approved by Councils and issued by NMFS, provide exemptions from fishery regulations to "test" experimental fishing methods of conducting a fishery. While the application process can take time, EFPs create a path for innovation in both fishing and management. Examples of EFPs range from quite small to large scale. A small-scale example would be if a single captain received a gear exemption from existing regulations to test a more selective gear. A midscale example would be if a fishing association were exempted from certain regulations so it could collectively manage the bycatch in a novel manner.

A larger-scale exemption example comes from the Gulf of Mexico Fishery Management Council (Gulf Council). It relinquished its in-season authority of the red snapper recreational fishery in 2018–2019 to test a new model for state-managed quotas. Under Amendment 50, five states (Alabama, Florida, Louisiana, Mississippi, and Texas) were allocated control over private angling. By relinquishing control, the Council allowed states to tailor management measures to their specific needs, increase management flexibility, and improve socioeconomic benefits to the region (Gulf Council, 2019b).

Although EFPs like the previous three examples enable flexibility by allowing people to develop and test alternative ways to conduct fishing and management, more permanent changes cannot be implemented without the full rulemaking process, which can be a rather long and onerous process. Therefore, the long-term capability of EFPs to enhance flexibility is determined by a Council's ability and willingness to engage in more lengthy policy-making processes that can achieve permanent change, and the overall long timeframe needed to promulgate rulemaking.

5. Portfolio Diversification

Individuals, fishing associations, and ports can be more flexible and resilient in their fishing activities if they engage in a diverse portfolio of fisheries. Diverse portfolios provide a means for the industry to continue fishing across the broadest set of ecological, social, and economic conditions. If one species has shifted out of the area or the season has closed, vessels can turn to alternative species to remain operational. Accessing and maintaining a diverse set of fishing permits can be challenging, however, largely due to costs and various permit limitations (e.g., "use or lose" provisions, vessel length requirements, transfer requirements and limits). Numerous state and federal limited entry fisheries on the West Coast have been beneficial to the fisheries and their management, but they typically come with high entry costs, requiring vessels to reduce their diversity (Holland & Kasperski, 2016).

6. Dynamic Permitting

Dynamic permitting is a concept that enables individuals and entities (e.g., fishing associations, communities, ports) to potentially hold a diversity of permits and/or quotas that could be used to target and catch the available resources. Quotas could also be leased up and down the coast to enable fishing as closures occur or stocks move temporarily or permanently. Creating this type of flexibility requires well-developed permit and quota regulations, appropriate markets, and changes to state and federal regulations.

7. In-Season Changes

In-season changes are often a focal point for discussions about flexibility. During the season, conditions can change rapidly, and appropriate, timely responses are required. However, managers can make changes during the season only if they are granted the authority and flexibility to do so in the FMP framework, as described previously (acknowledging the emergency action authority of the U.S. National Oceanic and Atmospheric Administration [NOAA]). Similarly, well-developed regulations for permit and quota transfers, as well as specific rules governing when and where different fishing techniques can be used, provide the industry with the flexibility to adapt to current conditions when the conditions deviate from the expected.

The flexibility to make in-season changes—to open or close an area, alter the season, change gear, or lease quotas—must already be written into regulations, along with decision points that define when to act. Fundamental to the process is recognizing when conditions have deviated so much from the expected that a change to fishery regulations is warranted. This means that managers require information to quickly identifying what is happening on the water and where, as discussed next.

8. Monitoring and Analysis

Monitoring and analysis are key to flexible fisheries management. The spatial and temporal scale of the information available for management defines how a manager *can* respond. A system that collects and analyzes data once a year and at the scale of the entire West Coast can only make informed decisions on an annual time step and only at the scale of the West Coast. Alternatively, a system that takes in and analyzes high-resolution data on the fishery and ecosystem (e.g., weekly monitoring on a fine-scale spatial grid) can make fine-scale decisions about where and when to open or close specific areas, change the length of the season, or modify gear. The data's resolution and the ability to process and analyze the data in a timely manner define how management can take action. The finer the information's resolution, the finer the response can be.

But increased resolution also adds to the monitoring system's cost and maintenance and the number of decision points that need to be evaluated. In addition, not all indicators are needed at high resolution, and some events only occur at annual or longer time scales. An evaluation of the monitoring requirements for different decisions that managers will have to make should be conducted. Good communication among managers and the fleet is required to ensure updated rules do not create a maze of regulations.

9. Partnerships

Partnerships with fishers, state and federal governments, and other entities (e.g., universities and research facilities, nongovernmental organizations, community groups) can increase flexibility. By working with vessels, managers or researchers can collect increased oceanographic data and catch information at higher specificity to better contribute to decision-making data. Working with fishing captains can also illuminate the challenges of implementing regulations on the water and provide new insights or solutions. Also, providing some decision-making authority to fishery participants through policies such as rationalization/quota programs (e.g., the West Coast Trawl Rationalization Program) could increase their on-the-water flexibility to deal with unexpected conditions.

Similar positive outcomes can be achieved through partnerships with state governments. Deferring some management authority to state entities can reduce the burden on the larger management structure and improve real-time responses by locating the decision-making power with the entities that are likely to have better knowledge of on-the-water situations and less burdensome regulatory processes. State agencies often have in-depth and extensive knowledge about their regions and can make informed management decisions.

Strong partnerships can also foster increased monitoring and better communication among the fishing fleet, potentially resulting in earlier detection of changes on the water and timelier responses. With good information and communication, the industry can act by itself or work with managers to determine where to fish and what techniques to use to meet industry and management objectives, such as landing the quota, avoiding bycatch, and reducing habitat interactions.

Whether partnering with vessels, government entities, or others, the larger management body sets the overall management objectives and has full oversight to ensure objectives are met. Full industry accountability (e.g., through observers or electronic monitoring) can be an important element of that oversight.

Flexibility in the Pacific Council's FMPs

PFMC's four FMPs use a range of tools to manage fisheries on the West Coast. The different life histories of the species, qualities of the fisheries, and management experiences have resulted in a variety of flexible management approaches across the FMPs.

