# DRAFT

# Fishery Management Plan

# for Fish Resources of the Arctic Management Area

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November 2008

**NOTE: This is an interim draft of what the Arctic FMP will look like. It is written assuming the Council chose Alternative 3 and exempted a small red king crab fishery in the eastern Chukchi Sea from this FMP. The Council has NOT chosen its preferred alternative, so this is merely an example of the FMP at this time. The Council also has not chosen its preferred option for specifying conservation and management measures; therefore, both Option 1 and Option 2 are included in this draft FMP. This draft does not fully respond to comments from the Council's SSC, particularly regarding Options 1 and 2; SSC comments on an earlier draft FMP are listed in the accompanying EA/RIR/IRFA. Please refer to this document for detailed analyses of the alternatives and options and for additional background information.**

NOTE: This document has not been cleared by NOAA General Counsel, Alaska Region.

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# Executive Summary

This Fishery Management Plan (FMP) governs all commercial harvests of fish in the Chukchi and Beaufort Seas.[1] The FMP management area, the Arctic Management Area, is all marine waters in the U.S. Exclusive Economic Zone of the Chukchi and Beaufort Seas from 3 nautical miles offshore the coast of Alaska or its baseline to 200 nautical miles offshore, north of Bering Strait (from Cape Prince of Wales to Cape Dezhneva) and westward to the U.S./Russia Convention Line of 1867 and eastward to the U.S./Canada maritime boundary (see Appendix A). The FMP covers commercial fisheries (any commercial harvests) for all stocks of fish, which include all finfish, shellfish, or other marine living resources except salmonids, Pacific halibut, Pacific herring, whitefish, and Dolly Varden char.

The FMP was implemented on (***DATE***). It may be referred to as the Arctic Fishery Management Plan.

## 1.1 Management Policy

The Magnuson-Stevens Fishery Conservation and Management Act, as amended through January 12, 2007 (Magnuson-Stevens Act), is the primary domestic legislation governing management of the nation's marine fisheries. In 2007, the United States Congress reauthorized the Magnuson-Stevens Act to clarify and strengthen U.S. fishery management policy. The Magnuson-Stevens Act contains ten national standards, with which all FMPs must conform and which guide fishery management. Besides the Magnuson-Stevens Act, U.S. fisheries management must be consistent with the requirements of other regulations including the Marine Mammal Protection Act, the Endangered Species Act, the Migratory Bird Treaty Act, and several other Federal laws.

Under the Magnuson-Stevens Act, the North Pacific Fishery Management Council (Council) is authorized to prepare and submit to the Secretary of Commerce for approval, disapproval or partial approval, a FMP and any necessary amendments, for each fishery under its authority that requires conservation and management. The Council conducts public hearings so as to allow all interested persons an opportunity to be heard in the development of FMPs and amendments, and reviews and revises, as appropriate, the assessments and specifications with respect to the optimum yield from each fishery (16 U.S.C. 1852(h)).

The Council has developed a management policy and objectives to guide its development of management recommendations to the Secretary of Commerce. This management approach is described in Table ES- 1. For Arctic fish resources, the policy is to prohibit all commercial harvests except for a small red king crab fishery described in Appendix A. See Section 3.4 for a description of the annual specifications process the Council will use to implement this policy. Red king crab harvest management, for a fishery as described in Appendix A, is exempted from this FMP and is deferred to the State of Alaska.

[1] The Magnuson-Stevens Fishery Conservation and Management Act defines "fish" as finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds.

**Table ES- 1 Arctic Fishery Management Approach**

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| The Council's policy is to apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, proactively rather than reactively, to ensure the sustainability of fishery resources and associated ecosystems for the benefit of future, as well as current, generations. The productivity of the North Pacific ecosystem is acknowledged to be among the highest in the world. For the past 30 years, the Council management approach has incorporated forward looking conservation measures that address differing levels of uncertainty. This management approach has in recent years been labeled the precautionary approach. Recognizing that potential changes in productivity may be caused by fluctuations in natural oceanographic conditions, fisheries, and other, non-fishing activities, the Council intends to continue to take appropriate measures to insure the continued sustainability of the managed species. It will carry out this objective by considering reasonable, adaptive management measures, as described in the Magnuson-Stevens Act and in conformance with the National Standards, the Endangered Species Act, the National Environmental Policy Act, and other applicable law. This management approach takes into account the National Academy of Science's recommendations on Sustainable Fisheries Policy.<br>As part of its policy, the Council intends to consider and adopt, as appropriate, measures that accelerate the Council's precautionary, adaptive management approach through community-based or rights-based management, ecosystem-based management principles that protect managed species from overfishing and protect the health of the entire marine ecosystem, and where appropriate and practicable increase habitat protection and bycatch constraints. All management measures will be based on the best scientific information available. Given this intent, the fishery management goal is to provide sound conservation and sustainability of the fish resources; provide socially and economically viable fisheries for the well-being of fishing communities; minimize human-caused threats to protected species; maintain a healthy marine resource habitat; and incorporate ecosystem-based considerations into management decisions.<br>This management approach recognizes the need to balance many competing uses of marine resources and different social and economic goals for sustainable fishery management, including protection of the long-term health of the ecosystem and the optimization of yield from its fish resources. This policy will use and improve upon the Council's existing open and transparent process of public involvement in decision-making. |

## 1.2 Summary of Management Measures

The management measures that govern the Arctic Management Area are summarized in Table ES-2.

Pursuant to Title II of the Magnuson-Stevens Act, there is no allowable level of foreign fishing for the fisheries covered by this FMP. While fishing vessels and fish processors of the U.S. have the capacity to harvest and process up to the level of optimum yield of all species subject to other Council FMPs, Council policy as articulated in this Arctic FMP is to prohibit commercial harvests of all fish resources of the Arctic Management Area. Management of commercial harvest of red king crab in the Chukchi Sea of the size and scope of the historic fishery in the geographic area where the fishery has historically occurred is exempted from this FMP and deferred to the State of Alaska. A description of the specific red king crab fishery that is exempted from this FMP is provided in Appendix A to this FMP.

## Table ES-2 Summary of Management Measures for the Arctic

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| **Management Area** | All marine waters in the U.S. Exclusive Economic Zone of the Chukchi and Beaufort Seas from 3 nautical miles offshore the coast of Alaska or its baseline to 200 nautical miles offshore, north of Bering Strait (from Cape Prince of Wales to Cape Dezhneva) and westward to the U.S./Russia Convention Line of 1867 and eastward to the U.S./Canada maritime boundary.<br>**Subareas:** While two contiguous seas (Chukchi and Beaufort) of the Arctic Ocean are referenced, this FMP does not divide the Arctic into subareas. |
| **Stocks** | All stocks of finfish, marine invertebrates, and other fish resources in the management area except salmonids, Pacific halibut, Pacific herring, whitefish, and Dolly Varden char. |
| **Maximum Sustainable Yield (MSY)** | The process for specifiying MSY in the Arctic Management Area is described in Section 3.4 of this FMP. |
| **Optimum Yield (OY)** | The process for specifying OY in the Arctic Management Area, is described in Section 3.4 of this FMP. |
| **Procedure to set Total Allowable Catch (TAC)** | In the future, if fisheries develop in the Arctic Management Area, measures that establish TAC will be specified following the procedures described in Section 3.4 of this FMP. |
| **Apportionment of TAC** | In the future, if fisheries develop in the Arctic Management Area, TAC may be apportioned by the Council based on criteria specified by the Council at that time. Currently, no TAC is specified for any fish resource of the Arctic Management Area.. |
| **Attainment of TAC** | In the future, if fisheries develop in the Arctic Management Area, measures that determine the attainment of TAC will be specified following the procedures described in Section 3.4 of this FMP. |
| **Permit** | Fishing permits may be authorized, for limited experimental purposes (exempted fishing permits), for the target or incidental harvest of fish resources that would otherwise be prohibited. |
| **Authorized Gear** | Gear types authorized by this FMP will be determined in the future, if fisheries develop in the Arctic Management Area, and then defined in regulations. |
| **Time and Area Restrictions** | No time and area restriction measures are established in this FMP. |
| **Prohibited Species** | In the future, if fisheries develop in the Arctic Management Area, prohibited species are Pacific halibut, Pacific herring, Pacific salmon and steelhead, Dolly Varden char, red king crab, and whitefishes. These prohibited species must be returned to the sea with a minimum of injury except when their retention is authorized by other applicable law. |
| **Prohibited Species Catch (PSC) Limits** | No PSC catch limits or other restrictions are established in this FMP. If fisheries develop in the future in the Arctic Management Area, PSC limits will be prescribed by the Council at that time. |
| **Retention and Utilization Requirements** | No retention or utilization requirements are established in this FMP. |
| **Community Development Quota (CDQ) Multispecies Fishery** | No CDQ program is established for the Arctic Management Area. |
| **Flexible Authority** | In the future, if fisheries develop in the Arctic Management Area, the Regional Administrator of NMFS is authorized to make inseason adjustments through gear modifications, closures, or fishing area/quota restrictions, for conservation reasons, to protect identified habitat problems, or to increase vessel safety. |
| **Recordkeeping and Reporting** | In the future, if fisheries develop in the Arctic Management Area, recordkeeping that is necessary and appropriate to determine catch, production, effort, price, and other information necessary for conservation and management may be required. This may include the use of catch and/or product logs, product transfer logs, effort logs, or other records as specified in regulations. Recordkeeping and reporting requirements will be specified as part of any exempted fishing permits issued for fishing activities in the Arctic Management Area. |

**Table ES-2 Summary of Management Measures for the Arctic**

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| **Observer Program** | In the future, if fisheries develop in the Arctic Management Area, U.S. fishing vessels that catch groundfish in the EEZ, or receive groundfish caught in the EEZ, and shoreside processors that receive groundfish caught in the EEZ, will be required to accommodate NMFS-certified observers as specified in regulations, in order to verify catch composition and quantity, including at-sea discards, and collect biological information on marine resources. |
| **Monitoring and Enforcement** | In the future, if fisheries develop in the Arctic Management Area, monitoring and enforcement measures necessary and appropriate to ensure conservation of Arctic fish stocks may be required. This may include the use of observers, electronic logbooks, VMS, or other measures that will be specified in regulations. Currently, commercial fisheries, other than the red king crab fishery described in Appendix A, are prohibited, and enforcement of the fishery closure of the Arctic Management Area will be by the U.S. Coast Guard and NOAA Office of Law Enforcement. |
| **Evaluation and Review of the FMP** | The Council will maintain a continuing review of the fish resources managed under this FMP, and all critical components of the FMP will be reviewed periodically.<br>**Management Policy**: Objectives in the management policy statement will be reviewed every five years or as determined necessary by the Council.<br>**Essential Fish Habitat (EFH)**: The Council will conduct a complete review of EFH once every 5 years, and in between these reviews the Council will solicit proposals on Habitat Areas of Particular Concern if fisheries develop, and/or conservation and enhancement measures to minimize potential adverse effects from fishing may be considered. |

## 1.3 Organization of the FMP

This FMP is organized into six chapters. Chapter 1 contains an introduction to the FMP, and Chapter 2 describes the policy and management objectives of the FMP.

Chapter 3 contains the conservation and management measures that regulate Arctic fish resource management. Two options are described; the Council will select one or a combination of these options for setting conservation and management measures. Sections 3.1 through 3.5 outline the details of the two options including procedures for determining harvest levels for the species and maximum sustainable yield and optimum yield specifications. Sections 3.6 and 3.7 describe overfishing criteria and procedures for setting TAC, respectively. Sections 3.8 to 3.11 contain permit and participation, gear, time and area, and catch restrictions information. No share-based programs are established for the Arctic Management Area (Section 3.12). Measures that allow flexible management authority are addressed in Section 3.13, and Section 3.14 designates monitoring and reporting requirements. Section 3.15 describes the schedule and procedures for review of the FMP or FMP components.

Chapter 4 contains a description of the Arctic's fish resources and their habitat (including essential fish habitat definitions), current fishing activities, the economic and socioeconomic characteristics of current fisheries and communities, and ecosystem characteristics. Additional descriptive information is also contained in the appendices. Section 4.4 provides a description of the Arctic ecosystem and interrelationships among the physical and biological components. It includes a discussion of potential climate change effects on the North Pacific and Arctic region. Chapter 5 specifies the relationship of the FMP with applicable law and other fisheries. Chapter 6 provides a fishery impact statement. Chapter 7 references additional sources of material about the Arctic, and includes the bibliography.

Appendices to the FMP include supplemental information. Appendix A describes the characteristics of the red king crab fishery exempted from this FMP and deferred to the State of Alaska. Appendix B contains descriptions of essential fish habitat and a discussion of adverse effects on essential fish habitat. Appendix C contains maps of EFH. Additional information about the Arctic Management Area, including its fish, bird, and marine mammal species, and an ecosystem description, are provided in the October 2008 Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis (EA/RIR/IRFA) for this FMP.

