Climate Readiness Synthesis

Prepared by the NPFMC Climate Change Task Force 2022

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The Climate Change Taskforce (CCTF) has compiled this climate readiness synthesis as a starting point for the North Pacific Fishery Management Council (Council) in ascertaining how "climate ready" the current management system is overall and to assist in augmenting existing management for improved climate resilience. This synthesis aims to understand the current[11] state of "climate readiness', meaning whether management tools, assessments, and information on-ramps are designed to address and consider long-term climate change and the unprecedented conditions and unique challenges that it presents (in contrast to addressing natural *climate variability*). Importantly, this synthesis does not evaluate management effectiveness.

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[11] This CRS is current through 2022.

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Executive Summary: Climate Readiness Synthesis

Climate change has already had large impacts on the Bering Sea fisheries and ecosystem and impacts are expected to increase over the next decade, with largest changes and risks associated with warmest future scenarios (i.e., higher carbon emission scenarios) (IPCC 2022). Recent national and regional strategic evaluations have identified the immediate need for climate integrated management advice and information (Peterson et al. 2021) and recent United States Government Accountability Office report to congressional committees (GAO-22-105132) identified two priority recommendations to (1) *"publicly disseminate information on actions taken by the Regional Fishery Management Councils and NMFS' Atlantic Highly Migratory Species Division to enhance the climate resilience of federal fisheries"* and (2) "*identify and prioritize opportunities to enhance the climate resilience of federal fisheries… and develop a plan to implement them."* This Climate Ready Synthesis helps advance these national and regional recommendations.

The Climate Change Taskforce (CCTF) has compiled this climate readiness synthesis as a starting point for the North Pacific Fishery Management Council (Council) in ascertaining how "climate ready" the current[12] management system is overall and to assist in augmenting existing management for improved climate resilience. This synthesis aims to understand the current state of "climate readiness', meaning whether management tools, assessments, and information on-ramps are designed to address and consider long-term climate change and the unprecedented conditions and unique challenges that it presents (in contrast to addressing natural *climate variability*). Importantly, this synthesis does not evaluate management effectiveness. Management measures and policies that are not designed to specifically address climate change can still be effective at managing resources in a changing climate, especially those that are designed to be robust to natural climate variability. However, climate change, the long-term trends, shifts in underlying ecological conditions, and especially the impacts of increasingly extreme conditions do pose a novel and large risk that may require approaches specifically designed to address this unique challenge. The first step in understanding what needs to be evaluated and developed to support climate ready advice and decision making is to identify the current state of climate readiness.

As such, this synthesis is organized into three sections. Section 1 provides a management overview of the current system highlighting management measures comprising the Bering Sea system and to what extent they may or may not address climate change. Section 2 provides a review of information—including climate-related information–currently included in the stock assessment and fishery evaluation (SAFE) reports, which describe the past, present, and near future status (1-4 years) of Bering Sea fishery resources on a stock-by-stock basis as well as the role of the target species in the broader social-ecological system. Section 3 focuses on the various knowledge bases which support climate readiness and adaptation measures. Each section includes a table for ranking the various components included in that section. An overall ranking of the entire synthesis is also provided. These rankings represent expert opinion based categorical characterization of the readiness level to provide relative context for current and future climate informed advice and adaptation measures. Additional information regarding the rationale for the overall scores provided in the table below are included in the individual sections. Each overall score represents an average over the component scores when viewing each aspect separately. These scores are to be viewed in a relative context and are not a measure of effectiveness.

[12] This CRS is current through 2022.

2022 Climate Readiness Rankings: Aggregate rankings for all three sections considered in this report

Section	Ranking	Description	Section Specific Details
Section 1: Management System	2	Implicit climate variability information associated with some management measures	Conceptually climate information informs management measure but is not directly implemented
Section 2: SAFE Reports	3	Somewhat ready	Climate and ecological information are included in the assessment, but climate change information is implicit (not explicitly discussed) in the assessment model, text, or advice.
Section 3: Knowledge Base Integration	2	Ranking depends on which knowledge base is being referred to. Overall, there are limited pathways for such information into management and decision-making.	Management measures include some/limited information from various knowledge bases and not others, though few are formally/explicitly informing, guiding, and directing actions and decisions. Integration into the NPFMC/NMFS system of information from the knowledge base of Indigenous communities is extremely limited; integration into the system from industry, agency, and other knowledge bases is a bit higher in general.

Overview of Climate Readiness

This section provides context for the work presented in this report by providing background for "climate readiness" and the manner in which "resilience" and "adaptation" are used here.

Climate readiness

As used in this document, "climate readiness" is intended as a measure of the degree to which the system is specifically designed to be resilient to climate-change. It includes whether the information, advice, and decision making includes measures specifically aimed to be robust to long-term climate change, absorb climate shocks, and facilitate equitable and timely responses to novel conditions and challenges that are unprecedented or outside of historical ranges. Climate ready policies can build off effective tools and processes already in place, but through evaluation with the lens of climate change (and modification if needed), can help ensure that the system as a whole is robust to climate change, supports adaptation and resilience, and continues to sustain ecosystems, people, and livelihoods. The understandings of resilience and adaptation are related and defined below.

Resilience

Community resilience has numerous interconnected aspects, including the epistemic (e.g. access to information, rich involvement in scientific-management-policy activities, etc.), individual well-being (e.g. mental and physical health), economic vitality, and sociocultural prosperity (e.g. social cohesion, self-determination, integration of community with natural resources, thriving intergenerational relationships, community sustainability and vibrancy, food security, economic diversity, adaptability to change, etc.). The ecological/ biological resilience of marine resources likewise spans a wide array of considerations including biological and genetic diversity, healthy habitats and populations, adequate resources, sustained recruitment, and a balanced trophic structure. Resilience must be considered at the nexus of these two domains, i.e., coupled social-ecological systems. This includes, for example: sustained strong connections between harvest species and humans and communities that rely on them; management that is capable of being adaptive, flexible and stable in order to sustaining ecosystems and livelihoods; strengthened resource management through ecosystem-based advice, co-management, community engagement, and co-production of knowledge; alignment of knowledge, management, and policy to challenges of variability and unpredictability; and strong information-based decision making that includes diverse knowledge sources and perspectives in order to ensure inclusive and just assessment of risks, impacts and tradeoffs.

Climate adaptation

The IPCC defines adaptation as “the process of adjustment to actual or expected climate change and its effects” (IPCC 2014, p. 5). In the context of Bering Sea fisheries, adaptation to support climate resilient social-ecological systems includes ecosystem-based management policies that embrace uncertainty, adjust at a rate that is consistent with observed changes (e.g., allows communities and fisheries to adapt in a proactive rather than a solely reactive manner), are inclusive of diverse knowledge sources and information that may change and evolve over time, and consider both direct and indirect impacts and interactions with other species, sectors, and stakeholders and the environment. The latter relies on understanding and considering biological trajectories of change as well as the social, cultural, and economic implications and scope of adaptation in the intricately coupled social-ecological Bering Sea ecosystem. Co-production of knowledge is essential for understanding changes as well as identifying, understanding, and promoting pathways of adaptation in both fisheries and fishing communities. Some social and ecological changes could help promote adaptation, but others might intensify negative impacts of climate-driven change.

Adaptation can include reactive responses as well as proactive, anticipatory planning and prevention. Adaptation is separate from, but can be synergistic with (i.e., have co-benefits for), “carbon mitigation” measures, which are actions at global or regional scales that aim to reduce or recapture atmospheric CO_2. Climate adaptation planning is a multi-step and iterative process that includes evaluation of key risks and needs, assessment of available potential tools and approaches, understanding of institutional capacity and feasibility for adaptation planning and implementation (and evolving limits and constraints to adaptation), and interactive inclusive discussions regarding realized costs, tradeoffs, and benefits of adaptation measures (Meredith et al. 2019). This evolving definition will serve as the basis for ongoing climate-biological-social-economic evaluations of management actions that address climate-driven impacts, utilize novel opportunities, and identify and promote equitable adaptive pathways.

1 Section 1: Management Overview

This section provides the management overview. First it provides a summary of the overall climate readiness ranking for the management system as a whole (as described previously regarding the ranking of the various components included in that section). The section then provides an overview of the limits and opportunities presented by the current management system. This begins with a general overview of the NPFMC management structure, including limits and opportunities that exist within the statutory and regulatory system. A series of case studies are then presented to identify provisions implemented under the management system that are more or less flexible and/or resilient to climate change. These case studies are provided as examples only and do not characterize the management system as a whole.

1.1 2022 Climate Readiness Rank

The management system is ranked "On the way to climate ready (2)" because, while some management tools may be effective, many measures presently used were not developed to respond explicitly to climate change. Other measures are static and their performance under climate change may need to be assessed to ensure they continue to impart the benefit they were designed to address (e.g., fixed area closures). As a result, there are a number of measures that while not designed specifically for climate change, may provide benefits or forestall climate change impacts (EBM and 2 MT cap; Holsman et al. 2020) or have inherent flexibility that could respond to climate change (e.g. adaptive management cycle), and at least one is designed to specifically address new challenges associated with climate change driven sea-ice loss (NBSRA; Stram and Evans 2009). Of note, steps have been taken to build climate and ecosystem information on-ramps (e.g., FEP and Ecosystem Committee), thus while climate readiness is currently low, measures could be modified to address climate change more directly ensuring the system has a high potential to be advanced in climate readiness. Additional provisions may need to be built into the overall management system to ensure Bering Sea fisheries and the ecosystem are able to adapt to climate shocks and long-term environmental change.

1.2 Ranking Methodology

Table 1-1 Climate readiness ranking criteria for fisheries management

Ranking	Description	Section specific details
1. Not Ready	No climate information included in management measures	Management measures are not designed to address climate change
2. On the way to climate ready	Some implicit climate variability information associated with management measures	Conceptually climate information informs management measure but is not directly implemented
3. Somewhat ready	Some implicit climate change information included in management	Some measures built into management to address climate change or changing environmental conditions
4. Nearly ready	Few modifications would result in climate readiness	Management measures have built in mechanisms to be responsive to changing environmental conditions and climate change
5. Climate ready	Process in place for regular (operational) climate change informed management	Management measures are designed to address climate change and climate extremes and provide informative feedback on performance

1.3 Process overview

The Council manages the fisheries in the North Pacific under the authority of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) and the respective fishery management plans (FMPs). The Council has six (6) FMPs: BSAI groundfish, GOA groundfish, BSAI crab, Alaskan Scallop, Salmon and the Arctic. In establishing and amending FMPs the Council adheres to the statutory requirements of the MSA, the National Environmental Policy Act (NEPA) as well as other requisite laws (e.g., ESA, MMPA).

FMPs must include conservation and management measures that are "necessary and appropriate for the conservation and management of the fishery to prevent overfishing and rebuild overfished stocks, and to protect, restore, and promote the long-term health and stability of the fishery" (16 U.S.C. 1853(a)(1)(A)). They also must comport with ten (10) "National Standards for Fishery Conservation and Management" (16 U.S.C. 1851) and set out the maximum sustainable yield (MSY) and optimum yield (OY) for each fishery ((16 U.S.C. 1853(a)(3)), among other requirements.

For most fisheries, these requirements are carried out by the Council in cooperation with NMFS and/or the State of Alaska. The Council (in cooperation with NMFS) has sole jurisdiction over the management of groundfish in the BSAI and GOA (3-200 miles offshore). For BSAI Crab and Alaska Scallops, this management is in cooperation with the State of Alaska: the Council has responsibility for federal requirements in cooperation with NMFS and delegated management measures under the FMP to the State of Alaska.

Pacific halibut is subject to international regulation. The International Pacific Halibut Commission (IPHC) and NMFS manage Pacific halibut fisheries through regulations established under the authority of the Northern Pacific Halibut Act of 1982 (Halibut Act) (16 U.S.C. 773-773k). For the United States, regulations governing the fishery for Pacific halibut developed by the IPHC are subject to acceptance by the Secretary of State with concurrence from the Secretary of Commerce. After acceptance and concurrence, NMFS publishes the IPHC regulations in the Federal Register as annual management measures pursuant to 50 CFR 300.62. Section 5(c) of the Halibut Act also provides the Council with authority to develop regulations that are in addition to, and not in conflict with, approved IPHC regulations.

The Council is widely recognized as a leader in ensuring that fisheries management is sustainable and ecosystem-based. Many fisheries in the BSAI are certified as sustainable by the Marine Stewardship Council and the Responsible Fisheries Management Certification Program, and seafood products from Alaska are often heralded as sustainably harvested. In addition, the Council has led the creation of the Bering Sea and Aleutian Islands Fishery Ecosystem Plans (FEP), an ecosystem vision statement, and the Arctic Fishery Management Plan (in which the Arctic was closed to all fishing activities pending further understanding of the system and its inherent vulnerabilities in a changing climate; see Arctic FMP).

In furthering this work, the Council has prioritized finding ways to enhance resilience and adaptation in the face of rapidly changing climate. The dramatic changes in the Bering Sea have been documented thoroughly, are summarized in the Climate Change Task Force's workplan, and thus will not be repeated here. These rapid, and often unanticipated changes create substantial challenges for managers, commercial fisheries, and subsistence and others who depend on ocean resources.

As explained in more detail below, despite the advances made by the Council, there are not always tools available to respond to observed changes. In some part, this challenge can be attributed to the system described above. The MSA and the Council's rulemaking and policy processes were created at a time when climate change was not considered a significant threat. In fact, the phrase "climate change" does not appear in the MSA. Similarly, even though it has substantial advantages, the current ecosystem-based fishery management (EBFM) framework in Alaska was not established to address climate change directly (Holsman et al., 2020).

The remainder of this report focuses on the way measures under existing management, within the system described above, provide- or do not provide- flexibility to adapt to rapid or address unexpected changes in the marine environment. The evaluation in this paper is intended to provide a backdrop for discussion about how climate issues and management measures could be considered in the Council's decision-making process. This synthesis is not intended to provide a comprehensive description of every management measure nor to suggest specific changes in management, but rather to begin a framework from which to examine feasible changes that will increase resilience and provide effective climate adaptations.

1.4 Selected management provisions and their relative flexibility

Federal measures that govern the in-season management of the BSAI are implemented through a complex set of regulations that have been developed through Council and agency processes. These regulations form the backbone of fishery management and govern basic functions of the fisheries that include allowable catch limits, allocations, area closures and bycatch control measures, monitoring and data collection, seasons, community measures, and provide for protected species and habitat. Some regulations are designed to provide flexibility to react to limited inter-annual variability in fishing activity or harvestable biomass while others have been put into place to address specific concerns and management objectives; these latter measures may prove less flexible to changes in stock status or environmental changes.

Climate change adaptation will require developing methods to assess and improve elasticity in Bering Sea fishery management systems to respond to climate changes and shocks. As shown in Table 1-2, a wide variety of regulatory actions govern fisheries in the BSAI. These regulatory measures rely on scientific and MSA processes used to establish stock status, Allowable Biological Catches (ABC), and Overfishing Levels (OFL) (see regulations for harvest specifications). Thus, there is likely some resilience built into the current management system (e.g., Holsman et al. 2020); however, the degree to which the current in-season regulations may be leveraged to mitigate climate impacts has not been investigated. This is likely a priority area of future research for the Council.