Salmon FMP

Despite considerable financial and political investments in protecting West coast salmon, stocks have been declining for years and vary dramatically from year to year. The salmon FMP includes relatively few species but contains a large number of stocks that vary considerably in their status (ranging from species listed under the Endangered Species Act to targeted fisheries). Aspects of the system have been developed over time in response to legal statutes and the need to continually evaluate the status of certain stocks. PFMC uses the fishery's FMP (PFMC, 2016) to protect and balance the needs of the species, ecosystem, and humans, including our food supply, jobs, communities, and recreational opportunities. Salmon management entities have responded to the fishery's high levels of risk and uncertainty by employing an array of adaptive tools. Lessons learned in this fishery can be transferred to climate change-related management challenges.

Points of Flexibility

The PFMC's salmon FMP integrates a number of components designed to enable management flexibility. As mentioned in the previous section of this paper, collaborative preseason planning allows for flexible management by giving managers and stakeholders a process for defining expectations, including opportunities for flexibility. This planning plays out as an example of enhanced management flexibility—the Council plans for each salmon season, conducting a series of preseason meetings to determine the expected abundance estimates, escapement goals, and allowable harvest. The annual predictions enable the most up-to-date information to be used to set and monitor reference levels.

However, they can also make it challenging for commercial and recreational partners to plan longer than a single year.

The FMP has been developed, at least in a general sense, with preplanned and preapproved decision points describing how and where the catch will be distributed at different thresholds of salmon biomass (e.g., >/< 300,000 lb). This TAC is partitioned among fishery sectors, port areas, and time periods, enabling more precise control of harvest. The partitioning requires that a process be developed to distribute the available quota transparently and equitably. Unused quota may be transferred from one fishery sector or area to another, achieved through a quota exchange. The FMP specifies a general system for exchanging quotas within the port areas or between commercial and recreational fisheries, enabling individual flexibility. (The FMP recommends a 4:1 ratio by species and has other suggestions for how exchanges should/could happen.) A postseason evaluation assesses the performance of the exchange.

Once the fishery's season has started, catch monitoring is conducted by both area and sector, at up to daily intervals, to provide spatial and temporal information on the number of removals that can be tracked against the quota. The FMP includes a decision process that can take in daily information, process it, and modify regulations as needed through consultation with fishery advisors. The season length, location fished, and gear can all be modified in-season based on the current information and daily and/or weekly projections. The regulations authorize a relatively wide array of changes that can be implemented in-season, and they require fine-scale monitoring and analysis to implement such changes with precision.

Groundfish

Over 100 stocks are managed under the Pacific Coast groundfish FMP (PFMC, 2019b), including dozens of species of rockfish, as well as groundfish species, flatfish species, assorted sharks, all endemic skates, all endemic grenadiers, ratfish, and a few miscellaneous bottom-dwelling marine fish species. Five sectors accommodate this diverse fishery: limited entry trawl, limited entry fixed gear, open access, tribal, and recreational. The groundfish fishery transitioned into the quota system in 2011. Before that, it was a limited entry system, and before that, it was open access. Management changes were made in response to a huge fishery crash in conjunction with extensive buyback and fleet consolidation.

Points of Flexibility

The groundfish FMP includes three framework provisions that provide the foundation for management flexibility: conservation, socioeconomic, and habitat. The fishery covers a large number of species and significant geographic area. So, while there is some flexibility to open and close the fishery, move quotas between different sectors within the fishery, and determine impacts on other species, the fishery's size and monitoring data's resolution decrease the overall regulatory flexibility.

Groundfish species are assessed at somewhat regular intervals depending on PFMC needs and data availability. The assessments evaluate the stock's current status compared to reference points and provide catch advice for 2 or more years. This provides an initial planning process and sets the expectation of the abundance and potential quota for upcoming seasons. Scientific uncertainty and management risk tolerance are then used to compute a precautionary reduction from the overfishing limit (OFL) to determine the acceptable biological catch (ABC) and subsequent catch limits. The risk tolerance largely reflects the quantity and quality of data available to evaluate a stock, with the ABC reduction from the OFL being greater for data-limited species than data-rich species.

While not included currently, the risk tolerance policies present a means to include ecosystem or climate considerations in the decision-making process. The output of tools—such as climate vulnerability assessments that evaluate the vulnerability of individual species to climate change—could be integrated into the risk tolerance to develop the buffer for determining the ABC from the OFL.

The groundfish fishery is managed with both fishery-independent and fishery-dependent data. The annual federal trawl survey provides a relative index of abundance for species as well as spatial information and length/age data. Fishery-dependent data is reported at the trip level, which varies spatially and temporally depending on the vessel size, gear, and target species. Trip lengths span from a single day for smaller inshore vessels to multiple weeks for larger offshore vessels. Observer coverage also varies by fishery: one to two observers are required on all whiting catcher and mothership processors (depending on vessel size), while all other groundfish vessels are required to abide by the NMFS observer coverage plan, which ranges from roughly 10% to 100% (PFMC, 2019b, p. 69).

Each West Coast state has a unique reporting ticket, and combined catch data is housed with the Pacific States Marine Fisheries Commission. The Groundfish Monitoring Team (GMT) tracks in-season data and recommends actions to the Council if catch projections are likely to exceed the quota or if other concerns arise. Fishery-dependent data are generally sufficient to track total catch in relation to the harvest specifications and reduce or close the fishery before the end of the season if needed. Closing the fishery once the catch limit is hit or projected to be hit is automatic. Most actions, however, require at least one Council meeting, if not more, plus public review and regional-administrator approval.

How quota is distributed and how it can be transferred are also important components that influence the fleet's flexibility. The limited entry trawl fishery, including both bottom trawl operations and pelagic (whiting) trawl, permits a limited number of vessels to engage in bottom or pelagic trawl fishing. In 2011, quota and harvest share systems were put in place and expanded the once-seasonal fishery to year-round access. Under this structure, allotments (or quota) of the annual TAC are available for purchase, and quota holders are allowed to buy, sell, or trade quota at will (PFMC 2019b).