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# List of Tables and Figures

# Acronyms and Abbreviations Used in the FMP

| | |
|---|---|
| **‘** | minutes |
| **%** | percent |
| **ABC** | acceptable biological catch |
| **ADF&G** | Alaska Department of Fish and Game |
| **AFA** | American Fisheries Act |
| **AFSC** | Alaska Fisheries Science Center (of the National Marine Fisheries Service) |
| **AI** | Aleutian Islands |
| **ALT** | Alaska Local Time |
| **AP** | North Pacific Fishery Management Council’s Advisory Panel |
| ***B*** | biomass |
| **BSAI** | Bering Sea and Aleutian Islands |
| $B_{x\%}$ | biomass that results from a fishing mortality rate of $F_{x\%}$ |
| **C** | Celsius or Centigrade |
| **C.F.R.** | Code of Federal Regulations |
| **CDP** | community development plan |
| **CDQ** | community development quota |
| **cm** | centimeter(s) |
| **Council** | North Pacific Fishery Management Council |
| **E.** | East |
| **EEZ** | exclusive economic zone |
| **EFH** | essential fish habitat |
| **ENSO** | El Nino - Southern Oscillation |
| **ESA** | Endangered Species Act |
| ***F*** | fishing mortality rate |
| **FMP** | fishery management plan |
| **FOCI** | Fisheries-Oceanography Coordinated Investigations |
| **ft** | foot/feet |
| $F_{X\%}$ | fishing mortality rate at which the SPR level would be reduced to X% of the SPR level in the absence of fishing |
| **GIS** | Geographic Information System |
| **GMT** | Greenwich mean time |
| **HAPC** | habitat area of particular concern |
| **IPHC** | International Pacific Halibut Commission |
| **kg** | kilogram(s) |
| **km** | kilometer(s) |
| **lb** | pound(s) |
| **m** | meter(s) |
| **M** | natural mortality rate |
| **Magnuson-Stevens Act or MSA** | Magnuson-Stevens Fishery Conservation and Management Act |
| **mm** | millimeter(s) |
| **MMPA** | Marine Mammal Protection Act |
| **MSY** | maximum sustainable yield |
| **mt** | metric ton(s) |
| **N.** | North |
| **NMFS** | National Marine Fisheries Service |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NPFMC** | North Pacific Fishery Management Council |
| **OFL** | overfishing level |
| **OY** | optimum yield |
| **PBR** | potential biological removal |
| **pdf** | probability density function |
| **ppm** | part(s) per million |
| **ppt** | part(s) per thousand |
| **PRD** | Protected Resources Division (of the National Marine Fisheries Service) |
| **PSC** | prohibited species catch |
| **S.** | South |
| **SAFE** | Stock Assessment and Fishery Evaluation |
| **SPR** | spawning per recruit |
| **SSC** | North Pacific Fishery Management Council’s Scientific and Statistical Committee |
| **TAC** | total allowable catch |
| **TALFF** | total allowable level of foreign fishing |
| **U.S.** | United States |
| **U.S.C.** | United States Code |
| **USFWS** | United States Fish and Wildlife Service |
| **U.S. GLOBEC** | United States Global Ocean Ecosystems Dynamics |
| **USSR** | Union of Soviet Socialist Republics |
| **W.** | West |
| **°** | degrees |

# Chapter 1 Introduction

This chapter contains a description of the fishery management unit covered by the FMP and addresses foreign fishing and processing in the Arctic Management Area.

## 1.1 Fishery Management Unit

This Fishery Management Plan (FMP) governs commercial fisheries or commercial harvests of fish resources of the Chukchi Sea and Beaufort Sea - the Arctic Management Area. The geographic extent of the FMP management unit is all marine waters in the U.S. Exclusive Economic Zone of the Chukchi and Beaufort Seas from 3 nautical miles offshore the coast of Alaska or its baseline to 200 nautical miles offshore, north of Bering Strait (from Cape Prince of Wales to Cape Dezhneva) and westward to the U.S./Russia Convention Line of 1867 and eastward to the U.S./Canada maritime boundary (Figure 1-1).

Figure 1-1 The Arctic Management Area.


The FMP covers management of all fish[2], as defined by the Magnuson-Steven Act, except salmonids, Pacific halibut, Pacific herring, whitefish, and Dolly Varden char. In terms of geographic fish resource management, the Arctic Management Area includes the Chukchi Sea and Beaufort Sea without a distinct boundary between these two contiguous seas of the Arctic Ocean. Red king crab management, for a

[2] finfish, marine invertebrates, and other marine plant and animal life, other than marine mammals and birds

fishery of the size and scope and geographic location of the historic red king crab fishery as described in Appendix A, is exempted from this FMP and deferred to the State of Alaska. The Council closes the Arctic Management Area to commercial fishery development until such time in the future that sufficient information is available with which to initiate a planning process for commercial fishery development. Criteria the Council will consider in the planning process for opening a fishery in the Arctic Management Area are provided in Chapter 3.

## 1.2 Foreign Fishing

Title II of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) establishes the criteria for the regulation of foreign fishing within the U.S. EEZ. These regulations are published in 50 CFR 600. The regulations provide for the setting of a total allowable level of foreign fishing (TALFF) for species based on the portion of the optimum yield that will not be caught by U.S. vessels. At the present time, no TALFF is available for any fisheries covered by this FMPand no processing capacity if needed to support commercial fishing. If in the future fisheries develop in the Arctic Management Area, the Council will specify TALFF and foreign processing at that time..

# Chapter 2 Management Policy and Objectives

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act or MSA) is the primary domestic legislation governing management of the nation's marine fisheries. In 1996, the United States Congress reauthorized the Magnuson-Stevens Act to include, among other things, a new emphasis on the precautionary approach in U.S. fishery management policy. The Magnuson-Stevens Act was reauthorized again in 2007 (PL 109-479). The Magnuson-Stevens Act contains ten national standards, with which all fishery management plans (FMPs) must conform and which guide fishery management. The national standards are listed in Section 2.1, and provide the primary guidance for the management of U.S. fisheries.

Under the Magnuson-Stevens Act, the North Pacific Fishery Management Council (Council) is authorized to prepare and submit to the Secretary of Commerce for approval, disapproval or partial approval, a FMP and any necessary amendments, for each fishery under its authority that requires conservation and management. The Council conducts public hearings so as to allow all interested persons an opportunity to be heard in the development of FMPs and amendments, and reviews and revises, as appropriate, the assessments and specifications with respect to the optimum yield from each fishery (16 U.S.C. 1852(h)).

The Council has developed a management policy and objectives to guide its development of management recommendations to the Secretary of Commerce for the Arctic Management Area. This management approach is described in Section 2.2.

## 2.1 National Standards for Fishery Conservation and Management

The Magnuson-Stevens Act, as amended, sets out ten national standards for fishery conservation and management (16 U.S.C. § 1851), with which all fishery management plans must be consistent.

1. Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.
2. Conservation and management measures shall be based upon the best scientific information available.
3. To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.
4. Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be A) fair and equitable to all such fishermen; B) reasonably calculated to promote conservation; and C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.
5. Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.
6. Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.
7. Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.
8. Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into

account the importance of fishery resources to fishing communities in order to A) provide for the sustained participation of such communities, and B) to the extent practicable, minimize adverse economic impacts on such communities.

9. Conservation and management measures shall, to the extent practicable, A) minimize bycatch and B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.

10. Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

## 2.2 Management Approach for Arctic Fisheries

The Council's policy is to apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, proactively rather than reactively, to ensure the sustainability of fishery resources and associated ecosystems for the benefit of future, as well as current, generations. The productivity of the North Pacific ecosystem is acknowledged to be among the highest in the world. For the past 30 years, the Council management approach has incorporated forward looking conservation measures that address differing levels of uncertainty. This management approach has in recent years been labeled the precautionary approach. Recognizing that potential changes in productivity may be caused by fluctuations in natural oceanographic conditions, fisheries, and other, non-fishing activities, the Council intends to continue to take appropriate measures to insure the continued sustainability of the managed species. It will carry out this objective by considering reasonable, adaptive management measures, as described in the Magnuson-Stevens Act and in conformance with the National Standards, the Endangered Species Act, the National Environmental Policy Act, and other applicable law. This management approach takes into account the National Academy of Science's recommendations on Sustainable Fisheries Policy.

As part of its policy, the Council intends to consider and adopt, as appropriate, measures that accelerate the Council's precautionary, adaptive management approach through community-based or rights-based management, ecosystem-based management principles that protect managed species from overfishing and protect the health of the entire marine ecosystem, and where appropriate and practicable increase habitat protection and bycatch constraints. All management measures will be based on the best scientific information available. Given this intent, the fishery management goal is to provide sound conservation and sustainability of the fish resources; provide socially and economically viable fisheries for the well-being of fishing communities; minimize human-caused threats to protected species; maintain a healthy marine resource habitat; and incorporate ecosystem-based considerations into management decisions.

This management approach recognizes the need to balance many competing uses of marine resources and different social and economic goals for sustainable fishery management, including protection of the long-term health of the ecosystem and the optimization of yield from its fish resources. This policy will use and improve upon the Council's existing open and transparent process of public involvement in decision-making.

### 2.2.1 Management Objectives

Adaptive management requires regular and periodic review. Objectives identified in this policy statement will be reviewed periodically by the Council. The Council will also review, modify, eliminate, or consider new issues, as appropriate, to best carry out the goals and objectives of this management policy.

To meet the goals of this overall management approach, the Council and NMFS will seek to maximize the overall long-term benefit to the nation of Arctic fish resources by coordinated Federal and State management. In this Arctic FMP, management of a red king crab fishery as described in Appendix A is exempted and deferred to the State of Alaska. The Council would follow these management objectives for the development of a fishery:

1. Biological Conservation Objective. *Ensure the long-term reproductive viability of fish populations, by: (a) preventing overfishing and rebuilding depleted stocks by adopting conservative harvest levels using adaptive management to develop harvest limits; (b) adopting procedures to adjust acceptable biological catch levels as necessary to account for uncertainty and ecosystem factors; (c) protecting the integrity of the food web by accounting for, and controlling bycatch mortality for target, prohibited species catch, and non-commercial species; (d) avoiding impacts to seabirds and marine mammals; and (e) incorporating ecosystem-based considerations into fishery management decisions, as appropriate.*

2. Economic and Social Objective. *Maximize economic and social benefits to the nation over time by: (a) promoting conservation while providing for optimum yield in terms of the greatest overall benefit to the nation with particular reference to food production, and sustainable opportunities for recreational, subsistence, and commercial fishing participants and fishing communities; (b) promoting management measures that, while meeting conservation objectives, are also designed to avoid significant disruption of existing social and economic structures; (c) promoting fair and equitable allocation of identified available resources in a manner such that no particular sector, group or entity acquires an excessive share of the privileges; and (d) promoting increased safety at sea.*

3. Gear Conflict Objective. *Minimize gear conflict among fisheries.*

4. Habitat Objective. *Preserve the quality and extent of suitable habitat by reducing or avoiding impacts to habitat where practicable.*

5. Vessel Safety Objective. *Include vessel safety considerations in the development of fisheries management measures, including temporary adjustments to the fishery to allow access, after consultation with the U. S. Coast Guard and fishery participants, for vessels that are otherwise excluded because of weather or ocean conditions causing safety concerns while ensuring not adverse effect on conservation in other fisheries or discrimination among fishery participants..*

6. Due Process Objective. *Ensure that access to the regulatory process and opportunity for redress are available to interested parties.*

7. Research and Management Objective. *Provide fisheries research, data collection, and analysis to ensure a sound information base for management decisions.*

8. Alaska Native Consultation Objective: *Incorporate local and traditional knowledge in fishery management and encourage Alaska Native participation and consultation in fishery management*.

9. Enforceability Objective: *Cooperate and coordinate management and enforcement programs with the Alaska Board of Fish, Alaska Department of Fish and Game, and Alaska Fish and Wildlife Protection, the U.S. Coast Guard, NMFS Enforcement, International Pacific Halibut Commission, Federal agencies, and other organizations to meet conservation requirements; promote economically healthy and sustainable fisheries and fishing communities; and maximize efficiencies in management and enforcement programs through continued consultation, coordination, and cooperation*.

10. Marine Mammal and Seabird Objective: *Cooperate and coordinate with the U. S. Fish and Wildlife Service and NMFS for the management and conservation of Arctuc marine mammal and seabird species to ensure fisheries management includes conservation of these species in the Arctic*

### 2.2.2 Criteria for Opening a Fishery in the Arctic (NOTE – the following assumes a blend of elements in both Options 1 and 2)

Until information is available to develop a sustainable fisheries management program, the Council prohibits commercial fisheries in the Arctic Management Area. A small red king crab fishery may have previously occurred in a localized area of the southeastern Chukchi Sea, as described in Appendix A; the Council exempts management of this red king crab fishery in this FMP and defers management of this fishery to the State of Alaska.

The Council will consider the following criteria for opening a new fishery:

A. The Council will initially require a plan for a new fishery that will ensure resource conservation, minimize impacts on other users of the area, complies with the Magnuson-Stevens Act and its National Standards, complies with other applicable laws and orders, and provides net positive economic benefits.

B. Any proposed fishing in the Arctic would be organized into one or more target fisheries. In most cases, the target would be a single species, though there may be situations where designating several species as a mixed species target may be more appropriate. Establishing a target fishery may require that the species be transferred from the ecosystem component category to the target species category.

C. The Council will consider designating a new target fishery in the Arctic Management Area upon receiving a petition from the public, or a recommendation from NMFS or the State of Alaska. The Council will initiate a planning process to evaluate information in the petition and other information concerning the proposed target fishery. The Council will require a fishery development analysis to ensure the best available science is used to move a species from unfished status to full fishery development. This analysis could be included in any NEPA and economic analysis required to support FMP amendments. The fishery development analysis will contain the following information:
:

- A review of the life history of the target species
- A review of available information on any historic harvest of the species, commercial, sport or subsistence
- An analysis of customary and traditional subsistence use patterns and evaluation of impacts on existing users
- Initial estimates of stock abundance ($B_0$) and productivity (M) sufficiently reliable to apply a Tier 5 control rule
- Evaluation of the vulnerability (susceptibility and productivity) of species that will be caught as bycatch in the target fishery.
- Evaluation of potential direct and indirect impacts on endangered species
- Evaluation of ecosystem/trophic level effects
- Evaluation of potential impacts on essential fish habitat, including biogenic habitat
- A plan for inseason monitoring of the proposed fishery
- A plan for collecting fishery and survey data sufficient for a Tier 3 assessment of the target species within a defined period
- Identification of specific management goals and objectives during the transition from unexploited stock to exploited resource
- Descriptions of proposed fishery management measures and justification for each
- Proposed regulations to implement the management approach

D. The analysis described above will be reviewed by the Council, and if appropriate the Council will initiate an environmental review consistent with NEPA and MSA and proceed through the process of amending this Arctic FMP, including appropriate initial review, public review, and final review and rulemaking and completion of the FMP amendment process as specified in the MSA and NOAA guidelines.