At a very high level, some general patterns can be identified from the current management environment (Table 1-2) For example, many types of management measures build off the harvest specification process (e.g., catch limits, Prohibited Species Catch (PSC) limits, ABC, and OFL). This includes species-specific allocations that are established via quota programs or managed in-season (e.g., Amendment 91, A-80, IFQ); spatial management measures (e.g., PSC management areas and associated limits and seasons); programs designed to provide harvest flexibility under the 2 million OY and for quota management (e.g., flatfish flexibility and non-specified reserve). Other measures are outside of the harvest specification process, and these provide specific controls over vessel, gear, areas, and retention of species. Further, supporting many of these measures is a comprehensive fishery-dependent data collection and monitoring program (Section 3).

Given the complexity and variety of measures, building resilience into the management system may require looking at the overall portfolio of management actions. This evaluation may show adaptive characteristics (i.e., flexibility and positive or neutral outcomes for participants) or maladaptive characteristics (e.g., negative outcomes), some of which are only identified if interactions among components of the regulatory system are considered (e.g., spatial management area with competing objectives). For example, flatfish exchanges and non-specified reserves provide flexibility to meet both ecosystem constraints (i.e., 2 million OY) and market variability (Table 1-2). Further, some management measures, such as cooperative development and data sharing, leverage regulations to improve the fleets' ability to address specific management objectives such as bycatch avoidance (e.g., rolling hotspot closures), community access to marine resources and food security (e.g., CDQ, processor quota shares). Gaps in management response may also exist, particularly in situations where stocks are driven to extremes due to climate shocks, resulting in direct loss of fishing opportunity for marine fishery participants or issues that impact participants in multiple sectors (e.g., large sablefish recruitment events, Bering Sea snow crab population decline, GOA Pacific cod decline).

Table 1-2 Management measures and potential strengths and weaknesses. (See Figure 1-1 for a snapshot of associated area closures.) Bolded items are examples that are further described and ranked below.

	Management Measures						
	Special Area Management	Quota Programs	Seasonal and Sector Reallocations	Retention Restrictions	TAC Adjustments/ Exchanges	Data Integration	Industry-led Measures
Examples of current actions	Protects critical habitat (e.g., skate nurseries, coral areas) Bycatch control/protection measures: **Salmon/Herring savings areas - winter/ summer herring areas)** CVOA limits and AFA CP restriction in B season. PHCZ, **NBSRA**, Walrus Islands, etc. **RKCSA,** Zones 1 and 2, SSL and other area protection measures	IFQ/CDQ/A-80,AFA, P-cod LAPP groundfish allocations Halibut CDQ Reserve PSC limits designed into some programs	Many seasons are related to SSL protection measures, some are halibut avoidance (May 1 arrowtooth/ Kamchatka/ Gturbot), some established for biological or market factors, **Sector reallocations (P-cod),** AI pollock reallocation, Seasonal PSC limits (i.e., April 1 for BSAI TLAS/rockfish)	Small boat fisheries in State waters (e.g., <58 ft state GHL), Trawl gear modifications (i.e., elevated sweeps), **Pot gear escape mechanisms,** Seabird deterrence, Crab retention size limits, **Decksorting**	TAC and allocations specified in regs (e.g., AI pollock, state-water cod), Reallocation rules, **Flatfish exchange (Yellowfin, Flathead, Rock Sole),** <u>Set asides,</u> Nonspecified reserves for non catch share species. Incidental Catch Allowances 2 million OY	Comprehensive landings and monitoring programs (e.g., observer and EM monitoring, eLandings, eFish), **Data warehousing and data services (e.g., online reports, data feeds, fishery applications, fishery independent information),** Industry data services (e.g., Sea State), EM data collection, including development of AI for improving utility of EM data and reducing costs	Cooperative bycatch monitoring and notification
Potential Climate Change Adaptive Attributes (Strengths)	Reduces fishing impacts to important habitat or stock component Can be designed to meet specific species, management, and habitat needs Can be defined to protect fishing opportunities for communities	Portfolio diversification Allows flexibility for fleet to compensate for increased fishing costs and operational needs (e.g., stacking permits) Flexibility to form Cooperatives in some cases - regulatory or voluntary May increase efficiency/ retention	Portfolio diversification Fishery openings timed to facilitate concurrent fishing (e.g., halibut/ sablefish)	Allows priority to nearshore waters to smaller community based vessels Provides species/ habitat protection	TAC is responsive to assessment and associated uncertainty, TAC provides spatial management, Reallocation allows responsive in-season management, Flatfish exchange can mitigate some annual variation in harvestable stock abundance/industry needs under 2Mt OY, Non-specified reserve can be used to deal with unanticipated harvest of non-allocated species	Comprehensive catch accounting using available data sources to estimate total catch and track vessel activity, Observer coverage provides at-sea information, including biological and marine mammal data collection, EM coverage provides accounting of catch and discards, Precise salmon PSC information for salmon in pollock fisheries, Integration of environmental and climate model output with fisheries information	Rolling hotspot closures allow time and fleet - dependent flexibility to control fishing and reduce discard/PSC

	Management Measures						
	Special Area Management	Quota Programs	Seasonal and Sector Reallocations	Retention Restrictions	TAC Adjustments/ Exchanges	Data Integration	Industry-led Measures
Potential Maladaptive Attributes (Weakness)	Static and cannot respond to shifts in stock out of the area or changes in fishery, Management measures may have been established decades ago and no longer use best available information, Stock abundance shifts into a special area may strand harvestable fish, Interaction among areas with differing goals may create conflicts with area-specific/management objectives (e.g., halibut versus crab PSC)	Programs maybe focused on single species, leaving participants vulnerable if species declines or is variable, Quota/IFQ maybe area-specific and thus vulnerable to changes in stock abundance and dependent on apportionment method	Fish condition may change resulting in changes in abundance or product quality	Fish unavailable in GHL or special area waters Harder for CVs to fish further away from ports unless a mothership, CP or tender is available Closures are rigid and non-responsive to changes.	Expansion to other flatfish species impacts allocations Sector allocations that are narrowly defined may strand catch- i.e., incidental catch of one species can limit directed fishing of another (e.g., sablefish in arrowtooth and stranded p. cod	Observer and EM can be cost-prohibitive, Confidentiality, Inaccessible data platforms, Maintenance and development costs for data products, Lack of coordination among data providers resulting in duplication of efforts Staff and infrastructure intensive	Transparency and trust could be an issue for some members of the public
Opportunities for Improvements	Consider whether flexibility in certain Council- defined management actions would allow for more timely responses to change that would not be detrimental.	Consider giving sectors the ability to trade amongst themselves	As sector allocations have been refined seasonal limits have become binding on some but not on others. Looking at global seasonal harvest may allow for added flexibility (i.e., allowing sector(s) to harvest more fish in A season if globally the limit won't be exceeded)	Explore whether it makes sense to allow for flexibility if certain conditions are met.	Are there ways to increase flexibility by broadening the concepts of flatfish flexibility and use of the non-specified reserve?	Data products that integrate fishery dependent information with fishery independent information (e.g., habitat, oceanographic, survey, climate model outputs, stock dynamics) Coordination among data providers to streamline data services and development	Are there changes to data integration that can improve the timeliness and quality of data to better inform on-the-water decisions? Create favorable regulatory and funding environment for cooperative research on climate-related adaptation for mgt

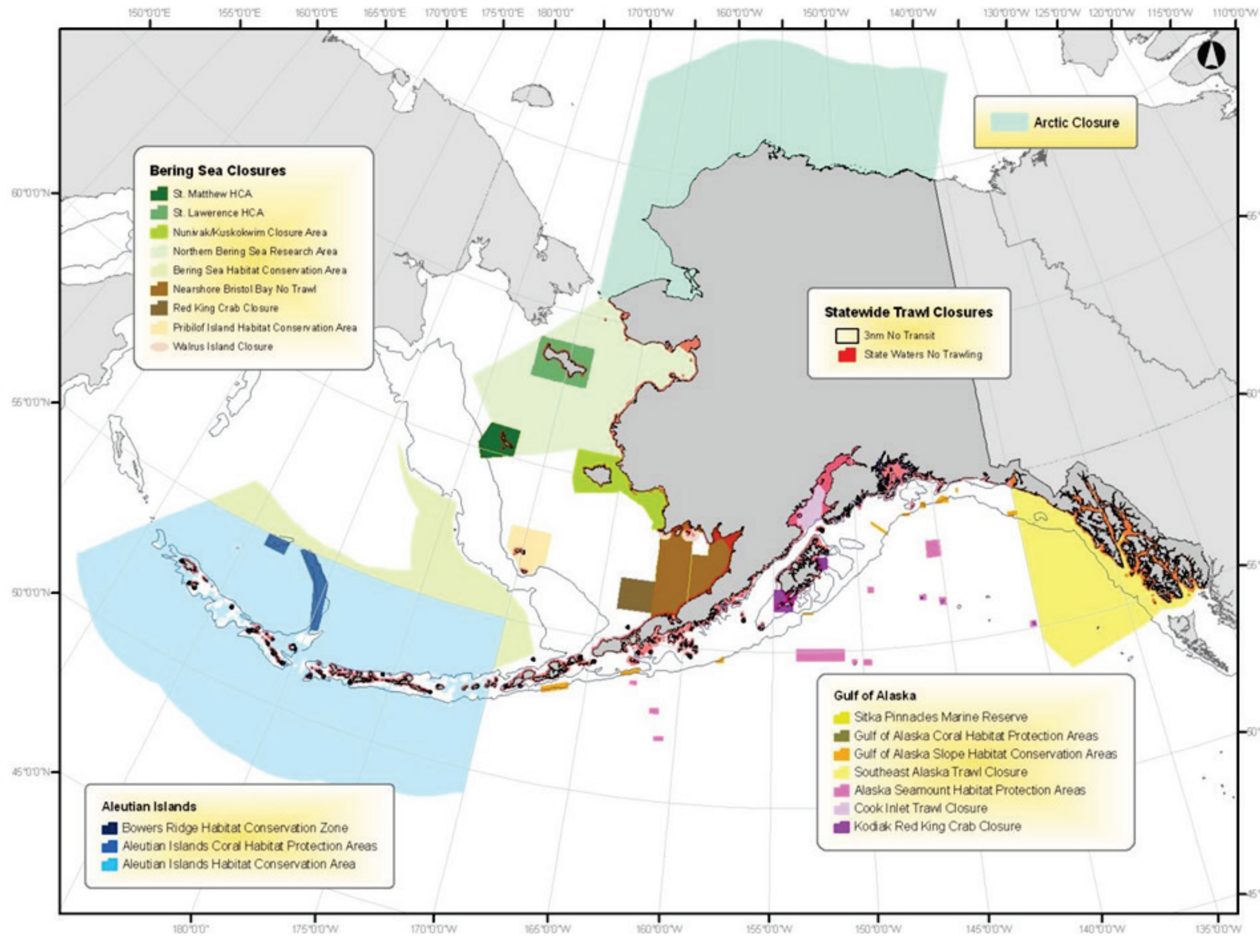

Figure 1-1 Overview of select closures in the Bering Sea, Arctic, and Gulf of Alaska

1.5 Select examples of management measures and relative ranking

The following are examples of individual management measures as listed in Table 1-2 and how they may be assessed against the ranking criteria in Table 1-1. These examples are chosen to highlight both strengths and weaknesses in the current suite of management measures as it relates to developing more climate ready fisheries management action.

1.5.1 Special area management

Herring Savings Area:

The herring savings areas are time/area closure triggered by a PSC limit equal to 1% of the estimated herring biomass established by the State of Alaska. The limit is apportioned to fishery categories in conjunction with the harvest specifications each year. When reached, the limit triggers spatial and temporal closures (see below). The timing and location of these closures were intended to reflect the best available information at that time on herring migration patterns. Thus, some flexibility in response to environmental conditions as it reflects herring migration was initially built into this system however over time these closures may no longer reflect current conditions. The measure could be considered a ranking of 2 but highlights the need for continued review and revision of these types of measures in the future. Climate readiness could be advanced through evaluation and implementation of dynamic climate-informed closure areas, like those being evaluated in other regions (Hazen et al., 2018)

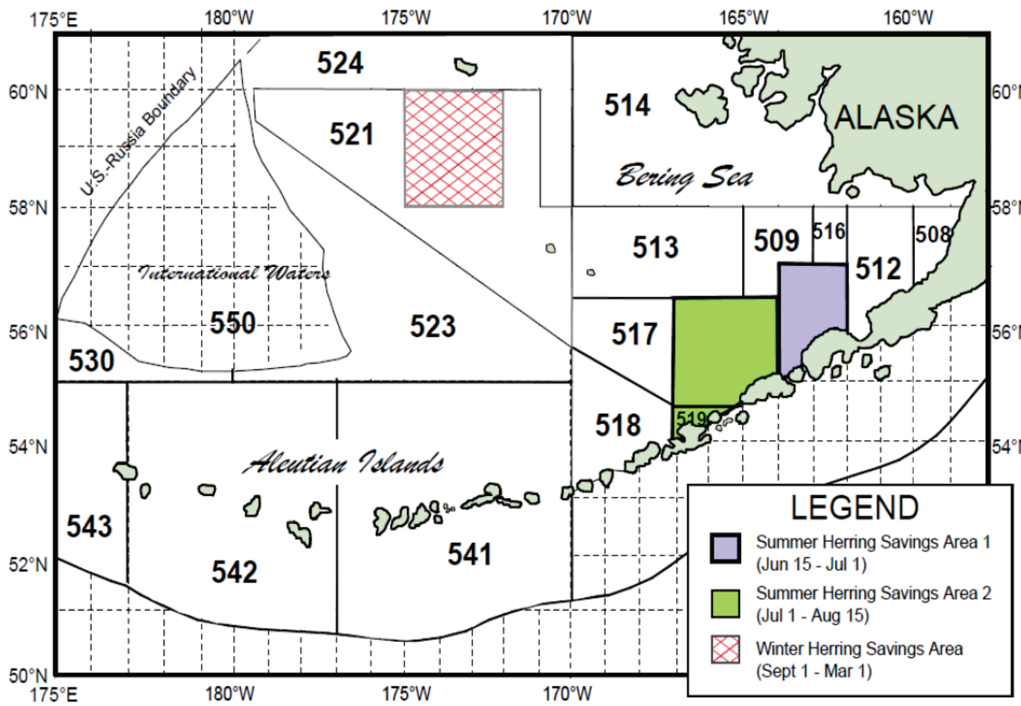

Figure 1-2 Bering Sea Herring Savings Areas

Red King Crab Savings Area

Initially closed by emergency rule by NMFS, the Red King Crab Savings Area (RKCSA) was established in 1995 (and subsequently modified through Amendment 37) to protect Bristol Bay red king crab during the molting and mating period January 20 to March 31st and subsequently closed year-round. No survey exists in the wintertime so there is limited data from which to assess if the area of this closure continues to contain molting and mating crab or if other areas in Bristol Bay would provide better protection to the stock. Thus, while initially precautionary due to a declining stock of BBRKC (a decline the stock is again experiencing in recent years) and temporally during the vulnerable molting and mating time, the now year-round closure itself is fixed and inflexible to potential population shifts and temporal flexibility. This measure ranks a 1 and highlights the need for further review of efficacy of fixed management measures over time.