Quota systems, also called catch share systems, are widely used across the world. However, the groundfish fishery is the first to adopt the structure on the U.S. West Coast. Although the quota structure is celebrated for its efficiency, ecosystem protection, and role in the regrowth of stocks, critics cite significant socioeconomic issues, including the loss of fishery diversification (Holland et al., 2017). Vessel flexibility between groundfish fisheries and other West Coast fisheries have been reduced under this system. Quotas are expensive to purchase and restrict vessel owners to particular gear throughout the year. Conversely, those who historically participated in the groundfish fishery but are not quota holders can no longer access the fishery. In addition, the catch share structure tends to promote fleet consolidation, which further reduces fishery diversification opportunities. Studies show that fishing communities with a wider fishery portfolio and steadier revenue may financially buffer communities in the face of uncertain climate change impacts on stocks (Cline et al., 2017; Holland et al., 2017).

Two framework procedures are written into all PFMC FMPs, the Point of Concern Framework and the Socioeconomic Framework, and offer another opportunity for increased climate-related flexibility. The Point of Concern Framework allows PFMC to develop management measures in response to conservation or ecological issues, while the Socioeconomic Framework authorizes PFMC to respond to social and economic issues that arise within the fishery and those who pursue it. If a point of concern is identified, current data are reviewed to determine whether an issue exists, and findings are provided at the next Council meeting. Measures within these frameworks may be imposed, adjusted, and removed at any time of the year (e.g., changes in harvest levels, closed areas, gear modifications) for any resource conservation, social, or economic reason consistent with the FMP. The system for groundfish is set up to ensure that the fishery does not exceed the seasonal or annual catch limits (ACLs), but by and large, it is not designed to include highly responsive, in-season actions at a fine spatial and temporal resolution. Finer-scale monitoring of fishery and climate indicators could be developed to trigger responses within the frameworks to provide additional flexibility for responding to changing ocean conditions.

In addition, the groundfish FMP includes a Habitat Conservation Framework. Like the other frameworks, this one allows the Habitat Oversight Committee to make recommendations to close or open areas or change gear requirements to reduce the impact on habitats and restore important areas. The Habitat Conservation Framework provides a means to adjust closed areas and modify gear requirements but typically operates at longer time intervals and generally requires the full amendment process to implement changes.

The FMP contains much of the basic structure (frameworks) needed to enable managers to take relatively rapid actions. However, the spatial and temporal resolution of incoming information limits the resolution of responses.

Coastal Pelagic Species

The West Coast Nearshore Pelagic Species Fishery includes Pacific sardine, Pacific (chub) mackerel, northern anchovy (central and northern subpopulations), market squid, jack mackerel, and krill/euphausiids. This management unit also covers two ecosystem component species: Pacific herring and jacksmelt. Species under this FMP (PFMC, 2019a) are split into three categories that enable pragmatic management given the species vulnerability, available Council resources, and scientific information available:

1. Active – Stocks and fisheries with significant levels of catch and relatively intensive management and monitoring procedures.
2. Monitored – Stocks and species that do *not* require intensive management and monitoring.
3. Prohibited harvest – Stocks (like krill) for which harvest is prohibited within the West Coast Exclusive Economic Zone (EEZ).

Points of Flexibility

Like the salmon and groundfish fisheries already discussed, the coastal pelagic species (CPS) fishery is managed under an FMP with components that enable flexibility. Harvest regulations are developed for each species following a similar process as other fisheries' FMPs, setting an OFL and then reducing the level based on the Council's overfishing risk aversion as determined in the Council risk policy. The policy specifies the ABCs and further ACLs or harvest guidelines.

The fishery's stocks of Pacific sardines and mackerel receive the most management attention. They fall in the previously defined active management category and are assessed every year, while species in the monitored category are simply tracked and managed with a more generic harvest control rule and overfishing definition. Any monitored species supporting catch and approaching the ABC are actively monitored unless there is a valid reason for not monitoring, such as technical limitations or a lack of data.

The general harvest control rule laid out in the FMP also includes an optional environmental consideration should the information exist to implement it. The FMP says that the formula for the harvest control rule for Pacific sardine depends on recent ocean temperatures because the productivity of the sardine stock is higher under ocean conditions associated with warm water temperatures.

The inclusion of an environmental component in an FMP is relatively rare. Pacific sardines are one of only a handful of species that explicitly include an environmental component within the regulatory process. The inclusion of the temperature term does not necessarily increase management flexibility. Still, it does prebuild environmental factors directly into the management process, potentially creating a system responsive to climate variability. In addition, when making annual specifications on the harvest, managers could consider the state of the ecosystem, predator–prey interactions, and fleet and processor considerations on use and capacity. Annual consideration of such factors with predefined, generalized responses to different scenarios—combined with real collaboration between managers and industry—are some of the pillars of adaptable management.

PFMC makes the final decisions on harvest regulations shortly before the season opens for Pacific sardines and mackerel. Prior meetings typically lay out the potential range of harvest policies being considered, and any additional information being considered. Northern anchovy, market squid, and jack mackerel are in the FMP but are largely managed by the states or have low harvest levels. These species are generally monitored to determine if they need to be actively managed in the future.

Incidental CPS catch in other West Coast fisheries can be important in determining the total harvest of CPS species and avoiding overfishing. The incidental catch is explicitly accounted for in setting catch limits each year. The FMP also contains a framework for reallocating the incidental catch toward the end of the season if the total incidental catch estimates have not been reached. Harvest guidelines are suggested in some circumstances, instead of specific quotas, potentially providing more flexibility to deal with various biological, conservation, social, and economic concerns related to CPS species as well as other fisheries.

In-season monitoring and recordkeeping in the CPS fishery differ considerably from the West Coast salmon and groundfish fisheries. Unlike the groundfish fishery, on-board observers are only required in special circumstances in CPS fisheries. Data collection methods for catch, effort, and other information differ across the West Coast as each state uses a unique protocol. The states are a major part of CPS management. Federal reporting requirements like logbooks are only implemented if the state systems fail to provide adequate information needed for management. Actions available in-season include Automatic Action and Notice Actions. NMFS may initiate Automatic Actions without prior public notice in circumstances like a necessary fishery closure after a fishery reaches allocated TAC, or a release of surplus incidental catch allowance. Notice Actions generally require at least one council meeting and one Federal Register notice. They are intended to have a temporary effect and are often adjusted as needed.