E. The Council may authorize the proposed fishery consistent with measures specified in the proposed FMP amendment and adopt additional measures it believes are necessary for stock conservation, fishery sustainability, and allocation considerations.

F. The Council may require onboard observers on fishing vessels, shoreside processing facilities, or at harvest sites if non-vessel platforms (i.e., ice) are used for harvesting. The Council also may require additional research associated with the new fishery, other monitoring programs, recordkeeping and reporting requirements, and periodic review of the fishery's performance relative to requirements of the MSA and other applicable law.

# Chapter 3 Conservation and Management Measures Note: this section will be revised with the selection of an option.

**Overview of the two options**

Two options for structuring the FMP are presented. Briefly, Option 1 focuses on following the steps for developing an FMP prescribed by the MSA, while Option 2 focuses on providing protection for large numbers of species by including them in an "ecosystem component" of the FMP. The FMP does not cover salmonids, whitefish, Dolly Varden char, Pacific halibut, or Pacific herring, which are listed as prohibited species in this FMP under option 2. Conservation and management measures contained in this FMP apply exclusively to domestic fishing activities. No foreign harvesting or processing of any fish resource is authorized in the Arctic Management Area. The features of option 1 and option 2 are summarized in table 3.1 and further explained in sections 3.4 and 3.5.

*Option 1*

Option 1 begins by identifying those fisheries with non-negligible probability of developing within the foreseeable future, and treats these as the fisheries that the plan is intended to manage. The fisheries for snow crab (*Chionoecetes opilio*), Arctic cod, and saffron cod are thereby identified as the subject of the FMP. If unanticipated fisheries develop in the future, Option 1 requires that the plan be amended to incorporate them. The option then proceeds to specify MSY, status determination criteria (both MFMT and MSST), OY, ACL, and ACT for the three managed fisheries. The OY specification is the result of a series of analyses in which possible reductions from MSY are examined, considering a variety of socioeconomic factors such as uncertainty, non-consumptive value, and costs, and ecological factors such as protection of keystone species. The result of these analyses is that OY is specified for each of the three fisheries as an annual *de minimis* catch, sufficient only to account for bycatch in subsistence fisheries for other species. However, Option 1 also contains a provision to the effect that, if new scientific information becomes available suggesting that the conditions estimated or assumed in the process of making this specification are no longer valid, a new analysis should be conducted. Because OY is virtually zero for every fishery with a non-negligible probability of developing within the foreseeable future, Option 1 protects all species in the ecosystem, even though it applies to the fisheries for only three target species.

*Option 2*

Option 2 begins by making species, rather than fisheries, the subject of the FMP. All species of Arctic finfish and marine invertebrates are included in the FMP. However, no fisheries are identified in the FMP. Instead, the species are included in the FMP by virtue of being members of an "ecosystem component" or a prohibited species category. Although Option 2 would not apply to any fisheries initially, this option contains a detailed procedure whereby the FMP would be amended to apply to one or more fisheries in the future.

The ecosystem component (EC) concept was introduced in the proposed rule for revising the National Standard 1 guidelines. According to the proposed rule (§600.310(d)(5)), EC species are not considered part of the fishery(ies) managed by an FMP, and they do not require specification of reference points such as MSY and OY, although a Council should consider measures to minimize bycatch thereof. Option 2 would not specify MSY, OY ACLs, and ACTs, for EC species or prohibited species. Under Option 2, these reference points would be developed in the future for a target species in parallel with the definitions in the BSAI and GOA groundfish FMPs. Option 2 prescribes a tier system for setting $F_{OFL}$ and $F_{ABC}$ for target species based on available information.

## Summary of Options for Conservation and Management Measures

| Option | Identification of FMP fisheries /species | Current FMP Fisheries | MSY | OY | Status Determination Criteria | | ACL | ACT |
|---|---|---|---|---|---|---|---|---|
| | | | | | MFMT | MSST | | |
| 1 | Creates an algorithm to identify FMP fisheries, which are fisheries with a non-negligible probability of developing as a significant commercial enterprise in the future. | Snow crab<br>Arctic cod<br>Saffron cod | Contains formula for setting MSY and specifies MSY values for the three FMP fisheries. | OY is specified as *de minimis* catch to only allow for bycatch in subsistence fisheries for other species. Provides methods to calculate OY from the MSY. | MFMT= $F_{MSY}$<br><br>Specifies values for $F_{MSY}$ for FMP fisheries. | MSST= $B_{MSY}$<br><br>Specifies values for $B_{MSY}$ for FMP fisheries. | ACL=OFL<br><br>$F_{OFL}=F_{MSY}$ | ACT=0 |
| 2 | Creates 4 categories of FMP species, identifies species in each category, and creates a process for moving species from the ecosystem component (EC) category to the Target Species category. | None – all species are either in the prohibited species or EC species categories. | MSY not specified (or required) for EC species. Provides 3 approaches for a system-level MSY. | Not specified but would be developed for a Target Species in parallel with the definitions in the BSAI and GOA groundfish FMPs. | Prescribes a tier system for setting $F_{OFL}$ and $F_{ABC}$ for Target Species based on available information.<br><br>Not applicable to EC or prohibited species. | | Not specified but would be developed for a Target Species in parallel with the definitions in the BSAI and GOA groundfish FMPs. | Not specified but would be developed for a Target Species in parallel with the definitions in the BSAI and GOA groundfish FMPs. |

## 3.1 Areas Involved

The FMP and its management regime governs fishing by United States (U.S.) vessels in the Arctic Management Area described in Section 3.1.1, and for those stocks listed in Sections 1.1 and 3.3. Fishing by foreign vessels is not permitted in the Arctic Management Area.

### 3.1.1 Management Area

The Arctic Management Area is all marine waters in the U.S. Exclusive Economic Zone of the Chukchi and Beaufort Seas from 3 nautical miles offshore the coast of Alaska or its baseline to 200 nautical miles offshore, north of Bering Strait (from Cape Prince of Wales to Cape Dezhneva) and westward to the U.S./Russia Convention Line of 1867 and eastward to the U.S./Canada maritime boundary (Figure 1-1).

Two contiguous seas of the Arctic Ocean are referenced in this FMP, the Beaufort Sea and the Chukchi Sea. While oceanographically different, both are poorly understood and no clear boundary between these seas can be defined; therefore,, this FMP does not divide the Arctic into subareas.

## 3.2 Definition of Terms

The following terms are definitions adopted by the Council for all fisheries in the Alaskan EEZ.

Maximum sustainable yield (MSY) is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions.

Optimum yield (OY) is the amount of fish which–

a) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems;

b) is prescribed as such on the basis of the MSY from the fishery, as reduced by any relevant economic, social, or ecological factor; and

c) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery.

Overfishing level (OFL) is a limit reference point set annually for a stock or stock complex during the assessment process, as described in Section 3.2.4, Overfishing criteria. Overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis. Operationally, overfishing occurs when the harvest exceeds the OFL.

Acceptable biological catch (ABC) is an annual sustainable target harvest (or range of harvests) for a stock or stock complex, determined by a Plan Team and the Scientific and Statistical Committee during the assessment process. It is derived from the status and dynamics of the stock, environmental conditions, and other ecological factors, given the prevailing technological characteristics of the fishery. The target reference point is set below the limit reference point for overfishing.

Total allowable catch (TAC) is the annual harvest limit for a stock or stock complex, derived from the ABC by considering social and economic factors.

## 3.3 Data Sources and Abundance Estimates

### 3.3.1 Background

The Arctic FMP will be based on the best available information. The following is a summary of the information analyzed to establish initial guidance on management of Arctic fisheries.

In 2008, data were scarce for estimating the abundance and biomass of Arctic fishes. Since the 1950s, several exploratory surveys have been conducted in the Chukchi and Beaufort Seas. Of these, data for only two were available for analysis in the databases maintained by the Resource Assessment and Conservation Engineering division of the Alaska Fisheries Science Center (AFSC). In 1976, a bottom-trawl survey of the southeastern Chukchi Sea was conducted by the Northwest and Alaska Fisheries Center (Wolotira et al. 1977; Fig. 3.1). In 1990 and 1991, a multidisciplinary study of the northeastern Chukchi Sea was conducted by the School of Fisheries and Ocean Sciences of the University of Alaska Fairbanks (Barber et al. 1994) that included a comprehensive bottom-trawl survey (Barber et al. 1997; Fig. 3.1). Both of these studies used the same gear, a NMFS standard 83-112 survey otter trawl with a 25.2 m head rope and a 34.1 m footrope. The 1990 and 1991 surveys employed electronic net mensuration gear to obtain data on actual net width.

The 1990 survey was used to produce biomass estimates for the analysis in this FMP for three reasons: 1) it had the widest spatial coverage and greatest amount of available data of any of the surveys; 2) it was more recent than the 1976 survey; 3) the availability of data on net width provided more accurate estimates. Data from 1976 and 1991 are presented below to provide a description of temporal and spatial variability in the Alaskan Arctic. The Chukchi and Beaufort Seas are very different oceanographically as well as biologically, so the two areas were treated separately for this analysis. Because no usable survey data were available for the Beaufort Sea, this analysis is for the Chukchi Sea only. A NMFS exploratory survey was conducted in the Beaufort Sea in August 2008 and data from that study will be incorporated into this FMP as they become available.

### 3.3.2 Biomass estimates for the Chukchi Sea

Catch-per-unit-effort (CPUE) for each station of the survey was calculated by the swept-area method. The catch weight for each species in each haul was divided by the area swept during the haul (distance hauled X measured net width) to produce an estimate of kg/km$^2$. Values for all hauls within the analysis area were averaged to produce an area-wide CPUE estimate for each species. This mean value was multiplied by the total analysis area of the Chukchi to produce an estimate of total biomass.

Only part of the Alaskan Chukchi Sea area was included in this analysis. Fishing is likely to occur only on the continental shelf and upper continental slope, and is unlikely in very shallow nearshore areas. Therefore, the analysis area was limited to waters where bottom depths ranged from 20 to 500 m (Fig. 3.1). The analysis area was also bounded by Bering Strait and the U.S. borders with Russia and Canada. Bathymetry data from the International Bathymetry Chart of the Arctic Ocean and an Albers Equal Area projection were used in this analysis. The total analysis area for the Chukchi and Beaufort Seas was 257,329 km$^2$. Although a precise boundary between the two seas is difficult to establish, the Beaufort section of this area was approximately 15% of the total. To obtain the area of the Chukchi section, the total area was multiplied by 0.85 to yield an analysis area of 218,730 km$^2$.

### 3.3.3 Temporal variability: 1990 vs. 1991

Eight of the stations sampled in 1990 were sampled again in 1991, using the same gear (Figure 3.1). Biomass data from the 1991 study were not available for analysis; however relative abundance data for these eight stations were obtained from the literature (Barber et al. 1997). The density (number of fish/$km^2$) for the eight stations was averaged to produce annual estimates of relative abundance for a subset of species (Table 3.1). The comparison between 1990 and 1991 suggests there is substantial interannual variability in fish abundance. Most of the listed species were more abundant in 1990, and several species caught in 1990 were not observed in 1991. Three species were more abundant in 1991. Only warty sculpin abundance was similar between years.

### 3.3.4 Temporal and spatial variability: 1976 vs. 1990

Biomass data were available from the 1976 survey and were used to compare biomass of species groups between 1976 and 1990. The fishing gear used in both surveys was the same (Wolotira et al. 1977), but the 1976 survey did not provide measurements of actual net width. The average net width in the 1990 survey (15.276 m) was used to calculate CPUE for the 1976 survey. The two surveys did not cover the same area: the 1976 survey focused on the southeastern Chukchi, while the 1990 survey covered the northeastern Chukchi (Fig. 3.1). Species groups for commercial crabs (snow, red king, and blue king), mollusks, and shrimps were analyzed as well as the major fish species groups.

As in the interannual comparison, biomass estimates varied considerably between the two surveys (Table 3.2). The biomass of most species groups was greater in 1990, as was the total fish biomass. There was no spatial overlap between the two surveys. As a result, it is difficult to know whether the differences in the biomass estimates between the two years are a result of temporal or spatial variability. It is likely that the differences are a result of both, which underscores the difficulty of estimating species biomass for this region.

### 3.3.5 Chukchi Sea snow crab size composition

It should be noted that snow (opilio) crabs in Arctic Alaska appear to be much smaller than snow crabs in the Bering Sea. During the 1991 survey of the northeastern Chukchi Sea (Barber et al. 1994; see Figure 3.1 for station location), snow crab carapace width varied with latitude. Carapace width of females averaged 35 mm and 45 mm at two stations in the southern part of the survey area, and 33 mm at the survey's northernmost station. Mean carapace width data were not available for males, but the mode of male carapace width was 50 mm in the south and 45 mm in the north. No males were observed larger than 85 mm and very few were larger than 75 mm. This finding suggests that most of the Arctic crab may be smaller than the minimum size limit for retention of male snow crab in the Bering Sea fishery (78 mm) and well below the minimum size preferred by the snow crab market (101 mm; Turnock and Rugolo 2008).