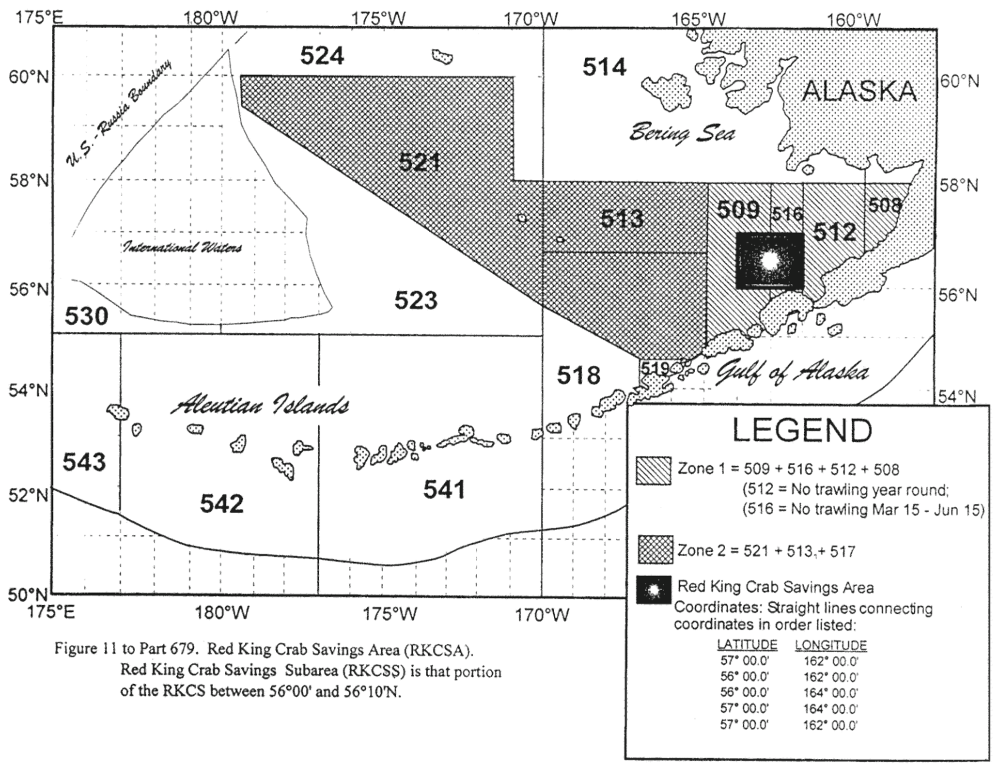

Figure 1-3 Location of Red King Crab Savings Area

Northern Bering Sea Research Area (NBRSA)

The Northern Bering Sea Research Area (NBSRA) was implemented in 2008 and prohibited bottom trawling in the northern part of the Bering Sea which includes the shelf waters to the north of St. Matthew Island (85,000 nm2). In taking this action, the Council noted that the changing climate was resulting in warming waters of the North Pacific and changes to the timing of the ice cover in the northern Bering Sea. They recognized this was likely to result in an ecosystem shift that may extend the distribution of crab and fish populations northward into the subarctic Regions. The area is to remain while development of a research plan was ongoing that would provide data to allow a better understanding of the potential impacts of trawling on the benthic and epibenthic fauna of the northern Bering Sea before any commercial trawling was authorized. This research plan has not yet been completed and the area remains closed to non-pelagic trawling. While this represents a static closure and the efficacy of it has not yet been determined, this management measures ranks as a 4 for being directly driven in response to shifting environmental conditions.

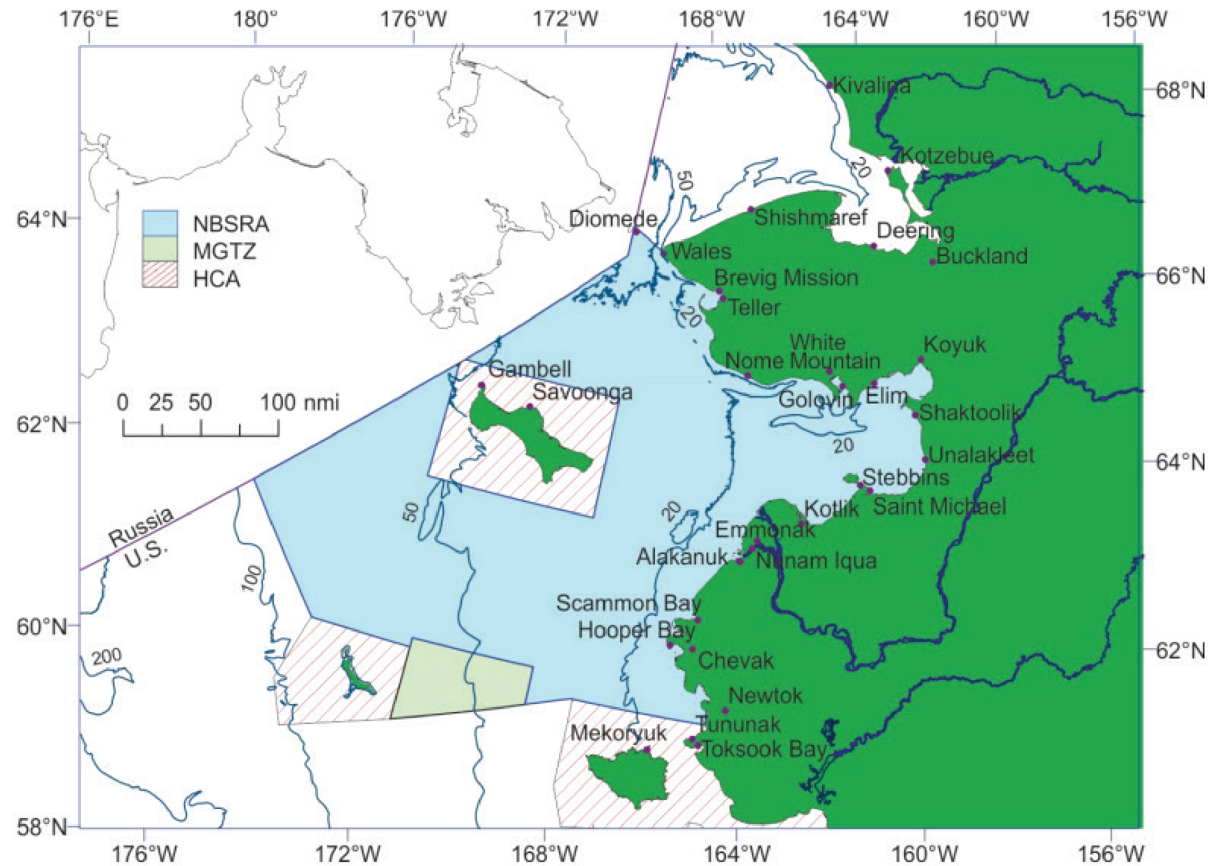

Figure 1-4 Location of the Northern Bering Sea Research Area (NBSRA) and bordering communities. Also shown are the Modified Gear Trawl Zone (MGTZ), and adjacent Habitat Conservation Areas (HCA).

1.5.2 Quota programs

In comparison to non-rationalized fisheries, quota programs such as IFQ, CDQ, A-80, AFA, and trawl CV P-cod (once implemented) offer participants enhanced flexibility and control over when and where they fish. This enables participants to incorporate climate information and climate-induced changes into their fishing plans. The enhanced flexibility offered under these programs does not extend to all aspects of these fisheries as seasonal limits, time/area closures, etc. still apply, but it does afford the opportunity to respond in ways those in non-rationalized fisheries cannot. Quota programs are somewhat ready ranking a 3 in terms of climate readiness but enhanced regulatory flexibility would advance their readiness ranking.

1.5.3 Seasonal allocations and sector reallocations

Seasonal allocations exist for many fisheries. Many seasons were created to distribute catch in space and time in order to effectuate Steller Sea Lion (SSL) protection measures, halibut avoidance, markets, and other factors. As sector allocations have been refined seasonal limits have become binding on some but not on others. Sector reallocations (P-cod) are a tool that NMFS Management employs to move fish that is likely to go unharvested in one sector to another sector that is likely to harvest it. While these measures are not currently employed to respond to climate change, linkages to climate change could be incorporated in future modifications to these measures. As such this is ranked a 1 for historical usage (as measures are presently not set up to incorporate ecosystem or climate information) but could advance in readiness ranking should measures be modified in response to climate indicators.

1.5.4 Gear/vessel/retention

Gear and retention requirements are components of many management programs and are designed to modify mortality associated with catch, improve utilization, or limit catch. These activities can be established in regulation (e.g., gear restrictions or vessel size requirements), a combination of regulation and industry efforts (e.g., deck sorting to reduce halibut mortality), or voluntary (trawl excluders). These measures may provide some management responses to climate by modifying bycatch mortality, but the connection is not explicit at this point. There is likely benefit in reducing PSC mortality through deck sorting and trawl modifications, for example, to avoid fishery closures and improve the survival of released fish. However, these modifications are designed to reduce PSC mortality and whether additional measures are needed to make them responsive to climate is unclear. Gear modifications for target fisheries such as escape mechanisms that change the selectivity of fishing gear may reduce mortality on components of a fish or shellfish population. However, the time and potential costs associated with implementing regulatory measures and gear modifications complicate implementing this as a near-term adaptive measure. Additionally, as an adaptive strategy to address near-term changes in population structures (e.g., large recruitment events or preservation of older fish), these measures may also have maladaptive characteristics that must be considered.

Overall linkages to climate adaptation in this category are not explicit and thus further work is likely needed to establish adaptive management strategies. This category is ranked 1 and whether this is an appropriate climate adaptation strategy is unclear.

1.5.5 TAC adjustments/exchanges

Flatfish exchange

Flatfish exchange is a process for Community Development Quota (CDQ) groups and Amendment 80 (A80) cooperatives to exchange harvest quota of one or two of three flatfish species (flathead sole, rock sole, and yellowfin sole) for an equal amount of another of these three flatfish species, while maintaining total catch below acceptable biological catch (ABC) limits. This process mitigates the operational variability, environmental conditions, and economic factors that may constrain these sectors from achieving, on a continuing basis, the optimum yield in the BSAI groundfish fisheries. This action is intended to result in higher retention and utilization of groundfish without increasing overall catch or bycatch of groundfish or non-groundfish species beyond existing limitations. The Council annually recommends an ABC reserve for flathead sole, rock sole, and yellowfin sole, which are allocated to CDQ groups and the Amendment 80 cooperative using the same formulas that are used in the annual harvest specification process. The ABC reserve for each species will be specified by the Council by evaluating the ABC surplus for the species (i.e., the differences between the ABC and TAC), and considering whether that amount needs to be reduced by a discretionary buffer based on social, economic, or ecological considerations. The Council will then designate some, all, or none of the ABC surplus as the ABC reserve. This program provides innate flexibility in the ability to modify the buffer based on those considerations and they may all be considerations under changing climate conditions. This program is ranked a 3 for the flexibility that is built into it.

Optimum Yield (OY) range

Established in the development of the Bering Sea FMP, the OY for the BSAI groundfish complex is established as a range from 1.4 to 2.0 mmt. This range was selected based upon catches (reduced by 15%) from 1968-1977. Note this is notably prior to the regime shift of 1977 so does not represent current environmental conditions experienced pre-1977. However, the OY is specified as the sum of the TACs in the BSAI and while capped at 2 mmt it could be set below that level if climate considerations indicated reduced productivity. At the same time climate conditions may indicate increased productivity in which case the upper end of the range is limiting. Therefore, the flexibility provided by setting OY as a range is only provided in the downward direction. This management measure is ranked a 3 for explicitly providing some flexibility but as with other individually specified measures could be evaluated to indicate whether changes are appropriate.

1.5.6 Data integration

The management of Alaskan fisheries are informed by comprehensive data collections that are supported by broad infrastructure and support needed to house, distribute, and communicate fishery dependent and independent data products, often in near-real time. Alaska has extensive at-sea and shoreside data collection programs that include onboard observers, electronic monitoring, shoreside landings and at-sea processing information. Current data-related processes and existing architecture are well-supported and able to accommodate changes in monitoring programs. Front end applications such as eLandings, tLandings, and eFish provide user interfaces to input catch information. On the backend, primary data services for fishery information are provided by the State of Alaska, National Marine Fisheries Service, and Pacific States Alaska Fishery Information Network (AKFIN). These services are also well positioned to incorporate emergent technologies in data acquisition processes, such as AI and electronic monitoring. In addition, NOAA has invested in information management modernization initiatives to better prepare the agency for the adoption of technologies that help manage ocean resources (Margolis et al 2020).

Responsive management to changes in oceanographic conditions (e.g., SST, Chlorophyll, satellite data) and linkages to stock and fishery information will require evaluation of both fishery and environmental conditions. Data products that integrate fishery independent sources such as surveys, genetics (salmon), community information, climate modeling, and oceanographic information with fishery dependent information are important areas of future development for climate-ready management. Creating broad access to climate-informative data products will require ongoing investment to provide data science and IT infrastructure services and to make improvements to database architecture and services. For example, improving salmon stock identification to inform industry-led salmon avoidance efforts requires data pipelines that provide information to industry on likely salmon stock distributions, real-time fishery data, environmental information, and access to support for data and analytical products. Many of these requirements are already available. The current state of data integration is ranked a 4 given the robust data architecture and processes currently available; however, it is not yet fully climate ready because there is development and coordination among research and database groups required to comprehensively integrate fishery dependent and independent data sources and incorporate operational climate advice products (e.g., climate, ecosystem, and species short-term forecast long-term projections, climate change risk assessment outputs)

1.5.7 Industry led measures

Cooperatives have unique abilities to engage in bycatch monitoring and establish notification procedures that allow members to respond to bycatch issues. Through third-party monitoring services, such as SeaState Inc., and internal policies and procedures cooperatives can establish hotspot management and notification procedures, fine scale bycatch limits, and create incentives for voluntary efforts to avoid bycatch. These types of voluntary efforts, within the bounds of regulatory constraints, allow industry to develop in-house management tools that can be quickly adapted to new scenarios. While there are limits to what industry can do, voluntary efforts offer the opportunity to try new things and see if effective measures can be found outside of the Council process. Industry led measures are ranked a 3 for “somewhat climate ready”.

1.6 Future directions/Potential Future Work

As previously discussed, this report is not intended to be a comprehensive overview of all management measures in the BSAI. Future work could create a set of metrics that provide measures of climate resilience across management actions and, potentially, climate warming scenarios. These key metrics could provide detail that better ties management actions to adaptation, maladaptation, limits to adaptation, and amount of adaptive flexibility relative to anticipated climate outcomes. In addition, time scales related to management response could also be considered such that some events may require a large and rapid response (e.g., heat waves), whereas other events may be slow to develop and offer a longer lead-in period for management response (e.g., movement of core stock areas).

1.6.1 Near-term considerations

- Evaluate the effectiveness and feasibility of measures that increase flexibility in current and future Council- defined management actions and which may allow for rapid responses to change
    - Seasonal flexibility in allocations, quota programs
    - Transferability amongst sectors and seasons
- Explore measures that support appropriate and timely response mechanisms in management
    - More rapid response in some circumstances while others may exhibit longer-term stability and/or flexibility in response timing
- Development of metrics to evaluate climate resilience in management measures
    - Improved integration of fishery dependent information with fishery independent information (e.g., habitat, oceanographic, survey, climate model outputs, stock dynamics) and coordination amongst data providers
- Explore the performance of, and feasibility to implement, spatial and temporal dynamic management measures through case studies (like those identified in this section)
- Evaluate / re-evaluate OY cap performance under climate change and alternative sub-designs (e.g, proportional caps, dynamic as function of climate indices) below the 2MT to ensure this measure continues to impart stability and productivity benefits under future change.
- Identify enabling factors to support industry led measures to increase rapid adaptation, reduce impacts, and respond to climate driven changes (e.g., communication and near-real time information sharing).