Similar to other PFMC FMPs, two frameworks enable the Council to make changes to regulations without needing to change the FMP through amendments: the Point of Concern Framework for resource conservation and ecology and the Socioeconomic Framework for social and economic issues. Harvest of CPS is monitored throughout the year to determine if catch allowances have been attained. Current information is used to assess issues and develop recommendations that are report to PFMC. Depending on the situation, PFMC might act in one or two meetings, with NOAA approval. It could initiate an in-season action and/or initiate actions to address the issues on a longer time scale if it is considered larger than a single in-season issue (e.g., spatial management, gear modifications). If new information is produced, the OFL and ABC control rules. Optimum yield specifications may need to be updated or modified, and the Point of Concern Framework allows this change to happen. Potential issues concerning technical interactions, and human-resource challenges such as resource allocation, can be addressed with the Socioeconomic Framework. The ability to use these tools is partially determined by the spatial and temporal scale of the available information.

Issues related to protected species (birds, marine mammals, and species listed under the Endangered Species Act), as well as species in other FMPs, can be addressed with either the Point of Concern or the Socioeconomic Framework. The CPS Management Team typically brings the issue before PFMC, though NOAA can also bring an emergency action. Beyond conservation, ecology, and protected species, potential issues concerning technical interactions and human-resource challenges, such as resource allocation, can be addressed with the Socioeconomic Framework.

In contrast to the groundfish fishery, access to the CPS fishery requires a federally issued limited entry permit for the following stocks: northern anchovy, chub, jack mackerel, and Pacific sardine landed south of 39°N. While annual limited entry capacity goal is 5,650.9 mt cumulative gross tonnage between all active limited entry fleets of vessels. This goal was set to ensure that the fishing capacity in the CPS limited entry fishery is in line with the TAC, OFL, and ABC. Permits can be transferred with some restrictions on the vessel size, but they cannot be leased. While PFMC does not use the current permitting process to introduce flexibility into the CPS fishery, generally speaking, lease and transfer systems can be used as vital components of flexibility.

Like all the FMPs, EFPs are used in the CPS fishery. Recently, an EFP was used to develop a new monitoring system for estimating an index of biomass using an aerial survey in the northern part of the West Coast of the contiguous United States. The aerial survey is an additional data collection method to inform the stock assessment and, potentially, spatial management.

The Essential Fish Habitat for CPS species is quite large but acknowledges that the properties of the water column define the habitat. The FMP includes dynamic thermal habitats that can vary with the current conditions. The FMP (PFMC, 2019a) states:

> The definition of [Essential Fish Habitat] for CPS finfish is based on a thermal range bordered by the geographic area where CPS occur at any life stage, where CPS have occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by CPS. … The east–west geographic boundary of [Essential Fish Habitat]

> for CPS is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10°C to 26°C (p. 20).

Again, this inclusion does not add flexibility to the management structure but does integrate the dynamic aspects of the environment into management.

Highly Migratory Species

The highly migratory species (HMS) fishery is complex, as it includes tuna (five species), billfish (two species), sharks (three species), and dorado/dolphinfish, along with various ecosystem component species and prohibited species that occur throughout vast areas of the Pacific. Knowledge of these species' stock statuses and distributions varies from moderate to minimal. These species are harvested by U.S. vessels within the U.S. EEZ, in foreign EEZs, and on the high seas.

Points of Flexibility

As mentioned previously, many FMP components that can enable flexibility involve stakeholder engagement, such as long-term planning, strategy development, and collaborative preseason planning. In the HMS fishery, many stakeholders who need a voice in these components live beyond national borders, so international cooperation is essential. International agreements have the potential to introduce greater rigidity into the management process, but they also create the infrastructure to facilitate communication and collaboration.

The management of HMS stocks requires international cooperation as West Coast-based vessels are only responsible for a small percentage of the stock's overall harvest. When a stock is subject to overfishing or is overfished, federal law requires unilateral action among participating nations. Two regional fishery management organizations (the Inter-American Tropical Tuna Commission [IATTC] and the Western and Central Pacific Fisheries Commission [WCPFC], established through treaties) are largely in charge of managing HMS stocks and associated nontarget species. These organizations primarily focus on swordfish, as well as tropical and temperate tunas. The HMS FMP (PFMC, 2018) clearly states that PFMC has limited control over the total fishing pressure of stocks outside the U.S. EEZ and requires a precautionary approach that considers the biological limitations of species and the growth rate of fisheries that fall under the HMS category.

Both ABCs and ACLs are set annually. Conversely, the maximum sustainable yield is set conservatively and in line with federal guidelines covering multiple fisheries. While ABCs and ACLs are required, guidelines include an exception for fisheries managed under an international agreement. Therefore, ABCs and ACLs are not set for some HMS stocks. A draft Stock Assessment and Fishery Evaluation (SAFE) document is submitted on a biennial basis with stock assessments and estimated maximum sustainable yields for regularly assessed stocks. An amendment is required to alter the actively managed species, which could limit PFMC if changes in certain oceanographic conditions cause historically abundant species to change distribution or new or rare species to become more common on the West Coast.

An official treaty between the U.S. and Canada for albacore tuna provides an example of an international agreement that could become even more important as projected climate changes cause stock shifts. The agreement enables vessels to fish and land albacore in either the country it is registered in or the other country, and it allows managers to share information and management responsibilities for a stock that crosses borders.

While the international nature of HMS fishing might, at times, limit the management flexibility available to the PFMC HMS FMP, an agreement such as the albacore treaty demonstrates how management plans and responsibilities can be founded upon the fishery's needs rather than political boundaries. Similarly, the HMS FMP offers an example of how state–federal partnerships can effectively respond to fishery needs and changing conditions.

State regulations are a large part of HMS management, and the FMP includes a system in which state rules can be incorporated into the federal HMS regulations. Some of the interplays between state and federal authority are based on historical legacy, but the drift gill net fishery's incorporation of both state and federal regulations could also be viewed as an example of an alternative model. In the alternative model, the federal FMP develops the overall goals and guidance for a fishery and provides oversight. Meanwhile, some management or regulatory implementation is deferred to the state or another group defined in the regulations. The state or other entity may be able to modify the regulations to address changing conditions resulting from climate change more rapidly than PFMC while still meeting the goals and guidelines of the FMP.