### 3.3.6 Forage fish species

The Council's intent is to prohibit commercial fishing on forage fish species. Forage fish are prey for other marine ecosystem fauna including fish, birds, and marine mammals. Both options discussed in the following pages include the prohibition of fishing for forage species, either explicitly (Option 1) or implicitly (Option 2). Many of the species listed as "Ecosystem Component" species are considered prey for other fauna.

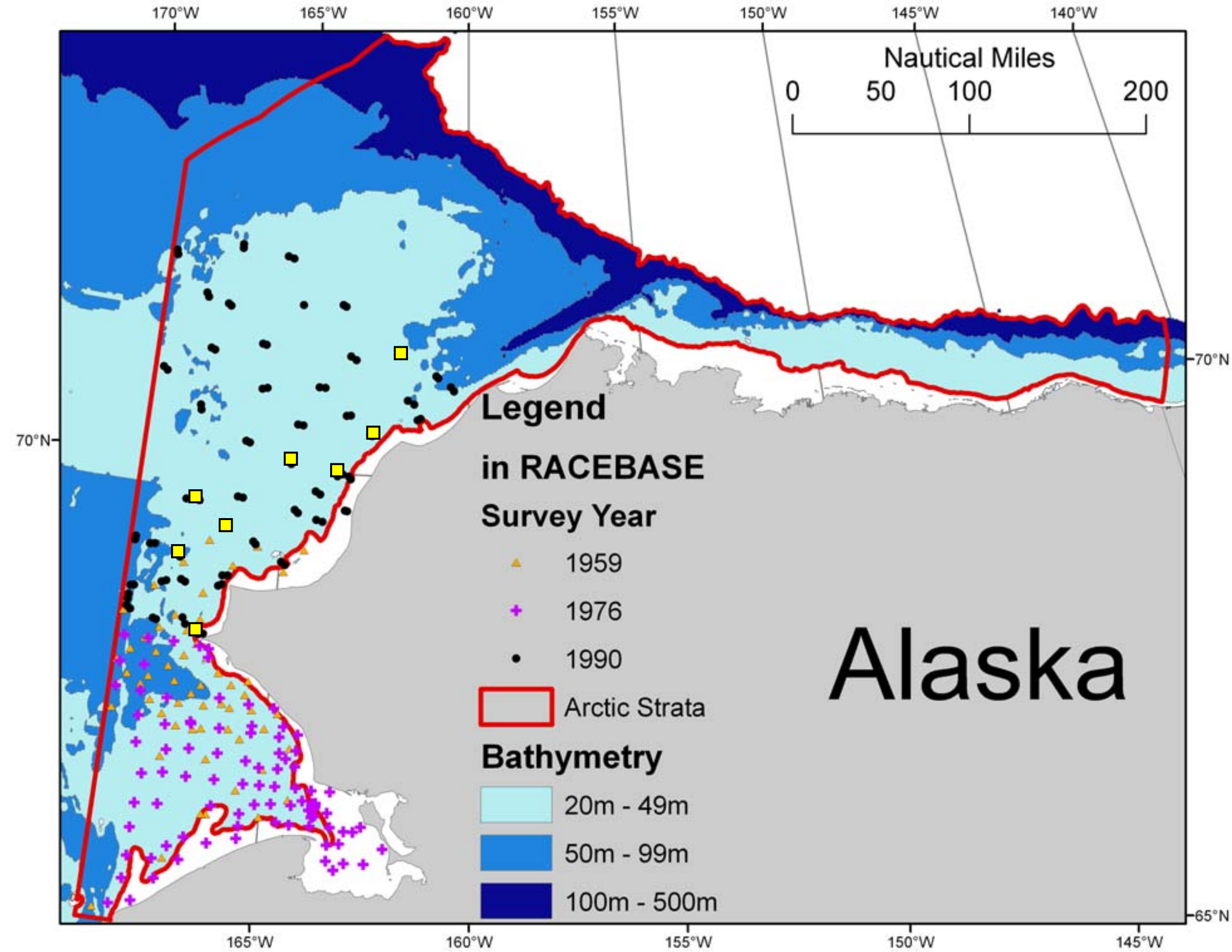


Figure 3-1 Map of the Alaskan Arctic indicating analysis area, bathymetry, and locations of survey stations. Yellow boxes indicate stations sampled in both 1990 and 1991

Table 3-1 Comparison of fish density (number of fish/$km^2$) in the Chukchi Sea between 1990 and 1991. Ratio 91/90 is the ratio produced when the 1991 values are divided by the 1990 values.

| | density (# of fish/$km^2$) | | |
|---|---|---|---|
| | 1990 | 1991 | Ratio |
| Arctic cod | 21,301 | 4,646 | 22% |
| Arctic staghorn sculpin | 364 | 803 | 221% |
| warty sculpin | 317 | 313 | 99% |
| miscellaneous sculpins | 241 | 8 | 3% |
| Bering flounder | 208 | 21 | 10% |
| marbled eelpout | 201 | 27 | 13% |
| wattled eelpout | 139 | 25 | 18% |
| Pacific herring | 137 | 0 | 0% |
| Pacific cod | 125 | 0 | 0% |
| ribbed sculpin | 64 | 83 | 130% |
| slender eelblenny | 58 | 97 | 166% |
| yellowfin sole | 50 | 0 | 0% |
| antlered sculpin | 9 | 242 | 2722% |

Table 3-2 Biomass estimates for species groups in the 1976 and 1990 surveys. Biomass is the total biomass for the Chukchi Sea analysis area described above. Catch of molluscs was not reported to species level in 1990, while it was possible to apportion the 1976 mollusc catch data to snails or bivalves. Snow crab dominated the commercial crab group in both years.

| species group | biomass (mt) | |
|---|---|---|
| | 1976 | 1990 |
| commercial crabs | 47,004 | 147,905 |
| eelpouts | 1,219 | 4,946 |
| flatfishes | 11,269 | 4,107 |
| gadids | 8,642 | 70,849 |
| greenlings | 0 | 9 |
| herrings | 13,159 | 2,874 |
| lumpsuckers | 0 | 29 |
| molluscs | | 69,600 |
| (snails) | 37,271 | |
| (bivalves) | 813 | |
| salmon | 41 | 0 |
| sand lances | 30 | 0 |
| poachers | 378 | 252 |
| pricklebacks | 317 | 269 |
| sculpins | 3,087 | 15,030 |
| shrimps | 4,022 | 6,264 |
| smelts | 4,191 | 272 |
| snailfishes | 1,604 | 557 |
| total biomass of fishes | 43,937 | 99,194 |

Table 3-3 shows the assignment of finfish and invertebrate species to categories of management in this FMP under Options 1 and 2.

Table 3-3 Initial assignment of species to categories.

| | Option 1 | | Option 2 | |
|---|---|---|---|---|
| | **Finfish** | **Invertebrates** | **Finfish** | **Invertebrates** |
| **Prohibited Species** | | | Pacific halibut<br>Pacific herring<br>Pacific salmon<br>Dolly Varden char<br>Whitefishes | Red king crab |
| **Target Species** | Arctic Cod, Saffron Cod | Tanner crab (C. opilio) | None | None |
| **Bycatch species** | | | None | None |
| **Ecosystem Component Species** | | | Arctic cod<br>Saffron cod<br>Yellowfin sole<br>Alaska plaice<br>Other Pleuronectids (flounders, plaice, dabs, turbot, sole)<br>Walleye pollock<br>Other gadids<br>Pacific ocean perch<br>Capelin<br>Rainbow smelt<br>Eulachon<br>Pacific sand lance<br>Skates<br>Sharks<br>Pholidae (gunnels)<br>Stichaedae (pricklebacks)<br>Zoarcidae (eelpouts)<br>Liparidae (snailfishes)<br>Cyclopteridae (lumpsuckers)<br>Agonidae (poachers)<br>Cottidae (sculpins)<br>Myctophidae (lanterfishes)<br>Gasterosteridae (sticklebacks)<br>Hexagrammidae (greenling) | Cephalopods<br>Blue king crab<br>Tanner crab (C. opilio)<br>Scallops |

The tier systems for specifications based on available information can be applied under either option (section 3.5.2). The specification of ACL and ACT in section 3.4.5 also may be used under either option. The following sections describe the methodologies for management under each option.

## 3.4 Option 1

### 3.4.1 Identification of target fisheries managed under the FMP

There are currently no significant commercial fisheries for groundfish or crab in the Arctic management area. Under Option 1, the FMP would be intended to apply to any fishery with non-negligible probability of developing as a significant commercial enterprise within the foreseeable future. In the event that a future fishery develops for some stock not covered by the FMP, the plan should be amended as soon as possible.

The algorithm for identifying the set of fisheries to which the plan currently applies consisted of the following steps:

1. From the most recent Economic SAFE Report (e.g. the 2007 Economic SAFE), tabulate ex-vessel price per pound from the years 2002-2006 for the following groups: pollock, Pacific cod, flatfish, rockfish, and sablefish. Convert these to metric units (dollars/kg).
2. From the most recent surveys (e.g. 2007 EBS shelf bottom trawl survey), tabulate mean CPUE (kg/ha) for each species in the above groups.
3. Calculate mean "revenue per unit effort" (RPUE) for each species encountered by the EBS survey that is also a member of one of the groups identified in Step 1 as (dollars/kg)×(kg/ha), where the average group-specific price from 2002-2006 is used as the estimator of price.
4. Sort the RPUE series obtained in Step 3; determine the lowest RPUE associated with any target fishery (about $3/ha in 2007), which is identified as the "cutoff" RPUE. This should not be taken to imply that an actual commercial vessel could operate profitably at such a rate or that an actual commercial vessel would locate its fishing activities independently of target species density (as the survey does); the minimum RPUE obtained here is simply a relative value.
5. Assess the CPUE for the Arctic. In this example the 1990 Arctic survey was used. The 1990 survey obtained catches of 119 "species" (some of these are true species, others include multiple true species, and a few are not even living organisms). If the list is restricted to species that are included in the BSAI groundfish or crab FMPs, the number of species observed in the 1990 Arctic survey drops to 52.
6. Account for species at the "tails" of their distribution. For example, of the 52 species identified in Step 5 using the 1990 survey, several may be at the tails of their respective geographic distributions; that is, they may just be minor components of populations already managed under the BSAI groundfish or crab FMPs. To focus on species that might actually have self-sustaining populations in the Arctic, eliminate all species that were observed in fewer than 10% (<8) of the hauls and have total biomass estimates of less than 1,000 t. This cuts the list of species down to 22.
7. For each of the 22 species identified in Step 6, assume that the true mean CPUE is equal to the upper 95% confidence interval of the mean (to err on the side of inclusion). Then, for each species compute the "breakeven" price needed to achieve the cutoff RPUE value (in this example the 2007 the cutoff RPUE value was $3/ha). Then, select all species with breakeven prices less than the highest price ever observed for any groundfish. For this example the period 2002-2006

was used (again, to err on the side of inclusion). In this example, this cut the list of species down to 4: snow crab (*Chionoecetes opilio*), Arctic cod (*Boreogadus saida*), saffron cod (*Eleginus gracilis*), and unidentified *Myoxocephalus* sculpins.

8. Of the species identified in Step 7, eliminate any for which markets appear to be nonexistent.
    a. Snow crab are taken in large numbers in the adjoining EBS and are a prized commercial species in that region, so they are not eliminated by this criterion.
    b. Arctic cod and saffron cod are not significant commercial species in the adjoining EBS, but this may be due largely to the fact that they are not abundant in that region. According to FishBase (Froese and Pauly 2008), both of these species are the targets of commercial fisheries in other parts of the world, so they are not eliminated by this criterion.
    c. Sculpins are not significant commercial species in the adjoining EBS, even though they are abundant in that region. With respect to the genus *Myoxocephalus* in particular, of the 17 species listed in FishBase (Froese and Pauly 2008), only two (*M. polyacanthocephalus* and *M. stelleri*) are reported as having any commercial importance whatsoever. Therefore, unidentified *Myoxocephalus* sculpins are eliminated by this criterion.

The result of the above algorithm is that the fisheries for snow crab, Arctic cod, and saffron cod are identified as those to which the plan applies.

### 3.4.2 Option 1 Specification of MSY

#### 3.4.2.1 Option 1 MSY Control Rule

The MSY control rule for these fisheries is of the "constant fishing mortality rate" form. That is, MSY for each fishery will be calculated as though the respective stock were exploited at a constant instantaneous fishing mortality rate.

##### 3.4.2.1.1 Methods

In the simple dynamic pool model of Thompson (1992, using different notation), equilibrium biomass $B$ is given by the equation

$$B(F|r) = \left[ \left( \frac{h}{M+F} \right) \left( 1 + \frac{1}{(M+F)d} \right) \right]^{1/r} \quad ,$$

where $F$ is the instantaneous fishing mortality rate, $M$ is the instantaneous natural mortality rate, $d$ is the difference between the age of maturity and the age intercept of the linear weight-at-age equation, $h$ is the scale parameter in Cushing's (1971) stock-recruitment relationship (with recruitment measured in units of biomass), and $0 \le r \le 1$ is the amount of resilience implied by the stock-recruitment relationship (equal to 1 minus the exponent).