2 Section 2: SAFE Report Review

2.1 2022 Climate Readiness Rank

Current readiness is “somewhat ready (3)”. This is due to the finding that there are natural places for climate change information to come into the SAFE reports and documents, as well as stock assessment models that are able to accommodate climate covariates and reference points (as deemed appropriate). However, such information was largely not yet included in the 2019- 2021 SAFE reports and there remains a need for coordination and dedicated resources (personnel time) to synthesize climate change information towards climate-informed advice. We feel these steps are highly feasible and will advance climate readiness rapidly once implemented.

2.2 Ranking Methodology

Table 2-1 Climate readiness ranking criteria for section 2.

Ranking	Description	Section specific details
1. Not Ready	No climate information included	Climate change information does not occur implicitly or explicitly in the assessment model, text, or advice.
2. On the way to climate ready	Some implicit climate variability information included	Climate and ecological information is included in the assessment but climate change information does not occur implicitly or explicitly in the assessment model, text, or advice.
3. Somewhat ready	Some implicit climate change information included	Climate and ecological information is included in the assessment but climate change information is implicit only (not explicitly discussed) in the assessment model, text, or advice.
4. Nearly ready	Few modifications would result in climate readiness	Climate and ecological information is included in the assessment but climate change information is only explicitly discussed in a few places to set the context for future directions but it is not used to explain trends or future directions, nor is used to adjust ABC, modify the model, or provide other advice.
5. Climate ready	Process and information in place for regular (operational) climate change informed advice	Climate change information is used to explain trends or future directions (or lack of sensitivity to climate change), and is used to adjust ABC, modify the model, or provide other advice. The assessment is therefore "climate change informed".

2.3 Introduction

Climate change and associated extreme events, climate shocks, and novel interactions pose an unprecedented challenge to species and ecosystem management. Thus, while natural climate variability is effectively accounted for through current stock assessment models and model design that can account for climate regimes (e.g., time varying suitability or growth) and Ecosystem Based Management advice (e.g., Ecosystem Status Reports, Ecosystem and Socioeconomic Profiles, and Ecosystem Considerations sections of species assessment chapters), climate change information and climate-integrated tools may be needed to plan for, anticipate, and detect climate impacts and provide climate-informed Ecosystem Based Fisheries Management advice. Both positive and negative changes in Bering Sea stocks have occurred rapidly in response to recent marine heatwaves (attributed to climate change; Jones et al. 2020, IPCC WGI 2021), challenging assumptions of assessment models, the current pace of adaptive management cycles, the definition of expected or acceptable variability. Rapid change in the Bering Sea, and the potentially substantial additional change anticipated for the region over the next few decades to century underscore the importance of timely action now to build climate-integrated advice to address climate change impacts and challenges.

Stock Assessment and Fishery Evaluation (SAFE) reports describe the past, present, and near future status (1-4 years) of Bering Sea fishery resources on a stock-by-stock basis as well as the role of the target species in the broader social-ecological system. They are intended to also contain information that summarizes the ecosystem and economic status for consideration in the Council process for setting harvest recommendations. The stock assessment sections include recommended acceptable biological catch (ABC) and overfishing levels (OFLs) for each stock and stock complex managed under the Fisheries Management Plan. The documents contributed to the SAFE report are subject to AFSC internal review before dissemination to the Plan Teams and the Council's Scientific and Statistical Committee (SSC) that finalizes the ABC and OFL recommendations. The information is provided to the NPFMC and ADFG to be used as the basis of ecosystem-based fisheries management and their harvest management decisions, which are subsequently approved and disseminated by the Secretary of Commerce through the NOAA Fisheries Service. For more information see Section 1 of this report detailing the management process.

Presently, ecosystem information is readily incorporated at various scales into stock assessments, including but not limited to (a) inclusion as covariates in population dynamics models that underlie the assessment, (b) mechanistic underpinnings for model design and parametrization, (c) species specific ecosystem and ecological context for setting the ABC (qualitative context), (d) cross- species/ ecosystem-wide context for setting the ABC and other limits for individual species. As part of this, climate variability is often included in SAFE reports, and increasingly climate change attributed events are included (e.g., recent Marine Heatwaves or loss of sea ice). The goal of this review was to evaluate the extent to which climate change information is readily incorporated into the advice of species that have exhibited distributional or productivity responses to climate change in order to identify more broadly if and how the SAFE reports might be raising the issue of climate change or using climate change information to provide management advice. In particular, this review aimed to identify the common on-ramps for climate change informed advice and will recommend practical near-term steps to expand or enhance climate change information on-ramps in the SAFE reports.

2.4 Methods

2.4.1 Rapid automated scan

All SAFE documents from 2019-2021 in pdf form were downloaded from the NPFMC online repository (https://www.npfmc.org/library/safe-reports). Scripts programmed in R and using the package pdfsearch (LeBeau 2018)) were used to scan each pdf document for 15 key terms (or slight variants on those terms, e.g., "forecast" and "forecasts"); "climate change", "climate prediction", "climate", "long-term change", "global warming", "environmental change", "warming", "warm" (and "warmer"), "forcast", "prediction", "anomalously", "cold pool", "OA", "ocean acidification", "sea ice", "sea level rise"). The code also identified major section headings, allowing for identification of where in the document each search term appeared. This information was synthesized for the figures and graphs included in this report and is available upon request.

2.4.2 In depth review

The Climate Change Task Force (CCTF) systematically reviewed the last three years (2019, 2020, 2021) of the Bering Sea groundfish and crab SAFE reports (Sections 2.4.6, 2.4.7and 2.4.8), the Ecosystem Status and Economic Status Reports (2019-2020) of the Eastern Bering Sea (Section 2.4.4), and the September/November Plan Team meeting minutes (2019-2021; Section 2.4.3) to identify where and what extent climate change advice or climate information is built into the reports and presentations. A standardized keyword search criterion was used to record the frequency and context of use of each keyword, whether it was associated with future long-term trends/predictions, whether climate change trends or predictions were integrated into the advice, and whether climate change information was implicit in the text of the assessment (e.g., the number of citations that contained the search term). The page number and a brief summary of the associated text was also recorded. Searches were conducted within the SAFE introduction, the Ecosystem Status Report, Economic Status Report, September and

December Plan Team meeting minutes, and individual chapters for the eight species; Bering Sea snow crab, Bering Sea red king crab, Bering Sea Pacific cod, Bering sea yellowfin sole, Alaska sablefish, Bering sea pollock, and Bering sea forage (includes herring and squid). Copies of these assessments can be found on the AFSC website at the following LINK.

In total 80 documents totaling more than 9 thousand pages were reviewed using systematic search word criteria. Each document was searched for the following 15 terms (or slight variants on those terms, e.g., "forecast" and "forecasts"); "climate change", "climate prediction", "climate", "long-term change", "global warming", "environmental change", "warming", "warm" (and "warmer"), "forecast", "prediction", "anomalously", "cold pool", "OA", "ocean acidification", "sea ice", "sea level rise". For each document and search term, the team noted the total number of in-text mentions as well as number of references with the term, additionally the context for the term was characterized by 5 levels of information (Table 2-1) and a brief description was given to how the information was used. Finally, for traceability, where appropriate key sentences from each document were recorded to provide additional information for the context of the term. The team also noted if future climate projections were included in the text. The results of the keywork search were compiled in a google spreadsheet and are summarized below. (Note that key words in table contents, figure legends, section titles, and tables were not counted).

Table 2-2 Categories of inclusion of climate change information in stock assessments

Category	Description
Climate change information explicitly included in stock assessment model	Was climate change information (either past attribution or future projections) included in the stock assessment model (e.g., in the design of the model or as a covariate)?
Climate change information explicitly included in text	Was climate change information included in the text in order to set the context for observed or future productivity or distributional changes?
Climate change information implied in text	Was climate change implied in the text, for example as "anticipated changes may require additional attention to X" or through climate change citations, even if climate change was not specifically included?
Climate covariate used in stock assessment	Was a climate covariate, like temperature, used in the stock assessment model?
Climate change information used in the risk table to adjust ABC	Was climate change information (includes events externally attributed to climate change, e.g., MHWs or sea ice loss) used in the risk table to adjust the ABC?
Climate change discussed in risk table	Was climate change discussed in the risk table?
Climate driven changes discussed in risk table	Was climate variability or climate driven change discussed in the risk table?
Not included/discussed	None of the above (not discussed).

2.4.3 Plan Team Minutes-Reports

The Bering Sea and Aleutian Islands (BSAI) Groundfish Plan Team meetings provide opportunities for researchers to present relevant novel or cutting-edge efforts that have not been fully developed but can provide context and meaning to the BSAI Plan Team's goals. As a result, the CCTF reviewed the September and November 2019-2021 BSAI Groundfish Plan Team minutes using the search criteria described above.

2.4.4 Ecosystem Status Reports (ESR)

The CCTF evaluated the last three years of the Ecosystem Status Reports of the Eastern Bering Sea (ESR) using the keyword search criteria described above. The ESR sets out to summarize and synthesize climate and fishing effects on the eastern Bering Sea shelf and slope regions on an annual basis and is temporally constrained from an extensive time-series hindcast spanning decades up to a 9-month forecast. Contained within the report are four chapters communicating ecosystem information at a range of scales from visual figures to more lengthy reports. Within each ESR report, climate, fishery, and ecosystem information are summarized within 3-4 chapters which include a Report Card, an Ecosystem Assessment, and an Ecosystems Indicators chapter. In ESRs prior to 2021, they contained an Executive Summary of Recent Trends chapter. Additionally, statements utilizing the keyword were selectively added to the summary search database to better contextualize the use of the keyword.

2.4.5 Economic SAFE report (Econ SAFE)

The Economic SAFE report (Econ SAFE) reflects the intersection of climate related effects on ecosystem productivity, fishery regulation, and economic forces. The report contains "detailed information about economic aspects of the groundfish fisheries, including figures and tables, economic performance indices, 2021 product price and ex-vessel price projections, year-to-date information on volume and value, an Amendment 80 fishery economic data report (EDR) summary, a Gulf Trawl fishery EDR summary, and market profiles for the most commercially valuable species." The CCTF evaluated the 2019 and 2020 Econ SAFE reports using the previously described keyword search criteria. Like the ESR analyses, statements utilizing the keyword were selectively added to the summary search database to better contextualize the use of the keyword.

2.4.6 SAFE Report Introduction

The introductions for the groundfish SAFE reports and Crab SAFE reports provide the overall summary of stock status as well as raise overarching themes or issues for consideration across species-specific assessments. The CCTF reviewed the introductions from the 2021, 2020, and 2019 SAFE reports for groundfish and crab using the standardized search criteria outlined above.

2.4.7 Groundfish SAFE: Species Specific Assessments & ESP Appendices

Each stock assessment chapter of the groundfish or crab SAFE reports includes information regarding current status and trends in the fishery stock, as well as relevant background information for the design of the population dynamics model underpinning the status assessment. Each chapter also includes an Ecosystem Considerations section, as well as ecological and social-economic information important for the context of the status and trends of the species. For some stocks there is an expanded Ecosystem and Social Profile (ESP) appendix with additional social and ecological indicators relevant for the stock. Multiple groundfish species chapters also include a Risk Table section that details considerations or concerns (or lack thereof) that underpin adjustments (or not) to the model-recommended ABC and OFL. For each stock assessment chapter, we applied the search criteria to the entire stock assessment as well as associated ESP appendices, when applicable. We included the following case study species in this review: Bering sea yellowfin sole, Alaska sablefish, Bering sea pollock, and Bering sea forage (includes herring and squid). Copies of these assessments can be found on the AFSC website at the following LINK.

2.4.8 Crab SAFE: Species Specific Assessments:

Each stock assessment chapter of the crab SAFE report similarly includes information relevant to status review. The two stock assessment chapters of the crab SAFE reports reviewed, Bering Sea snow crab and Bristol Bay red king crab (BBRKC), each include information regarding current status and trends in the stock, as well as relevant background information for the design of the population dynamics model underpinning the status assessment. Specific sections on ecosystem considerations are variable. An Ecosystem Considerations section is in the snow crab assessment for each of the years reviewed. The BBRKC chapter had no formal ecosystem section in 2019 but in the following years there was an Ecosystem and Social Profile (ESP) appendix with additional social and ecological indicators relevant for the stock. An ESP section or appendix for snow crab is expected to be included in upcoming assessments. There are no risk tables included in the Intro or crab SAFE chapters currently. Copies of these assessments can be found on the AFSC website at the following LINK.

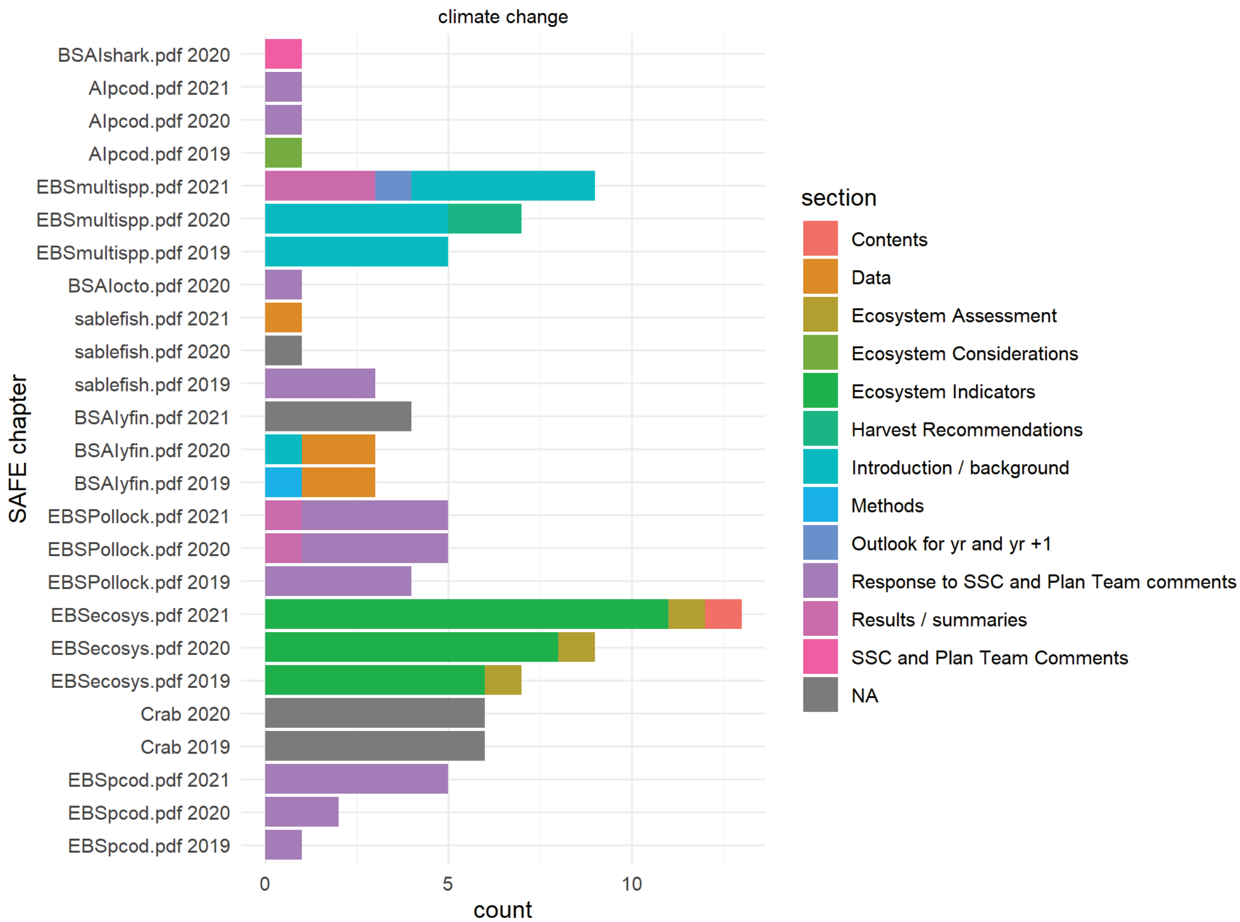

Figure 2-1 Number of times "climate change" was mentioned in the text of each SAFE chapter (only for those chapters where the term appeared). Section refers to the sub-section of various chapters. Note partial assessments were removed from the figure.