The HMS FMP contains some predefined scenarios and actions to address them that are responsive to changes in oceanographic conditions. For example, the Pacific Loggerhead Conservation Area is closed during certain months when an El Niño is predicted or occurring. Like other flexibility components in this section, the action does not explicitly increase the flexibility of PFMC but can enable a timely response or even a preventive action to address a climate change-driven issue, such as unwanted protected species bycatch due to changes in oceanographic conditions.

The HMS FMP contains similar framework adjustments as other Council FMPs, enabling in-season action should conditions warrant it. Framework actions can be applied quickly and without altering the FMP. Furthermore, automatic actions, abbreviated rulemakings, and full rulemakings may be implemented, adjusted, or removed during the year or per the management cycle. Examples of actions that fall under this framework process include monitoring systems, bag limits, harvest guidelines, and gear restrictions.

Permits are required for all vessels pursuing HMS stocks. Each permit is endorsed for the specific gear utilized. No qualifications are necessary to obtain a permit, but permits are attached to specific vessels. Data regarding catch, catch disposition, and effort are all required and must be submitted to NMFS via the logbook. NMFS may require onboard observers on vessels pursuing certain stocks. Currently, vessels equipped with certain gear include mandated observer programs, and requirements could expand in future actions.

Harvest guidelines are in place for common thresher and shortfin mako stocks. Harvest guidelines provide an additional layer of protection for managing vulnerable stocks where data are limited or lacking. Both harvest guidelines and quota allocations are authorized in the HMS fishery when deemed necessary (i.e., they must align with various factors.)

The Essential Fish Habitat for sharks generally includes only geographic ranges, but the definitions of the habitats for tunas and some other species include temperature and dissolved oxygen content. By including dynamic variables, the FMP recognizes that habitats change with conditions, which should help ensure that fisheries management can account for shifts in distribution as well as species and technical interactions. The FMP does not identify any Habitat Areas of Particular Concern but recommends further research and includes a framework to incorporate this information should it be identified.

Examples of Flexibility in the U.S. and Internationally

A range of tools and methods is used to manage fisheries around the world. The following section describes examples and approaches that enable climate change actions to be incorporated into the management structure. (Not all the examples specifically address flexibility.)

Reducing stressors and maintaining healthy spawning stock biomass are fundamental to fisheries management and important aspects of preparing for climate change (Pinsky & Mantua, 2014). Maintaining healthy levels of spawning stock biomass increases resiliency to climate variability, but it often requires managers to address challenges beyond fishing, such as habitat loss, technical interactions, pollution, and management improvements for stocks with limited information and overfished stocks (Bell et al., 2011, 2020).

Assessments and Reference Points

The environment can impact stock productivity, which directly impacts reference points and harvest levels. In Alaska, changes in the Pacific Decadal Oscillation and other environmental drivers have resulted in regime shifts that have had major impacts on managed species (Hare & Mantua, 2000). The North Pacific Fishery Management Council (NPFMC) and Alaska Fisheries Science Center have incorporated these regime shifts into fisheries management by utilizing different time series of data corresponding with different regimes when conducting stock assessments, such as for tanner crab (Stockhausem et al., 2013) and for groundfish (NPFMC, 2012).

Single-factor environmental correlations have generally performed poorly (Myers, 1998), with Pacific sardine as a notable exception, but research investigating how multiple environmental factors can regulate recruitment has shown potential in assessment models (Kendall et al., 1996; Tolimieri et al., 2018). Age-structured stock assessments can often estimate biomass well, with or without environmental terms. When included, environmental terms enhance assessments and help explain the current situation and inform projections (Bell et al., 2018). Even acknowledging that productivity can vary over time when the mechanistic drivers are not known can enable stocks to be projected with demographic information that fits the current oceanographic regime, such as recent recruitment data, maturity, and weight-at-age.

Many management organizations include a risk policy that determines the risk aversion of stocks becoming overfished. As mentioned above, it is possible to include a greater range of factors when determining the managing entity's risk tolerance. Currently, only the quantity and quality of data are typically included when setting ABCs and ACLs from OFLs. With reports such as the West Coast species vulnerability assessment and other information, it may be feasible to consider the impacts of species interactions, technical interactions, and climate change when determining the risk of overfishing and, accordingly, reduce the ABC and ACL from the OFL.

Planning

Both long-term and near-term preseason planning meetings are important tools for anticipating, preparing for, and mitigating climate change impacts. Currently, PFMC conducts a range of meetings, from full Council meetings to working groups to stakeholder engagement. However, few dedicated meetings help the Council plan for long-term climate actions and related near-term issues. Such meetings and efforts, like the Council's CCI, could help PFMC and stakeholders prepare and adapt to changing conditions.

Long-term planning can take various forms, but the overall goal is to identify the climate change drivers, the impacts, the needed adaptations for each fishery, and the barriers to adopting those adaptations. The PFMC has taken a major step with its recent scenario-planning workshop, which, at the end of the process, should provide information on actions that would likely prepare the Council and the fisheries for projected changes.

A good example of long-term planning that entailed full stakeholder participation occurred in Tasmania (Pecl et al., 2014). This group of managers and fishermen worked through each fishery, examined the current known environmental–fishery linkages and anticipated changes, and outlined what adaptations would be needed to deal with those changes. The group identified autonomous adaptations that individuals or communities might undertake on their own (e.g., diversify operations, shift operations, shift locations, change gear) as well as adaptations that would need to be made at an institutional level (e.g., changing allocations, changing catch levels). They included supply chains and shoreside infrastructure and produced a list of recommendations for each fishery that would better prepare it for the impacts of climate change.

Before conducting various planning initiatives, an array of information is needed. It can be useful to understand the challenges, concerns, and perceptions of the different stakeholders to determine how to organize the planning process and what actions are needed to address climate change (Robinson et al., 2019). Many ongoing and completed studies provide important information and insights. Alongside the PFMC scenario-planning process, researchers at the University of Washington are currently conducting a survey on the perception of climate change among stakeholders on the West Coast that can contribute to the process (Phillip Levin, personal communication). Previous work on the connectivity among fisheries and ports, the diversity of permits, and their connection with social vulnerability on the West Coast can also provide background for planning and strategy development (Fuller et al., 2017) and provide information necessary to identify areas of needed flexibility in fisheries.