The ratio of equilibrium biomass to equilibrium unfished biomass is given by

$$Bratio(F|r) = \left[ \left( \frac{M}{M+F} \right)^2 \left( \frac{(M+F)d+1}{(M+F)d} \right) \right]^{1/r} \quad .$$

Equilibrium (sustainable) yield is just the product of $F$ and equilibrium biomass:

$$Y(F|r) = F\,B(F|r) \quad .$$

Likewise, the ratio of equilibrium yield to equilibrium unfished biomass is given by

$$Yratio(F|r) = F\,Bratio(F|r) \quad .$$

Equilibrium yield is maximized by fishing at the following rate:

$$F_{MSY}(r) = \left(\frac{M}{2(1-r)}\right)\left(1 - \frac{2-r}{M\,d} + \sqrt{\left(\frac{2-r}{M\,d}\right)^2 + \frac{4-6r}{M\,d} + 1}\right) - M \quad .$$

If it is assumed that the area-swept biomass estimate from the 1990 survey represents equilibrium unfished biomass $B_0$, an estimate of the MSY stock size $B_{MSY}$ can be obtained as

$$B_{MSY} = Bratio(F_{MSY}(r)|r)\,B_0 \quad ,$$

and an estimate of MSY can be obtained as

$$MSY = Yratio(F_{MSY}(r)|r)\,B_0 \quad .$$

Application of the above equations requires an estimate of the resilience $r$. Typically, this parameter (or its analogue, depending on the assumed form of the stock-recruitment relationship) is very difficult to estimate in a stock assessment. In the case where no stock assessment even exists, it is necessary to assume a value on the basis of theory. As noted by Thompson (1993), in order for $F_{MSY}$ and its commonly suggested proxies $M$, $F_{0.1}$, and $F_{35\%}$ all to be equal, a necessary (but not sufficient) condition is that $r$ take the value 5/7 (≈0.714). Therefore, the value 5/7 will be taken as the point estimate of $r$ for each species in the specification of MSY.

### 3.4.2.1.2 Option 1 MSY for Qualifying Species

The following provides the specifications based on the available data at the time of the FMP development. The specifications of MSY, BMSY, and FMSY can be revised during the stock assessment without FMP amendment.

Snow crab: As implied by Turnock and Rugolo (2008, p. 40), the age at maturity for snow crab likely ranges between 7 and 9 years. The age at maturity will be estimated here as the midpoint of that range (8 years). Turnock and Rugolo also list 0.23 as the value for $M$. Together with the default estimate of $r$ (5/7), and assuming that the age intercept of the linear weight-at-age equation is zero, these values give an $F_{MSY}$ estimate of 0.36, a $B_{MSY}/B_0$ of 0.193, and an MSY/$B_0$ ratio of 0.069. The area-swept biomass estimate from the 1990 Arctic survey is 147,196 t, giving $B_{MSY}$=28,409 t and MSY=10,157 t.

Arctic cod: FishBase (Froese and Pauly 2008) reports that the age at maturity for Arctic cod likely ranges between 2 and 5 years. The age at maturity will be estimated here as the midpoint of that range (3.5 years). FishBase also lists a value of 0.22 for the Brody growth parameter $K$ and a value of 7 years for maximum age. Using Jensen's (1996) Equation 7, an age of maturity equal to 3.5 years corresponds to an

$M$ of 0.47, while Jensen's Equation 8 implies an $M$ of 0.33. Using Hoenig's (1983) equation, a maximum age of 7 corresponds to an $M$ of 0.62. Taking the average of these three estimates (0.47, 0.33, 0.62) gives an $M$ of 0.47, which is the estimate that will be used here. Together with the default estimate of $r$ (5/7), and assuming that the age intercept of the linear weight-at-age equation is zero, these values give an $F_{MSY}$ estimate of 0.70, a $B_{MSY}/B_0$ of 0.196, and an MSY/$B_0$ ratio of 0.136. The area-swept biomass estimate from the 1990 Arctic survey is 60,042 t, giving $B_{MSY}$=11,768 t and MSY=8,166 t.

Saffron cod: FishBase (Froese and Pauly 2008) reports that the age at maturity for Arctic cod likely ranges between 2 and 3 years. The age at maturity will be estimated here as the midpoint of that range (2.5 years). FishBase also lists a value of 7 years for maximum age. Using Jensen's (1996) Equation 7, an age of maturity equal to 2.5 years corresponds to an $M$ of 0.66. Using Hoenig's (1983) equation, a maximum age of 15 corresponds to an $M$ of 0.30. Taking the average of these two estimates (0.66, 0.30) gives an $M$ of 0.48, which is the estimate that will be used here. Together with the default estimate of $r$ (5/7), and assuming that the age intercept of the linear weight-at-age equation is zero, these values give an $F_{MSY}$ estimate of 0.62, a $B_{MSY}/B_0$ of 0.207, and an MSY/$B_0$ ratio of 0.128. The area-swept biomass estimate from the 1990 Arctic survey is 10,195 t, giving $B_{MSY}$=2,110 t and MSY=1,305 t.

The main reference points derived above for the three stocks are summarized below:

| Stock | $F_{MSY}$ | $B_{MSY}$ | MSY |
|---|---|---|---|
| Snow crab | 0.36 | 28,409 t | 10,157 t |
| Arctic cod | 0.70 | 11,768 t | 8,166 t |
| Saffron cod | 0.62 | 2,110 t | 1,305 t |

### 3.4.3 Option 1 Specification of Status Determination Criteria

The National Standard Guidelines require specification of two status determination criteria: the maximum fishing mortality threshold (MFMT) and the minimum stock size threshold (MSST).

#### 3.4.3.1 Maximum Fishing Mortality Threshold

The National Standard Guidelines state the following in paragraph (2)(d)(i): "The fishing mortality threshold may be expressed either as a single number or as a function of spawning biomass or other measure of productive capacity. The fishing mortality threshold must not exceed the fishing mortality rate or level associated with the relevant MSY control rule. Exceeding the fishing mortality threshold for a period of 1 year or more constitutes overfishing."

The MFMT for these fisheries is specified as $F_{MSY}$, the MSY control rule. If a future stock assessment results in an improved estimate of $F_{MSY}$, as determined by the Scientific and Statistical Committee, the improved estimate will replace the $F_{MSY}$ value listed in the FMP. The overfishing limit for each fishery is specified as the catch that would result from fishing at the MFMT.

#### 3.4.3.2 Minimum Stock Size Threshold

The National Standard Guidelines state the following in paragraph (2)(d)(ii): "The stock size threshold should be expressed in terms of spawning biomass or other measure of productive capacity. To the extent possible, the stock size threshold should equal whichever of the following is greater: one-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock or stock complex were exploited at the maximum fishing mortality threshold specified under paragraph (d)(2)(i) of this section. Should the actual size of the stock or stock complex in a given year fall below this threshold, the stock or stock complex is considered overfished."

Because no stock assessments have been conducted for the target stocks, it is impossible to determine the range of stock sizes over which rebuilding to $B_{MSY}$ would be expected to occur within 10 years under an $F_{MSY}$ exploitation strategy. In the absence of information indicating that such a rebuilding rate would be expected for any stock size below $B_{MSY}$, the MSST for these fisheries is therefore specified as $B_{MSY}$. If a future stock assessment results in an improved estimate of $B_{MSY}$, as determined by the Scientific and Statistical Committee, the improved estimate will replace the $B_{MSY}$ value listed in the FMP. Also, if a future stock assessment enables estimation of rebuilding rates under an $F_{MSY}$ exploitation strategy, then the MSST would be reduced according to the National Standard Guidelines definition.

### 3.4.4 Option 1 Specification of OY

The MSA states that optimum yield is to be specified "on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor." According to the National Standard Guidelines, OY is supposed to be specified by analysis, as described in §600.310(f)(6). Among other things, this section of the guidelines states, "The choice of a particular OY must be carefully defined and documented to show that the OY selected will produce the greatest benefit to the Nation." The following subsections analyze possible reductions from MSY as prescribed by relevant socio-economic and ecological factors; doing so one at a time to begin with, then in combination.

#### 3.4.4.1 Reductions from MSY prescribed by relevant socio-economic factors: Uncertainty

##### 3.4.4.1.1 Methods

Decision theory can be used to compute the appropriate reduction from MSY resulting from consideration of uncertainty. This requires specification of a utility function. One of the simplest and most widely used utility functions is the "constant relative risk aversion" form (Pratt 1964, Arrow 1965), which will be assumed here. Given this functional form, it is also necessary to specify a value for the risk aversion coefficient. A value of unity will be assumed here. Finally, it is necessary to specify a measure of the nominal wealth accruing to society from the fishery. It will be assumed here that the nominal wealth accruing to society from the fishery is proportional to the equilibrium yield. Given these specifications, the decision-theoretic objective is to maximize the geometric mean of equilibrium yield.

It will also be assumed that the values of parameters *M* and *d* are known and that parameter *r* is a random variable, in which case geometric mean equilibrium yield is given by

$$Y_G(F) = Y(F \mid r_H) \quad ,$$

where $r_H$ is the harmonic mean of *r*.

Geometric mean equilibrium yield is maximized by fishing at the constant rate $F_{MSY}(r_H)$. Similarly, the geometric mean of the ratio between equilibrium yield and equilibrium unfished biomass is given by

$$Yratio_G(F) = Yratio(F \mid r_H) \quad .$$

It will also be assumed that the area-swept biomass estimate from the 1990 survey represents equilibrium unfished biomass and that this estimate is lognormally distributed with

$$\sigma_B = \sqrt{\ln\left(1 + \frac{\mathrm{var}(CPUE)}{\mathrm{mean}(CPUE)^2 N}\right)} \quad .$$

Given the above, OY can be estimated as

$$OY = Yratio_G(F_{MSY}(r_H) \,|\, r_H)\, B_0 \exp\left(-\frac{\sigma_B{}^2}{2}\right) \quad .$$

Application of the above equation requires an estimate of the harmonic mean of the resilience *r*. Given that no assessments have been conducted of the stocks targeted by the fisheries to which the plan applies, statistical estimates of this quantity (e.g., from a Bayesian posterior distribution) are not available. Therefore, it is necessary to use informed judgment to arrive at an estimate. Given the default value of 5/7 used in the estimation of MSY and the general lack of stock-specific information, it is reasonable to assume a logit-normal distribution for *r* with $\mu_r$=ln(5/2) and $\sigma_r$=1. This distribution has a median value of 5/7 (the point estimate used in the MSY specifications), a coefficient of variation close to 0.27, and a harmonic mean close to 0.60.

If the distribution of *r* is logit-normal with a given median, no finite value of $\sigma_r$ can reduce OY to zero. However, this result does not hold across all distributional forms. For example, if the distribution of *r* is beta with a given arithmetic mean, it is possible to find a coefficient of variation large enough that OY is reduced to zero.

#### 3.4.4.1.2 Results

Snow crab: Together with the default distribution assumed for *r*, the parameters listed in the MSY section imply an OY/$B_0$ ratio of 0.046. The estimate of $\sigma_B$ from the 1990 Arctic survey is 0.166, which, together with the biomass point estimate of 147,196 t, implies a geometric mean value for $B_0$ of 145,171 t. Considering the effects of uncertainty, then, OY would be 6,678 t, a reduction of 34% from MSY.

Arctic cod: Together with the default distribution assumed for *r*, the parameters listed in the MSY section imply an OY/$B_0$ ratio of 0.065. The estimate of $\sigma_B$ from the 1990 Arctic survey is 0.192, which, together with the biomass point estimate of 60,042 t, implies a geometric mean value for $B_0$ of 58,944 t. Considering the effects of uncertainty, then, OY would be 3,831 t, a reduction of 53% from MSY.

Saffron cod: Together with the default distribution assumed for *r*, the parameters listed in the MSY section imply an OY/$B_0$ ratio of 0.064. The estimate of $\sigma_B$ from the 1990 Arctic survey is 0.702, which, together with the biomass point estimate of 10,195 t, implies a geometric mean value for $B_0$ of 7,970 t. Considering the effects of uncertainty, then, OY would be 510 t, a reduction of 61% from MSY.

### 3.4.4.2 Reductions from MSY prescribed by relevant socio-economic factors: Non-consumptive value

#### 3.4.4.2.1 Methods

In addition to the benefits derived from the consumptive uses of a stock, it is possible for society to derive value from non-consumptive uses. For example, society might prefer a higher biomass to a lower biomass irrespective of the use of that biomass to generate fishery yields. Non-consumptive values can be combined with consumptive values to generate a measure of equilibrium total gross value *V* as follows:

$$V(F|r) = B(F|r)(p_B + F\,p_Y) \quad ,$$

where $p_B$ is the "price" per unit of biomass associated with non-consumptive use and $p_Y$ is the price per unit of yield associated with consumptive uses.

The fishing mortality rate that maximizes sustainable value is given by

$$F_{MSV}(r) = \left(\frac{M}{2(1-r)}\right)\left((1-u) - \frac{2-r}{M\,d} + \sqrt{\left(\frac{2-r}{M\,d}\right)^2 + \left(\frac{4-6r}{M\,d}\right)(1-u) + (1-u)^2}\right) - M \quad ,$$

where $u = p_B/(M \times p_Y)$. Note that this expression is identical to the equation for $F_{MSY}$, except that the quantity 1 is replaced by the quantity $1-u$ in three places.