2.5 Results

2.5.1 Plan Team Minutes-Reports

We did not conduct full searches through Plan Team minutes or reports, however, the SAFE reviewers noted that in several instances, it is known that peer group reviews occurring at the stock Plan Teams receive climate related research presentations. The information is very explicit to evaluate linkages to stock status for a number of stocks that may be reflecting dynamics that are related to changing conditions. The team reports (minutes) are typically compiled to reflect the topics covered and how they fit into stock considerations, and they are presented/reviewed by the SSC as part of the normal Council process. We note this to highlight that there is broader, more informal attention and inclusion of climate related impacts as part of typical Plan Team activity for both groundfish and crab. We briefly evaluated the Nov-Dec period for groundfish, and the Sep-Oct period for crab, both which align with stock-seasonal cycles for status determinations and management actions. In both cases there are references to climate research, ecosystem overviews, ESRs, ESPs, and other environmental issues with some directions and advice noted to address further climate-linkages to assessments.

The 2021 Sep-Oct and Nov-Dec Plan Team meeting minutes were the only place where climate change trends were presented and explicitly included in a stock assessment model. The presentations to the Plan Team focused on a climate informed multispecies stock assessment model and AFSC's ACLIM 2.0 climate modeling goals and objectives.

2.5.2 Ecosystem Status Report (ESR): Is climate change information included in the Bering Sea ESR?

In general, as is the intention of the ESR, ecological and climate information was clearly provided in terms of observed changes to date and anticipated changes for the next 9 mo- 2 years, including observations of climate-driven ecological trends as well as seasonal climate forecasts and trends in both large-scale and regional climate patterns. However, the report does not explicitly include climate change information, such as long-term (5-50+ year) climate change projections or discussion of climate change vulnerability or anticipated impacts for various ecosystem processes and fishery species. Climate change specific terms such as "climate change", "global warming" and "long-term change" rarely appear in the ESR reports (Table 2-2), and most often occur in terms of context (e.g., an index may be useful for predicting responses to future climate change) rather than detailing a specific prediction of future change (e.g., % change in recruitment anticipated by 2050 under low mitigation scenarios). That said, in multiple places extreme events and climate/temperature impacts are discussed in detail, events which in some cases have now been attributed to anthropogenic climate change, namely impacts of recent Marine Heatwaves (Laufkötter et al. 2020) and loss of sea ice (Jones et al. 2020), as well as changes in wind, circulation, and ocean chemistry that are consistent with anticipated future climate change (IPCCa 2021). **As such the ESRs provide a critical linkage between recent trends and long-term changes that could readily be used to provide climate change information for decision making.**

2.5.3 Economic Status Reports (Econ SAFE)

Five of the 18 search terms found in the 2019 and 2020 Econ SAFE reports were climate, forecast, projection, sea ice and unprecedented. In both the Overview section of the 2019 and 2020 Econ SAFE (pgs. 12 and 14 respectively), "climate trends" is mentioned as one of 7 listed concerns within the context of changing fishery management measures. The full paragraph is show below:

"There is considerable uncertainty concerning the future conditions of stocks, the resulting quotas, and potential changes to the fishery management regimes for the BSAI and GOA groundfish fisheries. The management tools used to allocate the catch between various user groups can significantly affect the economic health of the fishery as a whole or segments of the fishery. Changes in fishery management measures are expected to result from continued concerns with: 1) the catch of prohibited species; 2) the discard and utilization of groundfish catch; 3) the effects of the groundfish fisheries on marine mammals and sea birds; 4) other effects of the groundfish fisheries on the ecosystem and habitat; 5) the allocations of groundfish quotas among user groups; 6) maintaining sustainable fisheries and fishing communities that allow for new entrants into the fisheries; and 7) the response of the fisheries and ecosystem to climatic trends."

The remaining search terms – forecast, projection, sea ice, and unprecedented were aligned with economic price and production projections, the unprecedented effects of the covid-19 pandemic, and a vessel master survey and did not include climate change information.

2.5.4 SAFE Intro: Is the introduction raising the issue of climate change impacts?

In the crab SAFE Introductions, the information is generally focused on providing context directly for information related to OFL and ABC setting, data and assessment methodology, stock biomass and recruitment trends, and final recommendations. The crab SAFE Introduction covers all ten FMP crab stocks, with a few pages devoted to each species, with about 40 pages total per year. The Introduction searches performed reflected infrequent hits on our search terms, and a closer review in the Introductions show that the issues around climate change impacts for crab and groundfish are generally not raised in the crab SAFE Introductions.

2.5.5 Individual Stock Assessment Chapters

While climate variability and ecological impacts of events that have been attributed to climate change (i.e., MHW, changes in cold pool area, sea ice loss) frequently appear in the text of multiple assessments, climate change information is not yet explicitly included in individual stock assessment chapters. Of the reports reviewed, the term "climate change" only appeared in one stock assessment (EBS yellowfin sole, 2021) in response to a SSC comment pertaining to the potential for climate-driven redistribution. However, climate change was implicit in the text and discussion for multiple stocks. Often this appeared around discussion of the cold pool area, changes in bottom or surface temperature, and for Pacific cod, in terms of Ocean Acidification impacts on larval survival. This information most frequently appeared in text associated with the Risk Table, Ecosystem Considerations, Research Gaps, and ESP sections of the reports, specifically around changes in sea ice, MHWs, and shifting distributions. For crab, there were more contextual references to temperatures, warming, around the cold pool dynamics, regime shift, and current responses in the crab stock.

In addition, a few stock assessments used climate covariates directly within the assessment model, variables that are outputs of climate projections for the Bering Sea and therefore could potentially be used to extrapolate climate projections to species-specific changes. This includes temperature as a covariate on survey catchability for yellowfin sole and the cold-pool index in VAST biomass expansions used in pollock and Pacific cod accepted models. For other assessments, climate indices were included in candidate models but were not in selected models for a given year. For crab, the current assessments don't include environmental covariates, but there are references to research included for context of stock status and population dynamics in the Bering Sea around climate change, notably for snow crab and climate indices.

Climate change information from recent vulnerability assessments and climate change projections of redistributions and productivity were largely not included in individual stock assessments, despite these being widely cited in the peer reviewed literature. The exception was discussion of potential redistribution of yellowfin sole in that species' assessment where the author discussed that "shifts may occur under future climate change" that may impact yellowfin sole fisheries which cannot access fish in the NEBS where bottom trawling is restricted. That assessment author also pointed to the importance of monitoring nursery areas in Norton Sound and Kuskokwim-Togiak Bays as areas "experiencing anomalously high water temperatures because of climate change that are likely to impact fish growth and condition". While most assessments did not explicitly discuss climate change, many assessments included climate change citations in the references for the assessment. This indicates that climate change information is implicit in some of the context for recent trends or changes to model structure and design.

Table 2-3 Average number of times each search term appeared in an assessment (# per assessment). Note partial assessments were removed.

keyword	2019	2020	2021
anomalously	1.57	1.5	2
climate	6.8	6.58	8.41
climate change	3	2.57	3.17
cold pool	6.31	5.04	9.64
environmental change	2.8	1.17	2
forecast	3.62	3.76	3.64
global warming	0	1	1
long-term change	0	1	1
Ocean Acidification	4	3.4	3.5
sea ice	8.83	7.28	10.42
temperature	14.62	14.31	18.86
unprecedented	2.09	1.65	2.23
warm	11.52	8.77	11.25
warming	6.2	6.18	5.69

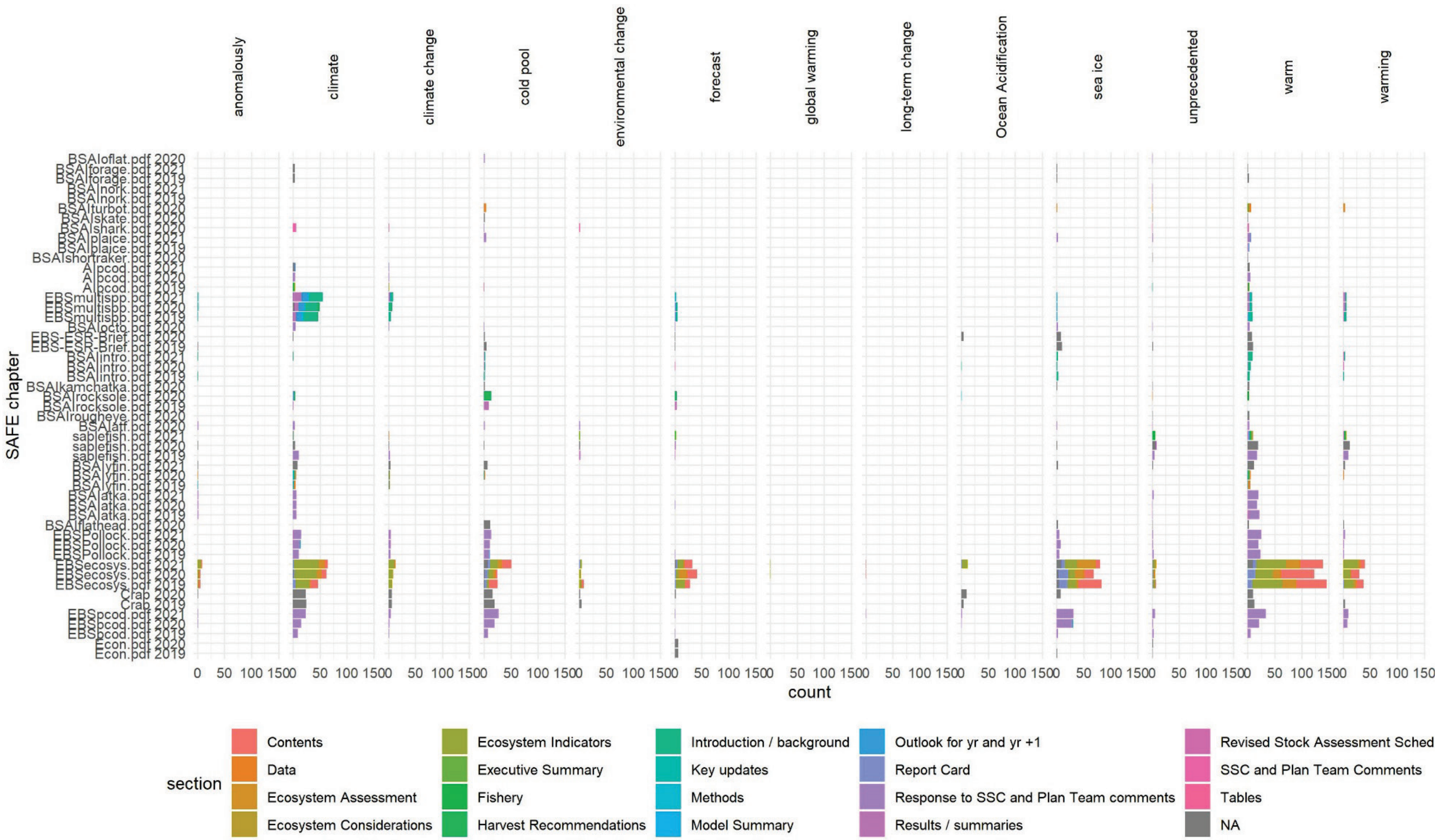

Figure 2-2 Number of times each search term was mentioned in the text of each SAFE chapter. "Section" refers to the sub-section of various chapters. Note partial assessments were removed from the figure

Table 2-4 Summary of the context for the terms "climate change" and "global warming" in each assessment (note that partial assessments have been removed from this table).

Search criteria	Report	# in main text	Climate change information integrated in the advice	Quoted or paraphrased text
climate change	December 2021 Plan Team Minutes	2	[climate change] explicitly included in text	Plan team discussed SSC and Council requests to find ways to estimate squid biomass and impacts of climate change. Plan Team recommends a forage species workshop which includes addressing how climate change may impact forage biomass and exploitation rates.
climate change	EBS 2020 ESR	1	[climate change] explicitly included in text	"Local richness and diversity reflect changes in the spatial distribution, abundance, and species composition that may be caused by fishing, environmental variability, or climate change. "
climate change	EBS 2021 ESR	1	[climate change] explicitly included in text	Understanding the trends as well as the distribution patterns of structural epifauna is important for modeling habitat to develop spatial management plans for protecting habitat, understanding fishing gear impacts, and predicting responses to future climate change.
climate change	EBS 2021 ESR	1	[climate change] explicitly included in text	Trends in metabolic demand from an adult bioenergetics model for groundfish in SEBS reflect MHW and long-term climate driven changes to thermal condition and prey resources.
climate change	EBS 2021 ESR	1	[climate change] explicitly included in text	"Factors influencing observed trends: Local richness and diversity reflect changes in the spatial distribution, abundance, and species composition that may be caused by fishing, environmental variability, or climate change."
climate change	EBS 2021 YFS	4	[climate change] explicitly included in text	No attribution yet of shifts to climate change but large shifts may occur in the future; shifts in distribution could impact fishery catch (if to NEBS non-trawling zone); Norton Sound and Kuskokwim-Togiak Bays should be focal areas for future research as they are nurseries that could be impacted by climate change.
climate change	November 2019 Plan Team Minutes	1	[climate change] explicitly included in text	" The Team noted that a review of the herring savings areas would be a good candidate for a case study for ecosystem management in the new Fishery Ecosystem Plan Climate Action module on Evaluating Climate Change Effects in the Bering Sea."
climate change	November 2020 Plan Team Minutes	2	[climate change] explicitly included in text	Ecological conditions in the N and S EBS continue to exhibit divergent responses to climate change including limited fish forage (N) and limited zooplankton forage (SEBS)
climate change	September 2021 Plan Team Minutes	2	[climate change] explicitly included in stock assessment model	Overview if ACLIM 2.0 by Kirstin Holsman and Alan Haynie.
climate change	September 2021 Plan Team Minutes	1	[climate change] explicitly included in text	"The Team deeply appreciates the summary of the approach, the CIE review, and commends the author and assessment co-authors on the approach and assessment as it is thorough and addresses novel challenges to the recent climate driven changes."

Search criteria	Report	# in main text	Climate change information integrated in the advice	Quoted or paraphrased text
climate change	EBS 2021 Pollock	1	[climate change] explicitly included in text	"The goals of the project include investigating the genetic stock structure of walleye pollock, testing if patterns are temporally stable, and evaluating if distributional shifts under climate change can be detected. "
climate change	EBS 2019 ESR	1	[climate change] explicitly included in text	"Understanding the trends as well as the distribution patterns of structural epifauna is important for modeling habitat to develop spatial management plans for protecting habitat, understanding fishing gear impacts and predicting responses to future climate change (Rooper et al., 2016); however, more research on the eastern Bering Sea shelf will be needed to determine if there are definitive links."
climate change	EBS 2020 ESR	1	[climate change] explicitly included in text	"As long-term climate change leads to warmer temperatures, the baseline used to define 'normal' will change as well, requiring consideration of how baseline selection affects our interpretation of deviations from normal and thus, events like marine heatwaves (Jacox, 2019; Schlegel and Smit, 2018)."
climate change	EBS 2021 ESR	1	[climate change] explicitly included in text	"The Arctic region of northern Alaska is undergoing rapid warming in association with global climate change, and the period of fall 2020 through summer 2021 was no exception. "
global warming	EBS 2020 ESR	1	[climate change] Implied in text	"Such shifts may be the most obvious response of animal populations to global warming (Parmesan and Yohe, 2003). "
global warming	EBS 2021 ESR	1	[climate change] Implied in text	"Many populations shift their distribution in response to temperature variability. Such shifts may be the most obvious response of animal populations to global warming (Parmesan and Yohe, 2003)."