Ecological information is available through meta-analyses, such as species climate vulnerability assessments (Hare et al., 2016) and the California Current Integrated Ecosystem Assessment status report (Harvey et al., 2020). Other examples include the broad range of material the Northeast Fisheries Science Center has developed to support the Mid-Atlantic Fishery Management Council (MAFMC) ecosystem approach to fisheries. As part of its ecosystem approach to fisheries, MAFMC is evaluating risks from climate change and other sources to prioritize where action is needed (Gaichas et al., 2016). These reports on ecological and social indicators of change and species vulnerability provide an understanding of fishery and species reactions to climate change that are essential to consider for planning and strategy development. Many of these indicators can also directly correlate with the decision-making process discussed in other sections.

In contrast to long-term planning, near-term or preseason meetings provide a system to assess the current ecological, social, and economic factors and make decisions about how best to manage the current conditions. Preseason meetings can range from managers simply stating what the upcoming season's regulations will be to working with stakeholders within regulatory limits to determine the best course of action given the current conditions. Preseason meetings attempt to use the most up-to-date information to develop the expectations of the stock (e.g., timing, size, location).

The North of Falcon preseason meetings for salmon (Washington Department of Fish and Wildlife, n.d.) determine how the federal harvest guidelines and regulations will be implemented across the states of Washington and Oregon and across the Treaty Tribes, ensuring that the regulations are responsive to current on-the-water conditions. This process is a part of the PFMC salmon season-setting process. In California, the Risk Assessment and Mitigation Program (RAMP; Ocean Protection Council, n.d.) involves a full stakeholder team that conducts risk assessments and numerous preseason and in-season meetings to develop management measures to reduce the likelihood of whale entanglements in the Dungeness crab fishery. The RAMP compiles a number of indicators related to oceanographic conditions, whale numbers, and locations, as well as information about the fishery, to evaluate entanglement risk. Additional climate-related issues could be evaluated for specific fisheries through a similar indicator-based risk assessment process, potentially utilizing the indicators already available from the ecosystem status report.

Monitoring — Data Collection

The spatial and temporal resolution of data collection determines the resolution of the management actions that can be successfully implemented and the temporal scale on which they can be adjusted. Fisheries-independent data are typically collected on an annual or seasonal basis, so the catch limits developed through stock assessments can only be updated in annual or longer intervals. Fishery-dependent data are collected with varying frequency, from daily in the salmon fishery to weekly for some offshore fisheries. Such frequencies enable in-season tracking of the catch compared to the quota, allowing decisions about whether the fishery might exceed the quota and require an early closure. Finer-scale spatial and temporal data allow finer-scale in-season actions, such as opening and closing smaller areas for shorter periods or altering gear to meet management objectives. As mentioned previously, the PFMC salmon fishery currently has a relatively high-resolution monitoring system that enables more precise management actions, particularly compared to the other FMPs on the West Coast.

Conferring management authority to local entities is an additional means to provide a finer-scale spatial resolution of management actions and potentially speed up response times. The NPFMC crab FMP (NPFMC, 2011) allows local managers (the state) to change harvest limits, season lengths, and closed areas based on incoming data. Depending on how it is implemented, this delegation of authority can increase managers' responsiveness. An additional means of improving data collection efficiency and timeliness is to move from paper reporting to electronic reporting. The New England Fishery Management Council and MAFMC recently issued a joint action (MAFMC, 2020a), switching their systems to fully electronic vessel trip reports. The move is expected to reduce costs associated with processing paper reports, improve reporting efficiency, and decrease errors.

Bycatch avoidance networks, habitat suitability models, and seasonal forecasts use a range of information to implement dynamic spatial management (Dunn et al., 2016; Hobday et al., 2014). By responding to changing oceanographic and ecological conditions, dynamic spatial management is a flexible tool that responds at a range of spatial and temporal scales. It has been implemented around the world to improve industry and conservation outcomes and is currently being used on the West Coast (Hazen et al., 2018).

Bycatch avoidance networks provide an example of how certain monitoring types can increase the flexibility and adaptability of fisheries management. Bycatch avoidance networks attempt to track information on the magnitude and location of bycatch in semi-real time in order to share that information with other vessels to increase target catch and reduce nontarget interactions. The information is typically used to develop move-on rules, hotspot avoidance, or small-scale time-area closures. The higher the resolution of the spatial and temporal data, the smaller the buffers needed around such areas. To be effective, a hard cap on specific nontarget species is typically required, along with the full participation of the industry. Participation by managers is not required, and the networks can often perform better without them.

The salmon bycatch avoidance program within Alaska's ground fishing fleet (Amendment 91 and 110) has been an effective network, as has the river herring bycatch avoidance network on the East Coast (School for Marine Science & Technology, n.d.). On the West Coast, certain fishing associations and cooperatives have developed their own bycatch avoidance networks and risk pools to manage the catch of nontarget species (Holland & Martin, 2019; Kauer et al., 2018). Generally speaking, bycatch avoidance networks were not developed specifically to manage climate change impacts. Still, they provide an excellent example of how flexibility can be included in fisheries and how climate change-induced challenges can be mitigated.

Along with bycatch avoidance networks, the use of monitoring data to develop habitat suitability indices is a promising area for reducing climate change risks. Habitat suitability indices can provide now-casts that allow industry and managers to make real-time decisions on when, where, and how to fish. EcoCast (Hazen et al., 2018) and TurtleWatch (Howell et al., 2015) provide two well-known examples of combining real-time oceanographic conditions with habitat suitability indices to predict and reduce interactions with protected species. Numerous additional species could be modeled, providing information on where interactions may arise. These products evolve with oceanographic conditions, decreasing the time between recognizing a signal on the water and responding to it. The products are also useful independent of fisheries management, providing information that vessel captains can use to make on-the-water decisions.