It is theoretically possible for $u$ to be sufficiently high that the optimal fishing mortality rate (and thus OY) is zero. This value is given by

$$u_0 = \left(\frac{M\,d + 1}{M\,d + 2}\right) r \quad .$$

#### 3.4.4.2.2 Results

There are no data on the value of $p_B$ for any of the qualifying fisheries in Option that would be covered by the plan. However, available information from other fisheries indicates that $p_B$ is likely to be very small. Based on the parameter values given in the section on MSY, the ratio of $p_B$ to $p_Y$ at which OY is reduced to zero for each of the three fisheries is as follows:

| | |
|---|---|
| Snow crab: | 0.12 |
| Arctic cod: | 0.24 |
| Saffron cod: | 0.24 |

It is very unlikely that the ratio of $p_B$ to $p_Y$ comes anywhere close to the above values for any of the three fisheries covered by the plan. The available information pertaining to non-consumptive value therefore does not support a reduction from MSY for any of the three fisheries.

### 3.4.4.3 Reductions from MSY prescribed by relevant socio-economic factors: Costs

#### 3.4.4.3.1 Methods

Costs of fishing can be viewed as including a fixed component, which is incurred at any level of fishing, and a variable component, which changes proportionally with the level of fishing. Equilibrium net wealth $W$ can then be written as follows:

$$W(F|r) = B(F|r)\,F\,p_Y - c_F - F\,c_V \quad ,$$

where $c_F$ is the instantaneous fixed cost rate and $c_V$ is the instantaneous variable cost rate.

The fishing mortality rate that maximizes sustainable net wealth has no closed-form solution.

It is possible for fixed cost rate or the variable cost rate (or both) to be sufficiently high that the optimal fishing mortality rate is zero. In particular, if $c_F$>MSY×$p_Y$ or if $c_V$>$B_0$×$p_Y$, the optimal fishing mortality rate, and thus OY, will be zero. It should be noted that these are sufficient, but not necessary, conditions for a zero OY.

#### 3.4.4.3.2 Results

No significant commercial fishery currently exists for any of the three stocks to which the plan applies. This implies that the expected costs of fishing outweigh the expected revenues. Because any significant level of commercial effort evidently results in a net loss, the available information pertaining to costs would appear to prescribe something close to a 100% reduction from MSY for each of the three fisheries so long as current cost and revenue structures remain unchanged.

### 3.4.4.4 Reductions from MSY prescribed by relevant ecological factors

#### 3.4.4.4.1 Methods

The MSFCMA requires that the specification of optimum yield take "into account the protection of marine ecosystems." In the Affected Environment section of the EA/RIR/IRFA that accompanies this document and in Chapter 4 below, Arctic cod is identified as a keystone species which needs to remain close to carrying capacity in order for the marine ecosystem to retain its present structure. No other keystone species are identified. Therefore, the OY for each of the three fisheries needs to be set at a level that limits impacts on Arctic cod to negligible levels. Available data pertaining to likely catches of Arctic cod in each of the three fisheries can be examined to determine if the respective fishery would be expected to have anything more than a negligible impact on the Arctic cod stock.

#### 3.4.4.4.2 Results

Snow crab: Because snow crab are exclusively fished with pot gear, the relative catch rates of snow crab and Arctic cod from the 1990 Arctic survey are probably not a good indicator of the likely incidental catch rate in a future Arctic snow crab fishery. Therefore, the best available data on potential incidental catch rates in a future Arctic snow crab fishery come from the Bering Sea snow crab fishery. Incidental catch rates for gadids in that fishery are typically on the order of 0.5% (individual gadids caught per individual snow crab caught), which could reasonably be interpreted as a negligible value. Snow crab is also a prey species for several marine mammals that are either petitioned or currently under review for ESA listing. The removal of prey species may increase stress on these marine mammal species and may affect the predator/prey relationship in the Arctic. It is difficult to quantify the amount of MSY reduction to provide for this factor considering the variety of food these marine mammals consume. Until more information is known, it is not possible to quantify a reduction of MSY based on the relevant ecological factors in the snow crab fishery.

Arctic cod: By definition, any directed fishery for Arctic cod would have non-negligible impacts on the Arctic cod stock. Therefore, the relevant ecological factors prescribe something close to a 100% reduction from MSY in the Arctic cod fishery.

Saffron cod: In the 1990 Arctic survey, if the station-specific data are sorted in order of decreasing saffron cod CPUE and consideration is limited to the upper quartile (to approximate a fishery targeting on saffron cod), the median incidental catch rate of Arctic cod is just over 5 kg per kg of saffron cod. In other words, the best scientific information available indicates that a target fishery for saffron cod would likely take about five tons of Arctic cod for every ton of saffron cod, which could not reasonably be interpreted as a negligible value. Therefore, the relevant ecological factors prescribe something close to a 100% reduction from MSY in the saffron cod fishery.

#### 3.4.4.5 Conclusion: Reductions from MSY prescribed by all relevant factors

The reductions from MSY resulting from the above analyses are summarized below:

| Fishery | Uncertainty | Non-consumptive value | Costs | Ecosystem |
|---|---|---|---|---|
| Snow crab | 34% | ~0% | ~100% | ~0% |
| Arctic cod | 53% | ~0% | ~100% | ~100% |
| Saffron cod | 61% | ~0% | ~100% | ~100% |

Interactions between the various factors were not considered in the analyses summarized in the above table, which could be problematic were it not for the fact that one factor (costs) prescribes something close to a 100% reduction from MSY for all three fisheries, and another factor (ecosystem) prescribes something close to a 100% for all but the snow crab fishery. On the basis of these analyses, then, OY is specified as an annual *de minimis* catch, sufficient only to account for bycatch in subsistence fisheries for other species. In the event that new scientific information becomes available suggesting that the conditions estimated or assumed in the process of making this specification are no longer valid, a new analysis should be conducted as soon as possible.

### 3.4.5 Option 1 Specification of ACL and ACT

Given the specification of OY as an annual *de minimis* catch sufficient only to account for bycatch in subsistence fisheries for other species, it is appropriate to set the "annual catch target" equal to zero. The "annual catch limit" is an additional reference point that does not have major significance for a fishery with an OY approaching zero. To avoid proliferation of superfluous reference points, the annual catch limit for these fisheries is set equal to the overfishing limit.

## 3.5 Option 2

Species covered by this Option include all Arctic finfish and marine invertebrates above a trophic level of approximately three. A trophic level of three indicates that these species are two steps removed from primary producers such a phytoplankton. While acknowledging that this is an arbitrary criterion, species that satisfy it are, in general, species than can be surveyed at least somewhat effectively using commonly-used survey methods, such as trawl and acoustic surveys, and are species that are vulnerable to fishing gear commonly used in other Alaska marine ecosystems. Taxa of marine invertebrates that would be excluded are hermit crabs, jellies, sea stars, sea cucumbers, and other benthic invertebrates. While every species is important, this Option focuses on species that are "manageable," i.e., those species potentially susceptible to direct or indirect fishing impacts, whose abundance trends can be effectively monitored, and which would be responsive to the management tools at the command of the Council.

### 3.5.1 Option 2 Species

Option 2 would establish four categories of species or species groups (Table 3.3), but initially would only populate two of those categories: a prohibited species category for species managed by non-federal agencies, and an ecosystem component category for all other species. Other categories are established for use in the future if or when fisheries develop in the Arctic. A key feature of this Option is an explicit and formal procedure for transferring a species from the ecosystem component category to the target species category. The four categories of species are the following:

1. Prohibited Species – are those species and species groups, the catch of which must be avoided while fishing, and which must be returned to sea with a minimum of injury except when their retention is authorized by other applicable law. The prohibited species category would include all species whose primary management is the responsibility of a non-federal agency.
2. Target species – are those species that support either a single species or mixed species target fishery. Status determination criteria are required for these species.
3. Bycatch species – are those species or species groups that are caught in non-negligible quantities while conducting a fishery for the target species. Such stocks could be subject to overfishing, or becoming overfished, without conservation and management measures. Bycatch of these species is monitored in-season and managed with maximum allowable impact restrictions that could be either a cap on the amount of bycatch or rate of bycatch.
4. Ecosystem component species – are those species and species groups which are not taken in any target fishery.

### 3.5.2 Option 2 Overfishing Criteria

These criteria may be applicable to Option 1. This will be addressed by the Council and SSC. Overfishing is defined as any amount of fishing in excess of a prescribed maximum allowable rate. This maximum allowable rate is prescribed through a set of five tiers which are listed below in descending order of preference, corresponding to descending order of information availability. The Council's Science and Statistical Committee (SSC) will have final authority for determining whether a given item of information is "reliable" for the purpose of this definition, and may use either objective or subjective criteria in making such determinations.

For tier (1), a "pdf" refers to a probability density function. For tiers 1 and 2, if a reliable pdf of BMSY is available, the preferred point estimate of BMSY is the geometric mean of its pdf. For tiers 1 to 5, if a reliable pdf of B is available, the preferred point estimate is the geometric mean of its pdf. For tiers 1 to 3, the coefficient $\alpha$ is set at a default value of 0.05. This default value was established by applying the 10 percent rule suggested by Rosenberg et al. (1994) to the ½ BMSY reference point. However, the SSC may establish a different value for a specific stock or stock complex as merited by the best available scientific information. For tiers 2 to 4, a designation of the form "FX%" refers to the F
associated with an equilibrium level of spawning per recruit equal to X% of the equilibrium level of spawning per recruit in the absence of any fishing. If reliable information sufficient to characterize the entire maturity schedule of a species is not available, the SSC may choose to view spawning per recruit calculations based on a knife-edge maturity assumption as reliable. For tier 3, the term B40% refers to the long-term average biomass that would be expected under average recruitment and F=F40%.

Tier 1 Information available: Reliable point estimates of B and BMSY and reliable pdf of FMSY .

1a) Stock status: B/BMSY > 1

FOFL = $m_A$ , the arithmetic mean of the pdf

FABC ≤ $m_H$ , the harmonic mean of the pdf

1b) Stock status: a < B/BMSY ≤ 1

FOFL = $m_A$ × (B/BMSY - a)/(1 - a)

FABC ≤ $m_H$ × (B/BMSY - a)/(1 - a)

1c) Stock status: B/BMSY ≤ a

FOFL = 0

FABC = 0

Tier 2 Information available: Reliable point estimates of B, BMSY , FMSY , F35% , and F40% .

2a) Stock status: B/BMSY > 1
FOFL = FMSY
FABC ≤ FMSY × (F40% /F35%)
2b) Stock status: a < B/BMSY # 1
FOFL = FMSY × (B/BMSY - a)/(1 - a)
FABC ≤ FMSY × (F40% /F35%)× (B/BMSY - a)/(1 - a)
2c) Stock status: B/BMSY ≤ a
FOFL = 0
FABC = 0

Tier 3 Information available: Reliable point estimates of B, B40% , F35% , and F40% .

3a) Stock status: B/B40% > 1
FOFL = F35%
FABC ≤ F40%
3b) Stock status: a < B/B40% ≤ 1
FOFL = F35% × (B/B40% - a)/(1 - a)
FABC ≤ F40% × (B/B40% - a)/(1 - a)
3c) Stock status: B/B40% ≤ a
FOFL = 0
FABC = 0

Tier 4 Information available: Reliable point estimates of B, F35% , and F40% .
FOFL = F35%
FABC ≤ F40%

Tier 5 Information available: Reliable point estimates of B and natural mortality rate M.
FOFL = M
FABC ≤ 0.75 × M.

### 3.5.3 Option 2 Maximum Sustainable Yield of Arctic Finfish and Invertebrates

As an exercise in examining wholistically the Arctic ecosystem and calculation of a system-wide MSY, this section considers methods to estimate the MSY that could be produced in aggregate by Arctic finfish and invertebrates. As has been noted elsewhere, MSY is a theoretical concept, and our treatment of MSY in this section is perhaps more theoretical than usual. Conceptually, such an aggregate harvest might be taken by a reduction fishery that attempts to maximize the yield of undifferentiated biomass. While such a fishery is not likely, a system-level estimate of MSY is useful to provide give a general sense of the magnitude of potential fishery yields in comparison of other ecosystems.

These methods are simple and inexact, and thus likely to produce estimates that are correct only to an order of magnitude. However, similar approaches were applied historically in North Pacific (Alverson and Pereyra 1969), and provided useful guidance for fisheries development. An advantage of trying several methods is that differing results can provide an indication of their uncertainty.

There are several important caveats to consider when applying these methods. First, these methods provide a point estimate of MSY, while the Arctic ecosystem is likely to be highly dynamic. Second, the Arctic is changing rapidly, and an estimate of MSY using historical data may not be representative of present or future conditions. Both of these considerations highlight the need for an ongoing monitoring program for key Arctic species and oceanographic conditions, and to re-evaluate ecosystem productivity on a continuing basis.

Three approaches were considered to estimate a system-level MSY and they are described below.

#### 3.5.3.1 $B_0$ approach to estimate MSY

The approximation developed by Alverson and Pereyra (1969), MSY = 0.5 * M * $B_0$, has been widely applied in data-poor situations as a rough guide for potential yield (Beddington and Kirkwoood, 2005). The deviation is loosely based on the Shaefer model, where $B_{MSY}$ = 1/2 $B_0$, and dynamic pool models, where $F_{MSY}$ = M is often a reasonable approximation. Thompson (1992) demonstrated that these two assumptions were inconsistent for dynamic pool models under fairly general conditions. Since biomass levels between 30% and 40% of unfished stock size are widely used proxies for BMSY, a simple modification to the original equation was used for MSY calculations, MSY = 0.35 * M * $B_0$. When applying this equation, total biomass estimates from exploratory surveys in the Arctic were used as an estimate of $B_0$, and the median natural mortality rate for assessed groundfish stocks in the Bering Sea/Aleutian Islands was used for M (conveniently, this happened to be 0.2). Given that the appropriate value of M is highly uncertain, results were reported for higher and lower values of M (0.1 and 0.3) to provide contrast.