2.6 Future directions

This table summarized the potential near-term, medium- high feasibility measures identified by the team. Details regarding these are provided below in the section "Potential On-ramps".

Table 2-5 Summary Table: Potential near-term On-ramps

Potential on-ramps	Near Term Feasibility
1. Indicator / climate change section in ESR	
a. Add ESR indicator regarding long term projections of climate variables (e.g., bottom temperature, cold pool, OA)	High
b. Add climate change synthesis section, similar to the climate variability and forecast section (Bond et al.) of the ESR	Medium
2. Separate section in SAFE or an independent climate change report	Low-Medium (requires an author to produce annually)
3. Intro section for each SAFE report could include a climate change section (e.g., in the ecosystem section)	Medium- High
4. SAFE Chapters (each species individual assessment) could include climate change information	Medium
a. Species specific climate change paragraph in each safe chapter	Medium
b. Each stock assessment chapter could include a climate change information section or slightly modified ESP	
c. Risk, vulnerability (and adaptation potential) table	
d. Safe author survey of climate readiness of each stock (based on their opinion and set criteria for climate readiness)	
5. Econ Safe Report could include climate change information (especially around risk, portfolio approaches to reduce risk, and future opportunities) a. General paragraph on climate change, global demand, and global to regional economics b. Risk, vulnerability (and adaptation potential) table c. Synthesis of integrated socio-econ MSE results (e.g. ACLIM)	Low-medium
6. Include a climate briefing as part of the Plan Team meetings to help inform this section	High
7. CCTF climate report(s) can be used to periodically update this information through producing synthesis sections for each species as well as the ecosystem as a whole.	Medium (will take coordination to draft and dedicated resources)

2.7 Potential On-ramps

2.7.1 On-ramp 1: Add climate change indicators and/or climate change section to the ESR for the Bering Sea

The rigorous and standardized methodology and operational, transparent, and timely approach to synthesizing management relevant advice provides a framework for summarizing management relevant climate change information through the CCTF Climate Change Report. The top 4 mentions in the 2019-

2021 ESRs are "*temperature*", *"warm", "sea ice"*, and "*cold pool"*, respectively. Climate change projections of these variables in the EBS have been done (Hermann et al. 2021, Cheng et al. 2021, Pilcher et al. 2022, Hollowed et al. 2020) and are likely easiest to include. In several cases, ESR authors relate their reported observations to one of the above. Some examples:

- Understanding how climatic perturbations, and particularly the recent warm periods (Stabeno and Bell, 2019) influence primary production is a critical component in understanding ecosystem dynamics in the Bering Sea.

- The variations of temperature and salinity between Bering Sea Project regions indicate that water mass properties vary considerably both spatially (horizontally across regions and vertically above and below the MLD) and interannually, and will impact ecosystem dynamics and distributions of zooplankton, fish, and other higher trophic levels.

- Recent warming in the EBS and NBS is unlike previous warm periods. The magnitude and seasonality of warming suggests that loss of sea ice may lead to an entirely different ecosystem, which could have drastic impacts on prey quality, predator-prey overlap, and locations of commercial fish populations.

- In the EBS, local species richness may be particularly sensitive to long-term trends in bottom temperature as the cold pool extent changes (Mueter and Litzow, 2008) and provides a useful index for monitoring responses of the groundfish community to projected climate warming (Alabia et al., 2020).

Suggestions for integration of climate change information to the ESR includes but is not limited to the following:

a. Add ESR indicator regarding long term projections of climate variables (e.g., bottom temperature, cold pool, OA)
b. Add climate change synthesis section, similar to the climate variability and forecast section (Bond et al.) of the ESR
c. A natural offramp to present climate change projections of temperature, sea ice and EBS bottom temperatures may be following ESR author reports detailing their observations/hindcasts to variations in observed EBS physical properties. It could then give stakeholders a more immediate view of the current conditions relative to climate change projections.

2.7.2 On-ramp 2: Separate section in SAFE or an independent climate change report

2.7.3 On-ramp 3: Intro section for each SAFE report could include a climate change section

a. Climate change section could include recent and new information on climate change hazards, risks, sensitivities, and adaptation options for reducing risk and impacts such as:
    - The ecosystem section of the SAFE intro could be expanded to include climate change projections, risks, and climate change attribution for recent events like MHWs.
    - Attribution studies for MHW and sea ice loss to anthropogenic climate change (could be in the ecosystem considerations sections of each assessment or could be included in the ESR or Introduction sections of each SAFE report).
    - Include projected changes in physical conditions under SSP1 26 and SSP5 85 for the EBS at near-term, medium term, and long-term (2100)
    - Upcoming climate change research/activities
        - While there were no long-term climate projections/forecasts/warming presented in the 2019-2021 ESRs or Econ SAFE, presentations showing the above were given to the 2021 December and September Plan Teams which included

Holsman's multispecies stock assessment modeling and future research plans for ACLIM 2.0. At the moment, the Plan Team has been the only on-ramp to communicate these long-term projections and could be a continued space, as noted below, to provide relevant climate change information – particularly ongoing research that could have NPFMC relevance.

2.7.4 On-ramp 4: SAFE Chapters (each species individual assessment) could include climate change information

a. Species specific climate change paragraph in each safe chapter
b. Each stock assessment chapter could include a climate change information section or slightly modified ESP with:
    i. Climate couplings for each species including current state of knowledge around OA, temperature, SLR, O2, and circulation
    ii. Climate projections for each species including estimates of re-distribution and productivity
c. Risk, vulnerability (and adaptation potential) table
d. Safe author survey of climate readiness of each stock (based on their opinion and set criteria for climate readiness)

2.7.5 On-ramp 5: Econ Report could include climate change information (especially around risk, portfolio approaches to reduce risk, and future opportunities)

a. Risk, vulnerability (and adaptation potential) table
    i. A table such as this would fit well in the Econ SAFE – a document that presently contains short-term price projections (1-3yr) but does not yet include any climate change/economic linkages. For example, ACLIM research and results could be a vital addition to the Econ SAFE document.

2.7.6 On-ramp 6: Include a climate briefing as part of the Plan Team meetings

2.7.7 On-ramp 7: CCTF climate report(s) can be used to periodically update these sources of information through producing synthesis sections for each species as well as the ecosystem as a whole.

Longer term Implementation ideas for the full climate report

- Climate change MSEs and quantitative risk assessments for each species
- EBFM harvest targets based on long-term projections
- Climate-integrated stock assessment models
- Climate-integrated real-time stock assessment by catch risk and adaptation measures

3 Section 3: Knowledge base overview

3.1 Introduction

This section of the synthesis focuses on the various knowledge bases that support climate readiness and adaptation measures. The first subsection below is devoted to the current status of these knowledge bases and the ways in which they inform such readiness and measures. That discussion focuses on three key knowledge bases - Indigenous community, industry, and NMFS/NPFMC - with brief discussion of others as well. The net is cast broadly to describe knowledge bases which support climate readiness and adaptation measures both in and outside the existing NMFS/NPFMC system. Doing such naturally leads to the second subsection, which builds off the previous section by identifying, through an implicit gap analysis, those elements of broader knowledge-base activities which are not but could be readily inputted into the NMFS/NPFMC management system to improve climate readiness and adaptation measures (i.e., ‘low-hanging fruit’).

The following ranking methodology (Table 3-1) is used to inform the ranking assessment for the various subsections of this section. The management/decision-making process referred to is the NPFMC/NMFS system, not others (e.g., Tribal stewardship/management of resources outside of co-management arrangements). Rankings pertain to the integration of climate-relevant information from the knowledge bases into the NPFMC/NMFS system (e.g., discussion; uptake; on-ramping; incorporation; informing, directing, adjusting management and decision-making; etc.), not an assessment of the knowledge bases themselves.

3.2 Ranking Methodology

Table 3-1 Climate readiness ranking criteria as applied to Section 3

Ranking	Description	Section specific details
1. Not Ready	Climate information and knowledge not included	Climate information is present in the knowledge base but is not discussed or utilized in the management/decision-making process.
2. On the way to climate ready	Some climate variability information and knowledge mentioned sporadically but not substantively/formally discussed or utilized	Climate variability information is present in the knowledge base and may be mentioned sporadically but is not substantively discussed nor utilized in management/decision-making processes.
3. Somewhat ready	Some information and knowledge relating to climate change discussed formally in process but not explicitly utilized in management/ decision-making	Climate change information is present in the knowledge base and discussed informally and formally in the process but does not figure explicitly in management and decision-making.
4. Nearly ready	Significant level of climate change information and knowledge included for context	Significant amounts of climate information are present in the knowledge base and discussed explicitly/ formally in the management/ decision-making process in an informing-manner, but are not used to direct and adjust management actions and decisions.
5. Climate ready	Process for significant and meaningful climate change information and knowledge input is in place and operational	Climate information is present in the knowledge base and discussed explicitly/formally in the management/decision-making process in both an informing and action/decision-directing manner.

Following from this, the 2022 Climate Readiness Rank for Section 3 is as follows, and flows from the discussion further below in this Section as well as relevant portions of Sections 1 and 2 above:

3.2.1 2022 Climate Readiness Rank

The overall climate readiness rank given to the Knowledge Base by the Taskforce is a 2. The ranking for individual sub-components varies from a 1 to a 3, so the overall rank was selected to lie in the middle of this range as something of an average. Generally speaking, there are limited pathways for climate information from the knowledge base into management and decision-making.

Table 3-2 Climate readiness ranking for subsections of Section 3

Sub-Section	Ranking	Details
Indigenous Community Knowledge Integration	1	Community knowledge is expansive and contains detailed information about changes and impacts. There is not a meaningful system of on-ramps for this knowledge to systematically enter into NPFMC/NMFS management and decision-making processes, and lack of sufficient collaborative engagement from research and management to bring together other information with community information.
Industry Knowledge Integration	2-3	Fishery dependent information is included in stock assessments and industry representatives participate in the Plan Team and Council processes to offer their insights and fishery observations. While much of this is qualitative it is explicitly incorporated into the management process.
Agency (Council, NMFS) Knowledge Integration	2-3	See rankings in Sections 1 & 2, as well as discussion of unique climate-relevant functions of various Council bodies below in Section 3.5. With regard to the latter, most higher-ranking activities most likely occur within the Ecosystem Committee, while an overall assessment of other activities would be lower ranking.
Other Knowledge Bases Integration	1-2	There are no distinct on-ramps currently available for the diversity of “other” knowledge bases described here other than through invited presentations, stakeholder testimony, or being indirectly brought into the process via other mechanisms (e.g., analyses). See Section 3.6 Gaps and Next Steps for recommendations regarding assessing the level of how these knowledge bases are incorporated into the process.

3.3 Summary and evaluation of knowledge bases feeding into current climate readiness and adaptation measures in Bering Sea fisheries

This subsection is divided into four parts, illustrating the knowledge bases which contribute to Bering Sea fisheries climate readiness and adaptation measures. These four subsections are: Indigenous community, industry, agency and Council (NMFS, NPFMC), and a brief discussion of other bases (e.g., academic, NGO, etc.).

3.3.1 Indigenous community knowledge base: marine stewardship, subsistence, and co-management contributes to current climate readiness and adaptation

Three existing "community"-based elements of the climate readiness knowledge base are discussed here. The first is the knowledge and epistemic tools (e.g., stewardship practices, principles of relationships to the environment, harvest flexibility, etc.) that Bering Sea Indigenous communities have, as well as the documentation and application of that knowledge (e.g., through applied social science). The second is the knowledge base that comes from co-management arrangements which has applications to climate readiness and adaptation. A third source of knowledge used in climate readiness that relates to Indigenous communities - the community knowledge which is inputted or integrated into the existing NPFMC and NMFS management system - is deferred to the section below. As the first two elements of this knowledge base are extant but may or may not be inputted into the NPFMC/NMFS management system currently, they are outlined here as part of the collective existing climate readiness/adaptation knowledge base, not the NPFMC/NMFS knowledge base. To the extent that their utility may be potentially utilized in the future for NPFMC/NMFS management to increase climate readiness and adaptation but are not (or not fully) currently, they may be noted further below with regard to a gap analysis and near-term recommendations.

3.3.2 Knowledge base of Bering Sea Indigenous communities

Two main categories of Bering Sea Indigenous community knowledge regarding climate resilience are identified here: 1) those pertaining to observations, perspectives and interpretation of changes and impacts resulting from changes, and 2) resilience tools (e.g., practices, values, systems, strategies, responses to changes and impacts, etc.).

The sources of data informing these categories can be largely broken down into three categories: 1) raw observations, 2) documentation and analysis of community knowledge, and 3) community knowledge shared within and between communities but that is not 'documented' (for lack of a better word) elsewhere. The first kind of data source can be found in places like the Indigenous Sentinels Network (ISN) and the Skipper Science Partnership, Alaska Arctic Observing and Knowledge Hub (AAOKH), Indigenous Observers Network (ION), Exchange for Local Observations and Knowledge of the Arctic (ELOKA) and the Local Environmental Observer (LEO) Network, among other local-level or community-driven monitoring programs and databases. Promoting and facilitating networking, expansion and syncing of these programs together may benefit incorporation of these data into the NPFMC/NMFS process, as data could be streamlined and made readily available to these efforts where they are not possible now.

The second kind of data source (documentation and analysis of community knowledge) mainly come from Tribal, non-profit, academic, agency, and private sources. This work may be in the form of collaborative or co-productive work, planning, guidance, and policy documents, other scientific work that doesn't fit into those categories, or other types of products. These data are typically available in peer-reviewed and grey literature.

The third kind of data source is community knowledge shared within and between communities but not 'documented' elsewhere; this likely forms the vast majority of community knowledge pertaining to the climate resilience and adaptation knowledge base, and as such can be one key area where management structures may look to enhance and develop mechanisms to bring this knowledge into their processes to increase climate readiness and maximize systemic resilience.