Seasonal forecasting is still a developing science, but it has been used for strategic planning for many years, particularly for HMS species (Eveson et al., 2015; Hobday et al., 2011). Researchers have also investigated the optimal methods for tracking and forecasting other aspects of the marine environment. The California Harmful Algae Risk Mapping project (C-HARM) has been implemented on the West Coast to track and forecast harmful algal blooms (Anderson et al., 2016), with similar programs existing in locations where harmful algal blooms have become major issues, such as the U.S. East Coast and southeastern Australia (DPIPWE, 2015). The use of seasonal forecasts comes with some risks and ethical considerations, however (Hobday et al., 2019). Forecasts can be incorrect and lead to serious problems for fisheries, such as the poor reception of a lobster forecast in the Gulf of Maine (Pershing et al., 2018).

Management Actions

Management actions and regulations are typically laid out in an FMP and continue to evolve as new information and results become available. Some FMP policies are designed to be implemented per rigid, predefined regulatory provisions, while others give decision makers discretion to implement adjustments if or when the fishery or related conditions change. The catch advice and reference points, as well as certain aspects of Essential Fish Habitat and gear restrictions, are typically implemented and reviewed annually or at longer intervals. FMPs also typically specify actions that can be taken at shorter intervals to react to current situations and provide in-season adjustments. An FMP needs all these elements to provide management advice; however, this section focuses on regulations that can typically be implemented at shorter time scales and are considered more flexible when responding to current developments on the water.

The NPFMC FMP for salmon (NPFMC, 2018) includes a flexible season-adjustment system that can respond to the real-time abundance of the resource. The season for the coho salmon troll fishery can be increased for a predetermined amount of time if the in-season numbers indicate high abundances and can be closed if realized abundance is below predetermined threshold levels. The system also contains an option for potentially reopening the season after an early closure if conditions change. The combination of high levels of monitoring and local management authority (state of Alaska) enables responsive management.

Coho salmon fisheries in southern Southeast Alaska are managed based on aggregate abundance and in cooperation with Canada under the guidelines of the Pacific Salmon Treaty (Pacific Salmon Commission, 2020). There are no harvest ceilings for Southeast Alaska coho salmon fisheries under the treaty; however, areas near the United States–Canada border are closed to trolling if the harvest by Alaska trollers in the border area falls below specified thresholds. While the season was developed to deal with annual variabilities in abundance, it has relevance for distribution shifts and addresses issues with shared stock across federal borders.

Stock assessments can rarely be updated in time to provide in-season guidance, but in the Gulf of Mexico red grouper fishery, the Gulf Council used a hybrid approach developed to deal with industry concerns. Industry requested updated catch advice during the season when their harvests suggested the resource was lower than model predictions. An in-season adjustment (Gulf Council, 2019a) was conducted using the predicted and observed index of abundance to develop a modified harvest control rule to deal with the discrepancy. The system was a means to track abundance, update catch advice, and modify harvest between assessments. In the New England Fishery Management Council's herring fishery, a different set of circumstances led to an in-season harvest adjustment (Greater Atlantic Regional Fisheries Office, 2018). The 2018 catch limit was reduced in-season despite having been specified through the 2019 season. Reviews of incoming monitoring data indicated poor recruitment that would likely have resulted in future biomass decline and steeper harvest reductions in upcoming years.

Spiny lobster in the U.S. Caribbean is a high-value fishery with limited management data. The FMP (NMFS, 2020a) contains the mechanisms for relatively broad framework adjustments to quickly modify reference points and management measures, as well as the season, closed areas, trip or bag limits, and size limits. The FMP provides a system to take action or respond quickly, but limited monitoring data can restrict the implementation of actual rule changes.

Flexibility for the industry is important, enabling commercial fishers to modify their practices while remaining in regulatory compliance and staying in business. Reducing regulations and shifting the responsibility of meeting management and conservation objectives to the industry can provide incentives to adopt preferred fishing practices, such as committing to high levels of monitoring. In New England, a group of vessels received an EFP to gillnet and fish for tuna on the same trip (NMFS, 2017). Tuna cannot be taken with gill nets, so a vessel working in both fisheries typically must declare into only one fishery when leaving the dock. The vessels receiving the EFP were in an electronic monitoring program and could clearly show that all tuna were caught with approved gear. This example demonstrates that the high level of monitoring and quality of data afforded by the electronic monitoring system can provide flexibility to both decision makers and industry. With full oversight, the relaxation of some rules enabled individuals to fish more efficiently while remaining within the regulations.

EFPs are an important tool for enabling flexibility in the fishery system. EFPs enable experimentation and novel approaches to tackle current or future challenges and improve efficiency. They also provide a system whereby industry can take a lead role and implement their ideas.

Other tools the Councils, state agencies, and NMFS employ are training courses to inform stakeholders about important topics. Some training sessions are mandatory, such as the Western Pacific pelagic fleet's course on reducing their impacts on endangered species (WPRFMC, n.d.). Others are optional, such as the Northeast's Marine Resource Education Program (Gulf of Maine Research Institute, n.d.), which works to educate stakeholders about scientific topics, such as stock assessments or ecosystem-based fisheries management. Councils could offer optional or mandatory training courses (in person or online) on a range of subjects to educate stakeholders about climate change impacts, new species entering an area, new fishing methods, and bycatch avoidance techniques. Or Councils could provide simple training videos on topics such as how to submit an EFP application.

Habitat

Habitat suitability indices combine a range of static and dynamic niche components for species to determine where they might be located in space and time. As discussed above, this information is useful for dynamic spatial management but should also be incorporated into Essential Fish Habitat descriptions. MAFMC is currently conducting a major review of species habitat (MAFMC, 2020b), with an emphasis on developing text descriptions and maps that include the features of dynamic habitat (e.g., water temperature, salinity, dissolved oxygen content) that update with the current conditions. The dynamic features ensure that the habitat characterizations remain relevant as oceanographic conditions change. Similarly, the Gulf Council (2016) is mapping the ecoregions and internal habitat types of the species in the coastal migratory pelagic FMP to map the distribution and abundance of species. This effort has broad potential to inform species abundance and spatial management with better habitat information.

Quality habitat is an essential component of climate resilience in fisheries. Work that preserves and restores habitat supports resilience, which can buffer climate change impacts. In addition, implementing strategies that incorporate sea level rise and make space for retreating coastal habitats can make fisheries more resilient to climate change.