#### 3.5.3.2 Bottom-up approach

Annual estimates of primary production in each ecosystem were used to estimate the potential fish production by assuming certain trophic transfer efficiencies. Iverson (1990) gives several equations for converting annual primary production in grams of carbon (C) or nitrogen (N) per square meter into annual fish production (wet weight per square meter). Here, we assumed that fish production was at trophic level 3.5 (the same assumption used in Iverson 1990). Estimates of primary productivity in the Arctic have wide ranges due to the extreme seasonality of production combined with high variability in conditions between years. However, the contrast between the areas remains clear despite these wide ranges: the Chukchi Sea (including the Russian portion) has a range of 20 to greater than 400 grams of carbon produced per square meter annually ($gC/m^2y$), while the Beaufort Sea (including the Canadian portion) has a narrower range of 30-70 $gC/m^2y$ (Carmack et al. 2006). This compares with the Eastern Bering Sea estimate ranging from less than 75 $gC/m^2y$ on the inner shelf to over 275 $gC/m^2y$ on the shelf break (Aydin and Mueter 2007, Springer et al. 1996), and to the Gulf of Alaska shelf estimate of 300 $gC/m^2y$ (Sambrotto and Lorenzen 1987). Iverson's (1990) equations were used to convert both the low and high ends of the range of primary production (PP) values given for each system to low and high estimates of annual fish production in metric tons as scaled to the area of each system (Table 3.5).

Estimates of annual fish production for the Bering Sea shelf and the Gulf of Alaska derived by this method appear higher than the estimates of annual surplus production estimated by Mueter and Megrey (2006), which were 2.5 million metric tons in the Bering Sea and 330,000 t in the Gulf of Alaska. Part of this discrepancy may arise from using the high PP estimates in the comparison, if this level of PP is not available in every year. Estimates in Mueter and Megrey (2006) also considered primarily currently fished species, and not all species at trophic level 3.5, which would include unfished forage species in those systems. Nevertheless, this is one caveat; the production estimates here do not account for commercial value or lack thereof.

Iverson (1990) suggests that the average fish catch is about 25% of total fish production for some ecosystems. Examination of this calculation based on a yield per recruit model for Alaskan ecosystems suggest that 25% would be a reasonable MSY estimate for these regions.

There are several other important caveats to this analysis.

First, we note that these equations area based on regression relationships for the conversion of phytoplankton C to N derived from systems between 15 and 65 degrees N, so may not be appropriate to the high-latitude Chukchi and Beaufort Seas. In addition, the equations cannot accommodate PP values lower than about 40 $gC/m^2y$, so values of 0 were included at the lower end of the primary production scale for the Arctic systems.

Second, conversion of primary production to fish biomass may not be direct in shallow Arctic seas with strong benthic-pelagic coupling as observed in the Chukchi Sea (Grebmeier et al. 1988, Grebmeier and McRoy 1989, Dunton et al. 1989, Dunton et al. 2005). Benthic clams and amphipods are important groups channeling the relatively high benthic production observed in the Chukchi Sea to birds and mammals, specifically walruses, bearded seals, and gray whales (Moore et al. 2000, Coyle et al. 2007, Dehn et al. 2007, Bluhm and Gradinger 2008). The limited available trawl survey data reviewed above suggest that the high benthic and primary productivity observed in the Chukchi Sea may not indicate similarly high fish biomass as is observed in the Bering Sea. Some authors suggest that the close coupling of primary production with benthic invertebrate biomass results from short food chains and little grazing in the pelagic zone (Dunton et al. 1989), thus leaving little energy for high fish biomass, but considerable energy for large benthic foraging mammals.

Third, in the Beaufort Sea, the total annual fish production estimated here corresponds closely to the estimated fish consumption of vertebrate predators in that ecosystem. Frost and Lowry (1984) estimated the consumption for the most common marine mammals and birds in the pelagic food web of the Alaskan Beaufort shelf, and included Arctic cod as both forage for these predators and as a predator on zooplankton. An estimated 123,000 tons of Arctic cod were required to feed late 1970's populations of Belugas, ringed seals, marine birds, and Arctic cod themselves in the Beaufort Sea. Belugas and ringed seals in particular were dependent on Arctic cod for a majority of their consumption, and birds for half their consumption. Fishery development in the Beaufort Sea will need to consider carefully the tradeoffs between potential benefits of the fishery and maintaining marine mammal and seabirds at existing levels.

Table 3-4 Primary production (PP, in $gC/m^2y$), area ($km^2$), and potential fish production (P, in t/y) in ecosystems off Alaska. Areas are as reported by A.Greig, AFSC, for the Chukchi and Beaufort Sea shelves off Alaska, and in Aydin et al. 2007 for the Eastern Bering Sea and Gulf of Alaska. The low and the high fish production estimates for the Eastern Bering Sea are derived from primary productivity estimates for the inner shelf and the outer shelf respectively.

| Ecosystem | Low PP $gC/m^2y$ | High PP $gC/m^2y$ | Area $km^2$ | Low Fish P t/y | High Fish P t/y | Proxy MSY (t) | Proxy MSY (t) |
|---|---|---|---|---|---|---|---|
| Chuckchi | 20 | 400 | 281,729 | 0 | 7,792,640 | 0 | 1,948,160 |
| Beaufort | 30 | 70 | 38,599 | 0 | 124,642 | | 31,161 |
| Bering Sea | 75 | 275 | 495,218 | 1,842,213 | 11,565,817 | 460,553 | 2,891,454 |
| Gulf of Alaska | | 300 | 291,840 | Not Available | 7,532,208 | Not Available | 1,883,042 |

#### 3.5.3.3 Comparative approach to estimate MSY

Estimates of total (benthic + pelagic) fish density are available for the Barents Sea, a well-studied and fully exploited ecosystem. Even though the Barents Sea is an Arctic ecosystem, its productivity is strongly influenced by flux from North Atlantic. It is unlikely that the Chukchi and the Beaufort Seas are more productive the Barents Sea. To obtain MSY estimates, it was assumed 1) current estimates of fish density in the Barents Sea as estimated by an ecosystem model were close to BMSY, 2) that BMSY fish densities in the Chukchi and Beaufort sea were the same as, one-half, or one-tenth the density in the Barents Sea, and 3) that FMSY = M = 0.2 was a reasonable proxy for FMSY.

#### 3.5.3.4 Summary of MSY Calculations for Option 2.

The three MSY calculations for Alt 2 shown in Table 3.4 indicate the system-level MSY for the Chuckchi Sea could range from 0 t to 1,948,160 t. The wide range suggests that none of these methods should be considered reliable estimates of system wide MSY for fishery management. The three approaches illustrate the range of fishery potential and its associated uncertainty.

Table 3-5 Summary of MSY estimates for the Arctic

| | Chukchi Sea | Beaufort Sea | Total |
|---|---|---|---|
| **Area (20 – 500m)** | **218,730 km$^2$** | **38,599 km$^2$** | **257,329 km$^2$** |
| | | | |
| **MSY estimation method** | | | |
| **Bottom-up approach low PP** | **0 t** | **0 t** | **0 t** |
| **Bottom-up approach high PP** | **1,948,160 t** | **31,161 t** | **1,979,321 t** |
| **MSY = 0.35 * M *$B_0$ (M = 0.1)** | **8,600 t** | **Not available** | |
| **MSY = 0.35 * M *$B_0$ (M = 0.2)** | **17,300 t** | **Not available** | |
| **MSY = 0.35 * M *$B_0$ (M = 0.3)** | **25,900 t** | **Not available** | |
| **Comparative (same as Barents Sea biomass density)** | **596,500 t** | **105,300 t** | **701,800 t** |
| **Comparative (0.5 Barents Sea biomass density)** | **298,300 t** | **52,600 t** | **350,900 t** |
| **Comparative (0.1 Barents Sea biomass density)** | **59,700 t** | **10,500 t** | **70,200 t** |

### 3.5.4 Option 2 Optimum Yield of Arctic Finfish and Invertebrates

Since no target fisheries are currently authorized under this FMP, the optimum yield is zero.

## 3.6 Overfishing Criteria

Overfishing occurs whenever a stock or stock complex is subjected to a level of fishing mortality or annual total catch that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis. Definitions of MSY are provided above for Options 1 and 2. The Council's SSC will have final authority for determining whether a given item of information is "reliable" for the purpose of this definition, and may use either objective or subjective criteria in making such determinations.

## 3.7 Procedures for Setting Total Allowable Catch

The NPFMC will adjust the recommended Total Allowable Catch (TAC) that is at or below the level that will prevent overfishing. In 2008, the available information was not sufficient to allow a fishery under either Options 1 or 2. Should such information become available, the Plan can be amended to provide for harvest specifications and fishery management.

## 3.8 Permit and Participation Restrictions

No commercial harvest of any other fish resource of the Arctic is authorized, and thus no permitting requirements are specified with the exception of exempted fishing permits as described below.

### 3.8.1 Exempted Fishing Permits

The Regional Administrator, after consulting with the Director of the Alaska Fisheries Science Center (AFSC) and with the Council, may authorize, for limited experimental purposes, the directed or incidental harvest of fish resources in the Arctic Management Area that would otherwise be prohibited. Exempted fishing permits will be issued only after the application has been received by the Regional Administrator, reviewed and approved by the AFSC and consultation with the Council is complete, by means of procedures contained in regulations and completion of the appropriate National Environmental Policy Act analysis.

As well as other information required by regulations, each application for an exempted fishing permit must provide the following information: 1) experimental design (e.g., staffing and sampling procedures, the data and samples to be collected, and analysis of the data and samples), 2) provision for public release of all obtained information, and 3) submission of interim and final reports.

The Regional Administrator may deny an exempted fishing permit for reasons contained in regulations, including a finding that:

a. according to the best scientific information available, the harvest to be conducted under the permit would detrimentally affect marine resources, including marine mammals and birds, and their habitat;

b. issuance of the exempted fishing permit would inequitably allocate fishing privileges among domestic fishermen or would have economic allocation as its sole purpose;

c. activities to be conducted under the exempted fishing permit would be inconsistent with the intent of the management objectives of the FMP;

d. the applicant has failed to demonstrate a valid justification for the permit;

e. the activity proposed under the exempted fishing permit could create a significant enforcement problem; or

f. the applicant failed to make available to the public information that had been obtained under a previously issued exempted fishing permit.

## 3.9 Gear Restrictions

No commercial harvest of any fish resource of the Arctic is authorized, and thus no authorized gear is specified. Appropriate gear types for any future fisheries would be amended to this FMP with the development of fishery management measures.

## 3.10 Time and Area Restrictions

No commercial harvest of any fish resource of the Arctic is authorized, and thus no time or area restrictions are specified. Seasons, geographic restrictions, and other related management measures may be specified by the Council if a fishery develops in the future in the Arctic Management Area.

## 3.11 Catch Restrictions

No commercial harvest of any fish resource of the Arctic is authorized, and thus no catch restrictions are specified. Catch limits, adjustments, and other catch restrictions may be specified by the Council if a fishery develops in the future in the Arctic Management Area.

## 3.12 Bycatch Reduction Incentive Programs

No commercial harvest of any fish resource of the Arctic is authorized, and thus no bycatch limits for any fisheries are specified.Bycatch limits may be specified by the Council if a fishery develops in the future in the Arctic Management Area.

## 3.13 Share-based Programs

No share-based programs are specified for the Arctic Management Area.

## 3.14 Flexible Management Authority

Descriptions of management measures that provide for fixed, frameworked, or discretionary management of fisheries may be specified by the Council if a fishery develops in the future in the Arctic Management Area. No commercial harvest of any fish resource of the Arctic is authorized.

## 3.15 Monitoring and Reporting

### 3.15.1 Recordkeeping and Reporting

The Council and NMFS must have the best available biological and socioeconomic information with which to carry out their responsibilities for conserving and managing target fish resources and nontarget marine resources that may be incidentally caught in a Council-managed fishery. This information is used for making inseason and inter-season management decisions that affect these resources as well as the fishing industry that utilize them. This information also is used to judge the effectiveness of regulations guiding these decisions. The Council will recommend changes to regulations when necessary on the basis of such information.

The need for the Council and NMFS to consider the best available information is explicit in the goals and objectives as established by the Council and contained in this FMP. They are also explicit in the Magnuson-Stevens Act, Executive Order 12866, the Regulatory Flexibility Act, the National Environmental Policy Act, and other applicable law. The Secretary, therefore, will require segments of the fishing industry to keep and report certain records as necessary to provide the Council and NMFS with the needed information to accomplish these goals and objectives. The Secretary may implement and amend regulations at times to carry out these requirements after receiving Council recommendations to do so, or at other times as necessary to accomplish these goals and objectives. Regulations will be proposed and implemented in accordance with the Administrative Procedure Act, the Magnuson-Stevens Act, and other applicable law.

Recordkeeping, reporting, and observer requirements for a fishery may be specified by the Council, including specific data to be submitted to NMFS and the Council to ensure effective management of the fishery. No commercial harvest of any other fish resource of the Arctic is authorized, and thus no other recordkeeping or reporting requirements are specified. Recordkeeping and reporting requirements may be specified in an exempted fishing permit issued under authority of this FMP.

### 3.15.2 Enforcement

Monitoring of fishing activities may be required to ensure compliance with regulations. The Council may consider mandatory use of observers, electronic logbooks, vessel monitoring systems, or other measures to assure compliance with regulations, gather data on marine species and performance of the fishery, and enforcement of the closures of the Arctic Management Area.