3.3.3 Observations, perspectives, and interpretation of changes and impacts from changes

The first main category of Bering Sea Indigenous community knowledge regarding climate resilience to be discussed here is that which pertains to community observations and interpretations of changes and their impacts. Impacts include environmental, social, and interlinked changes. There is a wealth of data describing these changes and their impacts, coming from a variety of sources (as noted earlier; e.g. Krupnik and Jolly 2002, Raymond-Yakoubian 2009, 2013, Aronson 2013, Kawerak 2013a, 2013b, 2014, 2021b, Fall et al. 2013, Johnson and Gray 2014, Gadamus and Raymond-Yakoubian 2015, Brinkman et al. 2016, Huntington et al. 2017, 2021, Raymond-Yakoubian and Raymond-Yakoubian 2016, Jantarasami et al. 2018, Raymond-Yakoubian and Daniel 2018, Slats et al. 2019, Igiugig Village Council 2020, Mustonen and Van Dam 2021). These include, but are not limited to:

- Changing weather, including winds, rain, and storms
- Changes to sea and river ice
- Sea level rise and storm surges
- Increase in wildfire risk
- Increase in flooding events
- Changing abundance, distribution, health, behavior, and presence of bird, fish and animal species
- Air and water temperature changes
- Landscape changes, such as erosion, drying up of lakes, and melting permafrost
- Overall ecosystem sustainability
- Changes to water quality (e.g., algal blooms, siltification, loss of potable water sources)
- Changes to vegetation
- Damage to infrastructure and potential needs for protection, mitigation, and relocation
- Contamination and pollution
- Changes to access to subsistence resources
- Changes in industrial activity (e.g., increases in shipping and vessel traffic)
- Changes in subsistence activities
- Other and wide-ranging social and cultural changes and impacts (e.g., relationships with animals, participation in exchange activities, intergenerational knowledge transmission, etc.)
- Economic changes
- Changes regarding health and well-being (e.g., psychological health, access to preferred dietary resources, etc.)
- Regulatory changes
- Changes with regard to research activities
- Cumulative and interlinked changes

Box 1. Critically examining climate change, impacts, and adaptation

Critical understanding of the concepts of climate change, impacts, and adaptation are key. It has been argued that there is a need for an indigenization of climate change, along the lines of Sahlin’s theorization of the indigenization of modernity (Sahlins 1993), wherein understandings of climate change are not seen in hegemonic terms (and thus understandings of it in relationship to communities are framed simply in terms of ‘effects’ on communities) but rather a focus is placed on understanding how this phenomena is situated contextually and made real through various cross-cutting lived discourses of various kinds (Raymond-Yakoubian and Raymond-Yakoubian 2015). Another critical perspective on the relationship between changes, impacts, and adaptation comes from Herman-Mercer et al. (2016), who notes the importance of examining generational differences as pertains to observations of changes and impacts and their relationship to developing adaptation strategies. The adaptation concept itself is also in need of constant critical analysis and interrogation; Thorton and Manasfi (2010) have noted the importance of such a critical approach, and that “human adaptation is not a single strategy but rather a set of diverse, intersecting processes that may evolve autonomously or through planning in response to the panoply of climatic and non-climatic stressors.”

3.3.4 Resilience Tools

The second main category of Indigenous community knowledge regarding climate resilience is that which can be broadly characterized as knowledge relating to resilience 'tools'. The term 'tools' is meant to be taken in a broad sense here ranging from what might be characterized as the more tangible (e.g., knowledge about and use of technologies) to the more abstract (e.g. values). A wide variety of tools are utilized by communities which already contribute to their climate resilience. The knowledge base pertaining to these tools spans from the information developed within communities and shared between generations and other communities of various kinds, to the documentation and analysis of these tools and their application in a variety of settings (e.g., policy-setting). The following list encapsulates some of these main resilience tools identified within this part of the knowledge base, as well as provides some information on the pertinent epistemic contexts (see e.g. Berkes 2002, Raymond-Yakoubian 2009, 2013, 2016, Thornton and Manasfi 2010, Aronson 2013, Huntington and Noongwook 2013, Kawerak 2013a, 2013b, 2014, 2015, 2021a, 2021b, Murray et al. 2013, Johnson and Gray 2014, Pearce et al. 2014, Gadamus et al. 2015, Gadamus and Raymond-Yakoubian 2015, Raymond-Yakoubian and Raymond-Yakoubian 2015, Huntington et al. 2017, 2019, 2021, Kettle et al. 2017, Raymond-Yakoubian et al. 2017, Jantarasami et al. 2018, Raymond-Yakoubian and Daniel 2018, Igiugig Village Council 2020, Carothers et al. 2021, Mustonen and Van Dam 2021, Steffen et al. 2021, Ellam Yua et al. 2022).

Table 3-3 Some Bering Strait Indigenous community resilience tools

Resilience tools	Examples/Discussion
Knowledge itself	● Inclusive of both research and non-research activities ● Forms of Indigenous Knowledge (e.g., Traditional Knowledge) ● Indigenous methodologies and the use of Indigenous evidence-bases for policy-making ● Integrative, Indigenous-informed, collaborative and co-productive research, management, and policy-making
Traditional Values	● Can function as a backbone for community climate resilience ● E.g., values pertaining to the ecosystem, health and well-being, economics, and culture
Attitudes and Skills (and knowledge which generates/supports them)	● Being aware, prepared and safe ● Persistence ● Innovation ● Flexibility, adaptability, and the ability to adjust ● Experimentation ● Respect
Actions, Practices, Strategies, and Institutions	● Supporting and increasing local autonomy and self-determination ● Adjusting harvest strategies and harvest use and processing strategies ● Stewardship and management ● Revitalization ● Cultural resilience in language, storytelling, and knowledge-sharing ● Increasing local capacity, funding, and support ● Indigenous leadership ● Decolonization processes ● Consideration of climate change in and alongside the context of other challenges
Planning and Visioning activities at oceans, regional, and community levels	● Planning that is inclusive, equitable, accounts for Indigenous priorities, and includes possibility for conservation ● Development of community climate resilience-related plans

3.3.5 The Climate-Relevant Knowledge Base from Co-Management Activities

Cooperative management, or co-management, is an evolving concept. Broadly speaking, the term co-management has come to mean a process of shared responsibility and authority for management of a natural resource or resources. This is typically realized between a formal designated government entity and specific resource users, with each co-manager having defined and specific rights and responsibilities relating to information gathering and decision-making (i.e., Pomeroy and Berkes 1997; Sen and Nielsen 1996). Definitions and examples of co-management structures are wide-ranging, and it is important for all parties involved to clearly define and mutually agree upon the goal and objectives of the co-management structure.

The most advanced co-management models exist in the context of fish and wildlife management, which is especially true in Alaska partially because of the unique situation resulting from the Alaska Native Claims Settlement Act, the Alaska National Interest Land Conservation Act, and related legislation (Washburn 2022). One tribal co-management example can be found in the co-management of marine mammals between Alaska Native Organizations (ANOs) and either NOAA NMFS or USFWS (polar bears, walrus). During a recent Marine Mammal Co-Management Review conducted by the Marine Mammal Commission together with a Steering Committee comprised of ANO representatives, the group came to a mutually agreed upon definition of co-management: “A partnership based on trust and respect, established between an Alaska Native Organization, as defined by the Marine Mammal Protection Act, and either NMFS or USFWS, with shared responsibilities for the conservation of marine mammals and their sustainable subsistence use by Alaska Natives” (Malek and Cornish 2019). The group also provided guidance on improving co-management relationships, which included: Co-management partners should clearly define and mutually agree upon their respective roles, responsibilities, and accountability mechanisms, and should be more transparent regarding partner limitations; and Co-management partners and stakeholders should work cooperatively to strengthen communications, trust, and respect within and among partners.

Examples of information that results from existing co-management frameworks in Alaska as related to fisheries management include, but are not limited to:

- Weather conditions, including anomalous, abnormal and changing conditions
- Changes to sea ice, including in the quality (e.g., rotten, solid), thickness, duration, extent, and safety
- Animal behaviors, including changes in prey or diet, shifting distributions, strange or anomalous behaviors (e.g., due to harmful algal bloom or contaminants exposure), interactions with other species
- Presence/Absence, levels of (i.e., counts, estimates) and changes in abundance
- Presence/Absence of diseases or parasites
- Animal health (blubber thickness, quality, texture, meat quality)
- Timing of arrival and departure of wildlife species
- Regulatory changes
- Levels of subsistence harvests (number of animals taken, age and sex class, animal behavior and quality)
- Entangled, wounded and stranded animals
- Biosampling and archiving of animal tissues (e.g., blubber, vibrissae or whiskers; which can be retrospectively tested for changes in diets, exposure to contaminants, etc.)

In the case of marine mammal co-management in Alaska, semi-annual and annual reports are produced and provided to the federal managing agency and made publicly available. Data from these reports are included in the Alaska marine mammal stock assessment reports (e.g. Muto et al. 2021). As projects are completed, scientific and public reports and publications are made available; this includes research investigating climate change impacts on marine mammals. Additionally, information regarding entangled, wounded, and stranded animals are provided through standardized reporting and also made publicly available. However, there is a wealth of knowledge that is shared between co-managers formally and informally that is not currently integrated into any potentially relevant NPFMC/NMFS processes.

Related to, but fundamentally different from, co-management is the process to create cooperative management plans. Cooperative management plans consider the concerns of Federal, State, Tribal, and other stakeholders through a highly cooperative planning process, even though, at the completion of the plan, stakeholders are not granted regulation enforcement status. If the Fishery Management Plans under the purview of the Council should be altered to become cooperative management plans, diverse community knowledge may be incorporated in many diverse ways, as the process is flexible and adaptable to the participating parties. This may be an ideal pilot project to undertake as a joint effort between the LKTKS TF and the CCTF regarding Bering Sea ecosystem-based fishery management.

There are a variety of co-management examples in the U.S. where federal lands are concerned, but we must look internationally for examples of co-managed marine areas, especially those that include local or Indigenous co-management. Tribal co-management differs from other types of collaborative management of federal lands in that a sovereign Tribal Nation enters into the agreement of shared management responsibilities with another government entity and thus governance is upon basic principles of American Indian law (Washburn 2022). Tribal co-management is commonly confused with stakeholder cooperation or public-private partnerships but is unique in that it is the practice of two (or more) sovereigns working together to address and solve matters of critical concern to each (Goodman 2000). Further, as Goodman (2000) states, "Co-management is not a demand for a tribal veto power over federal projects, but rather a call for an end to federal unilateralism in decision making affecting tribal rights and resources. It is a call for a process that would incorporate, in a constructive manner, the policy and technical expertise of each sovereign in a mutual, participatory framework.

3.3.6 NPFMC- and NMFS-related processes which include Indigenous community knowledge

Discussion of the topic of the extant community knowledge base which is captured in the NPFMC and NMFS management system is deferred to Section 3.5, below (with the exception of co-management activities, which are discussed above).

3.3.7 Industry knowledge base: Climate change information from industry expertise

The commercial and recreational fishing industries are subject to annual catch limitations that are determined by a well-defined analytical stock assessment process that integrates fisheries dependent and fisheries independent data using the best available scientific information. With respect to readiness, resilience, and adaptation to climate change the fishing industry must respond to: changes in annual TAC's associated with changes in stock size and catch buffers to mitigate for uncertainty, changing market conditions, changing fishing conditions, avoiding prohibited species, changes in stock distribution, and changes in stock productivity and capacity.

The large industrial commercial sectors rely primarily on high-volume, low-value, species. The smaller fixed-gear sectors tend to focus on low-volume, high-value species and are more limited in their range to access distant grounds. A climate ready fishing industry will have to be adaptive to potential changes in species abundance and composition and potential shifts in the primary fishing grounds where these fisheries operate. Furthermore, support operations such as Search and Rescue and tendering have to cope with increased response times and increased distances as fishing operations move further away from land-based operations (e.g., coast guard bases and fish processing plants).

There are two major industry concerns from a readiness perspective: changes in fish distribution and changes in species abundance and composition. Recent shifts in the Bering Sea pollock and cod stocks associated with the warm water events of 2018-2019, resulted in major shifts in the location of the summer fishing grounds. Also, there have been notable historical shifts in species-compositions in temperate marine ecosystems (e.g., shift from invertebrate fisheries to cod in the Gulf of Alaska) that are of concern. The combined effects of changes in species composition and the location of where the fisheries are prosecuted have a number of impacts on fishing cost, quality, and vessel safety. Fishing operations have now moved sufficiently far north that US Coast Guard search and rescue operations require additional logistical support outside of its normal operations. Shoreside processing capacity is becoming further from the fishing grounds, increasing transit time, reducing product quality, and increasing the risk of accidents.

The primary management objective is to prevent overfishing and the Council's tier harvest control rule system is designed to ensure that annual catch limits will prevent overfishing and allow overfished stocks to rebuild. Specifically, annual catch limits vary from year-to-year, to reflect the underlying changes in stock abundance and productivity. This annual variability in catch limits trades-off with the socio-economic objectives of minimizing catch variability that leads to community and economic stability. Climate resilience from the fishing industry's perspective is measured by how quickly climate effects can be detected in the stock assessment, and how robust the harvest control rule (e.g., a fixed harvest rate) is to model misspecification and uncertainty about climate effects.

There are a variety of high-quality fishery dependent observations (i.e., observer data) that are included in the annual stock assessment and fishery evaluation reports. This observer data is often coupled with reports from the various fishing sectors to the Plan Teams and Council that include fishery conditions, water temperature observations, and notable changes from past years. While much of these reports are qualitative, it gives fishery managers and scientists insights into how the fisheries are performing throughout the year as opposed to what was seen during the survey either annually or biennially and during the summer months only. Integrating this industry knowledge into the fishery management process occurs on a regular basis.

3.4 Other knowledge bases

There is a variety of climate-relevant information from other knowledge bases that are not detailed here. This includes, for example, international initiatives (e.g., IPCC, IOOS, ICES, Arctic Council), academic efforts, work at NGOs, and other Tribally-based initiatives (e.g. the Northern Bering Sea Climate Resilience Area Tribal Advisory Council). The potential complexity of devising an analysis of these various bases and whether/how they are brought into the current management process necessitates that such a task be postponed for future CCTF work. One potential avenue for analysis would be something akin to the SAFE report keyword analysis in this report (see Section 2 above), whereby a reasonably-complete list of major 'other knowledge base' efforts is crafted into a code list and utilized as a basis for searches of Council documents (e.g. posted documents, invited presentations, minutes, testimony, etc.) from 2019-2021 to see if and how they are on-ramped into the Council process. This could lead to recommendations for how such information could be better (e.g., more systematically) integrated.

3.5 "Agency" knowledge base: Climate readiness and adaptation knowledge currently integrated into the NPFMC and NMFS management process

3.5.1 NPFMC bodies and activities

A number of Council bodies, activities and processes have substantively worked on issues in a way that can be seen as constituting part of the knowledge base pertaining to climate resilience and adaptation. Here we summarize the bodies as relates to their unique functions in this regard. Although not comprehensive, this table indicates the most relevant or developed activities.

Table 3-4 Council bodies and unique climate-relevant functions

NPFMC body	Unique Climate-Relevant Functions
Council	● FMPs - see Table 1-2 and Section 1: Management Overview ● ABC, OFL, TAC, PSC - see Table 1-2 and Section 1: Management Overview and Section 2: SAFE Report Review
Science and Statistical Committee (SSC)	● Recommend research priorities to Council; Top Ten Research Priorities List only includes climate change impacts in one of the ten priorities. ● Discusses SAFE reports & emerging research as related to climate-informed assessments but does not explicitly include climate information in decision-making (ABC- and OFL-setting); Finalizes ABC, OFL - see Section 2
Advisory Panel (AP)	● Weighs in on issues to provide advice to the Council; brings in variety of information from various knowledge bases (through members, presentations, and stakeholder testimony) to discussions, motions, actions, rationales
Ecosystem Committee (EC)	● Discusses ecosystem-based knowledge and analyses and their relevance to the Council process, including providing for a for diverse sources of knowledge ● Led 2018 Ecosystem Workshop (Seattle), which had a key focus of providing a forum for discussion on climate change as it relates to the North Pacific. This included discussion of the impacts of climate change, management challenges associated with resource changes, key scientific efforts providing tools for dealing with challenges presented by environmental change, and consideration of next steps.
Community Engagement Committee (CEC)	● CEC Final Report contains a number of recommendations which if implemented can increase the flow of diverse sources of climate change information and resilience tools into the Council process
Bering Sea Fishery Ecosystem Plan Team (BS FEP Team) and Action Module Taskforces	● Plan Team and Taskforces (see below) potentially increase pathways for climate-ready knowledge and strategies into the management process. ● Local Knowledge Traditional Knowledge and Subsistence Taskforce (LKTKS TF) has been created, which is developing protocols which will, among other things, increase pathways for climate-ready knowledge to feed more directly into the NPFMC process. ● Climate Change Taskforce (CCTF) has been created, which evaluates the vulnerability of key species and fisheries to climate change and strengthens resilience in federal fisheries management.
Groundfish, Scallop, Crab Plan Teams	● Recommend ABC, OFL to SSC - see Section 2

3.5.2 National Marine Fisheries Service (NMFS)

Knowledge which pertains to climate resilience and adaptation is summarized at the agency level in two categories: knowledge from co-management activities, and (other) work at the Alaska Fisheries Science Center (AFSC) and Alaska Regional Office (AKRO). The latter is summarized here; the knowledge from co-management activities is not summarized in this section but rather are described previously in this section.