Permitting or Quota Regulations and Transfers

Permitting, quota allocations, and quota transfers are crucial aspects of fisheries management and directly affect equity and individuals' livelihoods. Any discussions of changes in allocation can directly affect the financial situation of the fishing industry and need to be approached carefully. Vessels, ports, and whole fisheries must adapt to remain in business as species shift their distributions. In some cases, vessel captains will choose to focus their businesses on another species. In other cases, they will follow the fish. And in still others, they may leave fishing entirely. Creating a system that enables fishers to adapt to long-term changes as well as sudden extreme weather events is essential to developing and maintaining climate-ready fisheries.

Quota allocation is generally based on catch history and tribal rights, but as the distribution of a species shifts with climate change, this emphasis on catch history can create challenges. On the East Coast, distribution shifts in recent decades have required vessels in the historically southern extent of a species range to travel farther to harvest permitted fish. At the same time, vessels in the historically northern extent of the range have lacked sufficient access to the resource and have had to discard legal fish because they lacked the quota to land them, creating frustration and eroding trust in the larger management system (Dubik et al., 2019).

This trend is not limited to East Coast fisheries. One West Coast example of range shift is the northward movement of market squid. Market squid is a federally managed West Coast fishery that is largely harvested in California, with limited catch in the West Coast's northern states. Since 2016, large landings in Oregon have been met with limitations in both processor and port infrastructure (Card, 2020). Both are struggling to take in high volumes of landings and accommodate out-of-state vessels pursuing the fishery.

Possible solutions to allocation issues among regions, Councils, or nations may require side payments (Miller & Munro, 2004), new systems for allocation, and new regulations around quota markets, quota transfers, and leasing. Conversations around distribution shifts must also consider the inshore infrastructure to offload, process, and distribute the product.

With species shifting distributions, either progressively with warming temperatures or erratically with extreme events, methods for improving catch allocation may involve combining catch history with the current distributions. When the eastern tip of Georges Bank was legally declared part of the Canadian EEZ, American vessels held the majority of the quota for the jointly managed species. A transition approach was developed that allocated an increasing proportion of the quota to vessels based on each year's current distribution of the species, rather than just catch history (Transboundary Management Guidance Committee, 2002). Other models have been examined for summer flounder on the East Coast (MAFMC, 2019b). They include allocation transitions, total reallocations, and changes in threshold levels in which catch history is used for allocation but all quotas over a given threshold are allocated based on the current distribution. What is essential is that the method can be repeated and can be objectively applied with changes in conditions.

On the West Coast, less conflict exists around shifts in distribution and allocation, specifically, but ensuring access to fishing opportunities remains an important issue. As the number of limited entry fisheries has increased, the diversity of individual fishing portfolios has generally decreased (Holland & Kasperski, 2016). Limited entry regulations and catch shares can be good for fishers and fisheries, but they can reduce the portfolio of species fished and thus decrease the resilience of a vessel or community if species distributions change (Kasperski & Holland, 2018). Declines in salmon over the decades and the impacts of the marine heat wave on Dungeness crab and other species have demonstrated the serious consequences of restricted fishing opportunities when conditions change. Incentivizing diverse fishing permit portfolios and encouraging the use of underutilized species can provide both flexibility and resiliency to the industry.

A range of examples defines how permits and quotas can be bought, sold, leased, and consolidated. Some can have both positive and negative consequences. The examples below show a small suite of transfer methods that have been incorporated into management. Well-developed transfer regulations are helpful when seeking to introduce flexibility.

A number of federally managed fisheries in Alaska (NPFMC) use dynamic permitting methods. Programs include Community Charter Programs, License Limitation Programs, Community Quota Share Purchases, and Crab Rationalization Community Protection Measures (NMFS, 2020b). Some specific examples include

- Community Quota Entity Programs for community residents to purchase commercial halibut and sablefish quota shares;
- the Western Alaska Community Development Quota Program for the Bering Sea and Aleutian Islands fisheries, including groundfish, prohibited species, halibut, and crab; and
- the Halibut Individual Fishing Quota Program for leasing in some areas, which is intended for nonresident holders to lease quotas to local residents in years where the catch limits are below certain thresholds (NMFS, 2021).

International examples of quota flexibility include the following:

- Transferability – The Canadian groundfish fishery allows the transfer of individual quotas between both vessels and fisheries to cover incidental catch.
- Catch entitlements – In New Zealand, Transferable Annual Catch Entitlements are traded separately from quotas, allow owners to obtain cash flow from their quota assets every year, and allow nonowners to participate in the fishery (Hale & Rude, 2017).

Along with transfers, systems must be in place to incorporate new fisheries and provide an off-ramp when species move out of an area. As part of MAFMC's unmanaged forage fish amendment, they included the requirements for developing a new fishery (MAFMC, 2017). In addition, they exercised both emergency action and long-term planning to incorporate a previously unmanaged forage fish, chub mackerel, into an existing FMP (MAFMC, 2019a). As species shift distributions and potentially move into the authority of new entities, sunset provisions may provide an initial means of exit.

Conclusion

FMP tools that enable flexibility—whether or not explicitly designed for climate change responsiveness—can enhance fisheries management by making it nimble enough to adjust when uncertainties and changing conditions arise. These tools provide essential information and enable stakeholders to execute actions that have been thought out and considered well in advance of the needed implementation. This review provides many examples of existing tools and future possibilities that the PFMC can deploy to improve fisheries' climate change readiness.

While flexibility can be incorporated into fisheries management in many different ways, a few core components continue to surface. Within FMPs, flexibility is enhanced when predefined actions are specified for the full range of potential situations likely to develop on the water. Careful consideration of what actions might be needed and the thresholds that will trigger them requires dedicated planning and strategy development. Preloading FMPs with measures that afford flexibility provides managers with the tools they need to respond to changes. In addition to managers, flexibility is essential to the fishing industry. Well-developed regulations around on-the-water actions, as well as the distribution and transfer of permits and quotas, enable vessels to access the resource and adapt to ever-changing conditions.

The ability to implement flexibility is highly dependent on available information about the fishery's and ecosystem's current state. The spatial and temporal scale of monitoring and analysis define the specificity and timeliness of responses to signals on the water. Fishing and fisheries management have always been iterative, adaptive systems that respond as conditions change. Some flexibility is built into FMPs, but the pace and scale of flexible decision-making can be magnified through by implementing the tools reviewed here.

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