- Strategic planning, training, and general activities: The AKRO has climate-related expertise in the Sustainable Fisheries, Protected Resources, and Habitat Divisions. Staff track climate issues both at the regional and national level, and in coordination with the NPFMC. Staff resources are constrained by other non-climate related priorities; however, climate-related topics are a priority in the recently completed AKRO strategic plan (NOAA AKRO 2022) and NOAA strategic plan

(NOAA 2022). Staff in AKRO have taken advantage of NOAA trainings on climate-related issues, such as the use of toolkits and climate adaptation concepts, and AKRO has incorporated climate related experience and knowledge into its hiring processes where appropriate.

The following activities and processes have either previously been summarized or are under development and will be summarized for their contribution to the agency knowledge base and integration into management/decision-making as needed in a future CRS.

- Climate Fisheries Initiative
- Climate Science RAPs
- ACLIM, GOA-CLIM
- AFSC Social Science work pertinent to climate
- ESRs
- Other (surveys, monitoring, etc.)

3.6 Gaps and next steps: knowledge base elements and activities which can potentially be brought into the existing management system in the near-term

The discussion above implicitly identifies areas of several large knowledge bases in the wider Bering Sea management system (conceived in a broad sense, beyond just the NPFMC/NMFS management system) which are not taken up into the NPFMC/NMFS system but could be. These include elements largely or entirely outside the current federal fishery management system (e.g., the knowledge base underlying Indigenous marine stewardship practices) or elements within the current system which are not yet fully implemented (e.g., full implementation of climate change-relevant Community Engagement Committee recommendations). More specifically, this subsection focuses on some potential elements and activities which could be brought into the existing NMFS/NPFMC management system in the near-term to help support climate readiness.

Potential near-term next steps in this regard as indicated by the discussion above include the following:

- Provide input into the Research Priority setting process foregrounding the importance of diverse sources of climate information and their relationship to climate-ready fisheries science and management
- Test mechanisms within the CCTF (e.g., Climate Briefings, Ecosystem Matrix tool, etc.) for bringing diverse knowledge sources related to climate change into the Council process
- Finalize and implement LKTKS Taskforce protocol regarding incorporation of LK, TK, and subsistence information into the Council process
- Track and consider climate change information and implications in light of recommended evaluations (as suggested by the Ecosystem Committee in March 2022) of the Programmatic EIS
- Scope development of Fishery Ecosystem Plans in other regions for connectivity issues (e.g., Gulf of Alaska, Arctic), as discussed at the March 2022 meeting of the Ecosystem Committee
- Increased development and implementation of EBFM tools across Council processes
- Work on marine planning and protections that are equitable and inclusive of a diverse set of communities, people, knowledges, methodologies, and values
- Implement a number of the CEC Final Report (NPFMC 2021) recommendations which could increase the flow of diverse sources of climate change information (including resilience tools) into the Council process. This includes:
    - Co-presentation from Tribal representatives on all agenda items
    - Standing Community Engagement or Tribal Advisory Committee
    - Increase the input of Tribal Consultation activities into the Council process
    - Council travel to rural communities for Council meetings and visits
    - Continuation and ongoing improvement of current outreach practices to foster two-way engagement
    - Taking steps towards Co-Production of Knowledge

    - Increased capacity at AFSC in the non-economic social sciences, particularly as regards expertise working with Alaska Native communities and their knowledge
    - Increased Indigenous inclusion on Council advisory and working bodies
- Increased uptake of broader climate change knowledge base not, or not fully, integrated into the Council process through additional steps not indicated above in other bullets, e.g., through exploring collaborations, partnerships and co-production (also see Section 2 for near-term steps to advance climate integrated advice)
- Conduct an analysis of Council documents as outlined above to explore whether and how the climate-relevant information from a variety of 'other' knowledge bases are currently making their way into the Council process in order to facilitate a gap analysis and recommendations for improvement, as necessary

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5 Appendix

5.1 Details on selected table elements

Flatfish Exchange

Flatfish exchange is a process for Community Development Quota (CDQ) groups and Amendment 80 (A80) cooperatives to exchange harvest quota of one or two of three flatfish species (flathead sole, rock sole, and yellowfin sole) for an equal amount of another of these three flatfish species, while maintaining total catch below acceptable biological catch (ABC) limits. This process mitigates the operational variability, environmental conditions, and economic factors that may constrain these sectors from achieving, on a continuing basis, the optimum yield in the BSAI groundfish fisheries. This action is intended to result in higher retention and utilization of groundfish without increasing overall catch or bycatch of groundfish or non-groundfish species beyond existing limitations.

Incidental Catch Allowances

A set-aside for fish caught while targeting some other species. For example, A-80 species caught by non-A80 participants or pollock captured by non-AFA pollock participants. Regional Administrator determines that the incidental catch allowance has been set too high or too low, he/she may issue in-season notification in the Federal Register that reallocates incidental catch allowance to the directed fishing allowance, or vice versa, according to the proportions established in federal regulations.

Non-specified reserves

The non-specified reserve is not designated by species or species group. Any amount of the non-specified reserve may be apportioned to target species (i.e., groundfish specified in the harvest specifications at § 679.20(a)(2)) that contributed to the non-specified reserve, provided that such apportionments do not result in overfishing of a target species and are consistent with other federal regulations.

Area Management[13]

Catcher Vessel Operational Area (CVOA)[14]

Under current CVOA regulations, a catcher/processor vessel authorized to fish for BSAI pollock under § 679.4 is prohibited from conducting directed fishing for pollock in the CVOA during the B-season pollock defined at § 679.23(e)(2)(ii), unless it is directed fishing for Pollock CDQ. The CVOA was established in the early 1990s (Amendment 18 FR-1991-12-20) and was intended to address the dependence of the BSAI inshore component on nearby waters for pollock resources, but provides an allowance for some access to this area by the offshore component during the "A" season in recognition of the high economic value of pollock roe obtained by the at-sea processors from this area.

[13] Not a comprehensive list

[14] For additional history see Effects of CVOA on Walleye Pollock Fishery on Marine Mammals in the EBS

Pribilof Islands Habitat Conservation Zone

Directed fishing for groundfish using trawl gear or pot gear, or fishing for halibut using pot gear, is prohibited at all times in the area defined as the Pribilof Islands Habitat Conservation Zone.

Zone 1 (NMFS Reporting Area 512) closure to trawl gear

No fishing with trawl gear is allowed at any time in reporting Area 512 of Zone 1 in the Bering Sea subarea.

Zone 1 (NMFS Reporting Area 516) closure to trawl gear

No fishing with trawl gear is allowed at any time in reporting Area 516 of Zone 1 in the Bering Sea Subarea during the period March 15 through June 15.

C. opilio Bycatch Limitation Zone (COBLZ)

A closure for EBS snow crab (C. opilio) is triggered if the limit is reached in specified fisheries. The limit accrues for bycatch taken within the C. opilio Bycatch Limitation Zone (COBLZ). That area then closes for the fishery that reaches its specified limit. EBS snow crab PSC limits are based on total abundance of snow crab as indicated by the NMFS standard trawl survey.

Red King Crab Savings Area (RKCSA) and subarea

Directed fishing for groundfish by vessels using trawl gear other than pelagic trawl gear is prohibited at all times, except as provided at § 679.21(e)(3)(ii)(B), in that part of the Bering Sea subarea defined as RKCSA.

The RKCSA was established in response to a decline in the BBRKC stock, specifically female abundance, and the need to further protect and conserve RKC in the Bristol Bay area of the Bering Sea. An emergency rule, promulgated by NMFS in 1995 (60 FR 4866, January 25, 1995), established and closed the Red King Crab Savings Area (RKCSA) from January 20 to April 25 to all nonpelagic trawling. In 1996, NMFS closed the RKCSA by inseason adjustment (60 FR 63451, December 11, 1995) from January 20 to March 31, 1996. Continued low abundance of crab stocks caused the Council to express additional concerns about opening the RKCSA, resulting in a recommendation at the January 1996 Council meeting for an extension to the 1996 inseason adjustment to close the RKCSA until June 15, 1996 (61 FR 8889, March 6, 1996) to further protect BBRKC during the molting and mating period. Based on information provided at its June 1996 meeting, the Council recommended expanded management measures under Amendment 37 to the BSAI FMP to protect the declining stock of RKC in Bristol Bay. In brief, the final rule (61 FR 65985, December 16, 1996) to implement BSAI Groundfish FMP Amendment 37 which closed NPT in portions of Bristol Bay including the RKCSA year-round, made adjustments to the prohibited species catch (PSC) limit for BBRKC in Zone 1 of the Bering Sea, and increased observer coverage in specified areas related to the trawl closures.

The Red King Crab Savings Subarea (RKCSS) is a 10 nm strip on the southern boundary of the RKCSA that NMFS may be open to non-pelagic trawling if a GHL fishery for BBRKC has been established for the crab season leading into that NMFS calendar fishing year. The RKCSS was originally established to allow for productive rock sole fishing in years when the RKC biomass is sufficient. The subarea is limited by a sub-apportionment of the total Zone 1 RKC PSC limit that is set annually in harvest specifications and may not exceed 25% of the Zone 1 PSC limit. As with the RKCSA, the RKCSS was fully implemented as a year-round area in 1997 after having been in place as a partial-year closure under emergency rule in the prior year (61 FR 65985, linked above).

Herring Savings Area

Concern about unregulated trawl bycatch of Pacific herring led to the establishment of the Herring Savings Area in 1991. The PSC limit of Pacific herring caught while conducting any domestic trawl fishery for groundfish in the BSAI is 1 percent of the annual eastern Bering Sea herring biomass. The PSC is apportioned into annual herring PSC allowances, by target fishery (50 CFR 679.21(e)(3)(iv)), and is published in the Federal Register along with the annual herring PSC limit in the annual harvest specifications. With some exceptions, when herring bycatch allowance or seasonal apportionment thereof is reached, specified for that fishery category in regulation, NMFS closures the Herring Savings Area. There are three closure areas associated with seasonal periods:

- Summer Area 1: June 15-July 1
- Summer Area 2: July 1 - August 15
- Winter: September 1 - March 1.

Amendment 16a (NPFMC 1991) established the herring savings areas based on the biological characteristics of the herring stock, fishery bycatch, and potential impacts to the pollock fishery due to time and area closures.

https://media.fisheries.noaa.gov/dam-migration/am16a_earirbsai.pdf

Salmon Savings Measures and Monitoring

Amendment 91 was an innovative approach to managing Chinook salmon bycatch in the Bering Sea pollock fishery that combines a prohibited species catch limit on the amount of Chinook salmon that may be caught incidentally with an incentive plan agreement and performance standard designed to minimize bycatch to the extent practicable in all years.Further detail is found here:
https://www.fisheries.noaa.gov/action/amendment-91-fmp-groundfish-bering-sea-and-aleutian-islands-management-area#:~:text=Amendment%2091%20is%20an%20innovative,minimize%20bycatch%20to%20the%20extent

Amendment 110 was designed to improve the management of Chinook and chum salmon bycatch in the Bering Sea pollock fishery by creating a comprehensive salmon bycatch avoidance program. This action was necessary to minimize Chinook and chum salmon bycatch in the Bering Sea pollock fishery to the extent practicable while maintaining the potential for the full harvest of the pollock total allowable catch within specified prohibited species catch limits. Further detail is found here:

https://www.fisheries.noaa.gov/action/amendment-110-fmp-groundfish-bering-sea-and-aleutian-islands-management-area

Habitat Conservation Area Maps

https://www.fisheries.noaa.gov/resource/tool-app/habitat-conservation-area-maps

Steller Sea Lion Protection Measures

https://www.fisheries.noaa.gov/alaska/commercial-fishing/steller-sea-lion-protection-measures

Special Area Maps

https://www.ecfr.gov/current/title-50/chapter-VI/part-679

Monitoring

In the groundfish and Pacific halibut fisheries, catch and discard data are collected through the North Pacific Observer Program (Observer Program). This program is the largest observer program in the country and is administered by the Alaska Fisheries Science Center (AFSC). It provides the regulatory framework to deploy observers and Electronic Monitoring (EM) systems to collect data necessary for the conservation, management, and scientific understanding of the commercial fisheries in the BSAI and GOA management areas. Data collection through the Observer Program provides a reliable and verifiable method for NMFS to collect fishery-dependent catch data, biological information on fish, and data concerning seabird and marine mammal interactions with fisheries. Observers and EM systems provide information on catch and discard onboard fishing vessels and at onshore processing plants. These data are used in the Catch Accounting System to extrapolate and estimate total catch and discards in the fisheries (Cahalan et al., 2014) and enable real-time catch information for in-season management of the fisheries.

Vessels fall into two categories of coverage, a full coverage category and a partial coverage category. In the full coverage category, vessels must have an observer onboard on every trip (many vessels with two observers), and vessels obtain observers by contracting directly with certified observer providers. Vessels in this category include catcher/processors as well as catcher vessels that are participating in specific limited access privilege program fisheries. The vast majority of the groundfish catch falls under the full coverage category. Vessels operating in the AFA pollock fishery have full retention requirements for salmon with electronic monitoring for purposes of enforcing the retention requirement. A recently approved EM program will expand this to all groundfish and PSC for participating AFA catcher vessels.

All vessels and processors that are not in full coverage are in the partial coverage category and are assigned observer coverage according to the scientific sampling plan described in the Annual Deployment Plan (ADP). The ADP outlines the science-driven method for deployment of observers and EM systems using established random sampling methods to collect data on a statistically reliable sample of fishing vessels in the partial coverage category.

Together, monitoring of the vessels in the full coverage and partial coverage categories provides a comprehensive data collection program from which to extrapolate and provide estimates of discards. In 2021 for example, 98.7% of the catch (including discards) in the BSAI groundfish and halibut fisheries occurred on a trip with an at-sea or shoreside observer or by EM (NMFS, 2022).

Data Acquisition

Data warehouses are maintained by NMFS, ADF&G, and the Pacific States Alaska Fishery Information Network (AKFIN) and summary reports can be found on agency websites. Landings and Processing reports are provided to NMFS and ADF&G through eLanding/tLandings applications and are made available in near real time to agency and AKFIN data warehouse processes. NMFS also provides data feeds directly to industry and provides support on issues associated with these feeds. Both fishery and scientific collections are available to agency scientists through AKFIN or the respective data warehouses (e.g., NMFS, ADF&G). The public can access data through agency websites and data requests can be made by the public to the agencies but must conform to data confidentiality regulations and policy. Other sources of data, such as ocean observing systems and AIS, also exist and have been integrated into specialized fishery data products in some situations.