### 3.15.3 Costs Incurred for Management

The costs to manage the fishery management measures specified in this FMP are limited to the collection and analysis of data regarding fish stocks in preparation of any stock assessments required for sustainable fisheries management and to the enforcement of fishery management measures to conserve marine resources. Enforcement costs for the U. S. Coast Guard and NOAA Office of Law Enforcement will be limited to patrols to ensure the prohibition on commercial fishing until fishery management measures are in place for a commercial fishery.

## 3.16 Council Review of the Fishery Management Plan

### 3.16.1 Procedures for Evaluation

The Council will maintain a continuing review of the environment of the Arctic Management Area and periodically review the provisions in this FMP through the following process:

1. Maintain close liaison with the management agencies involved, particularly the Alaska Department of Fish and Game and NMFS, but also including regional resource management entities in the Arctic Management Area such as the Alaska Eskimo Whaling Commission, the Eskimo Walrus Commission, and the North Slope and Northwest Arctic Boroughs, to monitor the development of fishery potential.
2. Promote research to increase knowledge of the marine environment and fishery resources of the Arctic Management Area, including birds and marine mammals, either through Council funding or by recommending research projects to other agencies. The Council is particularly interested in research that improves understanding of the Arctic ecosystem, predator-prey relationships, energy flow, and how climate warming affects these processes.
3. Conduct public hearings and outreach to Natives and communities at appropriate times and in appropriate locations to hear testimony on the ecological relationships in the Arctic Management Area and the potential for fishery development.
4. Consider all information gained from the above activities and develop, if necessary, amendments to the FMP. The Council will also hold public hearings on proposed amendments prior to forwarding them to the Secretary for possible adoption.

### 3.16.2 Schedule for Review

Adaptive management requires regular and periodic review. Unless specified below, all critical components of this FMP will be reviewed by the Council as warranted.

#### *Management Approach*

Objectives identified in the management policy statement (Section 2.2) will be reviewed every five years or as determined to be necessary by the Council. The Council will also review, modify, eliminate, or consider new issues, as appropriate, to best carry out the goals and objectives of the management policy.

#### *Essential Fish Habitat Components*

To incorporate the regulatory guidelines for review and revision of essential fish habitat (EFH) FMP components, the Council will conduct a complete review of all the EFH components of each FMP once every 5 years, or longer, pending the availability of new information, and will amend those EFH components as appropriate to include new information.

Additionally, the Council may periodically solicit proposals for habitat areas of particular concern and/or conservation and enhancement measures to minimize the potential adverse effects from fishing. Those proposals that the Council endorses would be implemented through FMP amendments.

# Chapter 4 Description of Stocks and Fishery

Currently, there is no commercial fishery in the U. S. EEZ of the Arctic Ocean except for a small red king crab fishery that has occurred infrequently and on a small scale in the southeastern Chukchi Sea, as described in Appendix A. No other commercial fishery or harvest of fish resources occurs, or is authorized, in the Arctic Management Area.

## 4.1 Habitat

### 4.1.1 Geography and Oceanography of the Arctic

The Arctic Ocean has two regional seas that are adjacent to Alaska, the Chukchi Sea and the Beaufort Sea. The Chukchi Sea is an embayment of the Arctic Ocean bounded on the west by the east Siberian coast of the Russian Federation and on the east by the northwestern coast of Alaska. With an area of about 595,000 $km^2$, it extends roughly from Wrangel Island at the eastern side of the East Siberian Sea to Point Barrow and offshore to the 200 m isobath (Weingartner 1997). Along the Alaskan coast of the Chukchi Sea, Kotzebue Sound is a large embayment between Bering Strait and Point Hope. Along the Alaskan Seward Peninsula coast between Point Lay and Wainwright, a chain of nearshore barrier islands form a lagoon system that becomes estuarine during summer.

Offshore, the Chukchi Sea is relatively shallow with depths generally under 60 meters. Warm, low salinity marine water seasonally freshened by outflow from the Yukon River enters the Chukchi from the south through Bering Strait. During the open water season water movement is northward through Bering Strait into the Arctic Ocean, and circulation is partly subject to wind driven currents. The Chukchi Sea is ice covered for about 8 months, with ice retreat occurring in June and July and ice returning by October.
The Beaufort Sea, covering an area of about 476,000 $km^2$, lies offshore north of the Alaskan arctic coast and extends generally from the Point Barrow area eastward to the delta of the Mackenzie River and the west coast of Banks Island in the Canadian High Arctic. The Beaufort Sea has a narrow Continental Shelf that extends offshore 50-100 km (30 to 60 miles). The Beaufort Sea is characterized by barrier island-lagoon systems extending along shore from the western Mackenzie Delta to the Colville River. Water circulation is dominated by the southern edge of the perpetual clockwise gyre of the Canadian Basin resulting in surface movement that is generally westward with a subsurface Beaufort Undercurrent flowing in the opposite direction (Aagaard 1984). Close to shore in the open water season, surface currents are primarily wind driven, with the predominant direction to the west. However, winds can be either easterly or westerly, and thus alongshore surface currents can flow either direction. Ice covers the sea for up to 9 months.

Both the Chukchi and Beaufort Seas are strongly influenced by seasonal ice cover. Ice directly affects the distribution and annual movement patterns of marine mammals and birds. Ice freezes to the bottom in the fall in shallow nearshore areas, and exhibits a shear zone where shorefast ice interfaces with the constantly moving offshore ice pack. Ice ridges, seafloor gouging, and other ice-related phenomena influence the benthic environment. Sea ice melting in spring nourishes primary production as the ice edge melts and retreats, opening a highly productive estuarine-like nearshore corridor in which anadromous and amphidromous fish, marine fish, shorebirds and other waterfowl flourish; many marine mammals generally remain with the ice pack as it retreats offshore.

Vessel movement in the region is restricted by ice conditions, generally allowing vessel transit during a short one to two month period each summer, although in recent years the length of the vessel transit season has been longer because of warmer water and reduced ice cover (Reiss 2008; Mellgren 2007). The Arctic Council's Arctic Marine Shipping Assessment evaluates impacts of increased arctic shipping activities if ice continues to melt and open shipping lanes.

Productivity of the Arctic Ocean is considered to be low, probably due to long winters of low light penetration and thus lower plankton production. The Chukchi is more productive, due partly to the influx of nutrients in waters from the Pacific Ocean and Bering Sea flowing northward through Bering Strait. During summer months production increases as sea ice melts, because water stratification limits summer vertical mixing during the open water season. In the Beaufort during summer, strong west winds may induce upwelling of cold, more nutrient rich waters inshore, and with melting of bottomfast ice, benthic organisms move inshore and support a rich fauna of fish and birds. During winter, seasonal ice freezes to thickness of two or more meters, through which seals maintain breathing holes and holes that are access to birthing lairs under snow cover. Polar bears range throughout the Arctic Ocean, and are more common close to shore during winter months when prey and ice conditions are more favorable. Very little is known of marine fish distribution, abundance, diversity, or habitat use patterns in the winter. Anadromous and amphidromous fishes overwinter in unfrozen pockets of fresh or brackish water in rivers and river deltas.

### 4.1.2 Human Habitation and Land Status

Human habitation of the Arctic has been continuous since the last ice age, and some evidence supports an ancient influx of humans from the west across a land bridge in the Bering Strait area. Communities along the coast of the Chukchi and Beaufort Seas are closely tied to the fish, birds, and marine mammals of the ocean as well as terrestrial mammals, particularly caribou. In the Chukchi region, many villages dot the shoreline, including the large community of Kotzebue and smaller villages such as Shishmaref, Point Lay, and Wainwright. In the Beaufort Sea region, Barrow dominates as the government seat of the North Slope Borough and the largest community north of the Brooks Range. Villages along or near the Beaufort coast include Kaktovik and Nuiqsut. With discovery of petroleum deposits in the Prudhoe Bay region in 1968, an industrial community of Deadhorse formed. The oil fields of the Prudhoe Bay region extend from the Colville River and Delta eastward to the Sagavanirktok River. Populations of villages in the Arctic region range from several hundred to five to seven thousand residents in Barrow and Kotzebue. Approximately 7,400 people work in the Prudhoe Bay oil fields (NRC 2003).

Land status in the Arctic Region includes a mix of local governmental, refuge, and park areas that border portions of the Chukchi and Beaufort Sea coasts. The North Slope Borough extends from the Chukchi Sea coast and along the entire Alaskan Beaufort Sea coast inland to the Brooks Range and eastward to the Canadian Border, encompassing over 228,000 km² (88,000 sq mi). The Northwest Arctic Borough, formed in 1986, encompasses the villages of northwest Alaska in the Kobuk and Noatak River drainages; this borough borders the Chukchi Sea from Cape Seppings in the north to just west of Cape Espenberg in the south. In the eastern Arctic, the Arctic National Wildlife Refuge covers over 7.3 million hectares (18 million acres), about 40% of which is wilderness. This refuge borders the Beaufort Sea coast from approximately the Canning River Delta to the Canadian border and is managed by the U.S. Fish & Wildlife Service. The 9.3 million hectare (23 million acre) National Petroleum Reserve Alaska, managed by the U.S. Bureau of Land Management, extends from the Brooks Range northward to the Beaufort coast. The Reserve extends along the Beaufort coast from the Colville River westward to Point Barrow and then southward, fronting the Chukchi Sea coast from Icy Cape to Wainwright. Cape Krusenstern National Monument and Bering Land Bridge National Preserve extend along large portions of the Chukchi Sea coast and are managed by the U.S. National Park Service. The most northerly parts of the Alaska Maritime National Wildlife Refuge are at Cape Lisburne and Point Hope.

The U.S. Canadian border extends north and slightly eastward in the offshore Beaufort Sea, and the demarcation between the U.S. and the Russian Federation is the International Date Line extending through the middle of Bering Strait northward at 169 degrees West longitude.

### 4.1.3 Description of the Environment in the Arctic Management Area

An ecosystem description for the Arctic Management Area is provided in Section 4.5.1 of this Arctic FMP and in the accompanying EA/RIR/IRFA.

### 4.1.4 Essential Fish Habitat

In 1996, the Sustainable Fisheries Act amended the Magnuson-Stevens Act to require the description and identification of EFH in FMPs, evaluate adverse impacts on EFH, and identify actions to conserve and enhance EFH. Guidelines were developed by NMFS to assist Fishery Management Councils in fulfilling the requirements set forth by the Act.

EFH means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of essential fish habitat: "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

The EFH Final Rule lists the mandatory contents of an FMP [50 CFR 600.815(a)]. These requirements are summarized in the following table and notes specific sections where the FMP meets any requirement.

| FMP's <u>shall</u> include: | FMP Section |
|---|---|
| a. Describe and identify EFH for all fish species in the fishery management unit. | App B |
| b. Evaluate and minimize fishing activities that may adversely affect EFH. | 4.2 |
| c. Identify any non-Magnuson-Stevens Act fishing activities that may adversely affect EFH, such as state fisheries. | 5.4 |
| d. A description of non-fishing activities that may adversely affect EFH [i.e. oil and gas exploration and development, lease sales, coastal development.) | App C |
| e. Identify actions to encourage the conservation and enhancement of EFH, including recommendations to avoid, minimize, or compensate for any adverse affects. | 4.1.6<br>App C |
| FMP's <u>should</u> include: | |
| a. A cumulative impacts discussion. | App C |
| b. A discussion of prey resources and any adverse affects from the action to prey of FMP spp. | 4.5.1 |

| | |
|---|---|
| c. Identify specific types or areas of habitat within EFH as habitat areas of particular concern (HAPCs). | 4.1.5 |
| d. Recommend (and preferably prioritize) research efforts to improve upon EFH description, the identification of fishing threats to EFH and from other activities, and the development of conservation and enhancement measures for EFH. | 4.7.1 |
| e. Review and revise EFH FMP components and, as recommended by the Secretary of Commerce, do so at least once every 5 years. For example, a review plan could include annual incorporation of new EFH information into FMP's through the SAFE's. Then once every 5 years, complete a more thorough review of information to asses changes in EFH. | 3.15.2 |

#### 4.1.4.1 EFH Text and Map Descriptions

FMPs must describe EFH in text, including reference to the geographic location or extent of EFH using boundaries such as longitude and latitude, isotherms, isobaths, political boundaries, and major landmarks. If there are differences between the descriptions of EFH in text, maps, and tables, the textual description is ultimately determinative of the limits of EFH.

The vastness of Alaska and the large number of individual fish species managed by FMP's make it challenging to describe EFH by text using static boundaries. To address this challenge, NMFS refers to the boundaries as defined by a Fishery Management Unit (FMU) for the FMP. The Arctic FMP FMU would be all marine waters in the EEZ of the Chukchi and Beaufort Seas from 3 nautical miles offshore the coast of Alaska to 200 nautical miles offshore, north of Bering Strait (from Cape Prince of Wales to Cape Dezhneva) and westward to the U.S./Russia Convention Line of 1867 and eastward to the U.S. Canada maritime boundary.

FMP's must also include maps that display, within the constraints of available information, the geographic location of EFH or the geographic boundaries within which EFH for each species and life stage is found. A GIS system was used to delineate EFH map descriptions for the FMP. EFH descriptive maps depict, and are complimentary to, each life history EFH text description, if known.

EFH Text and Map Descriptions are in Appendix C.

#### 4.1.4.2 Essential Fish Habitat Conservation

In order to protect EFH, certain EFH habitat conservation areas may be designated. A habitat conservation area is an area where fishing restrictions are implemented for the purposes of habitat conservation. No EFH habitat conservation areas have been designated in the Arctic.

### 4.1.5 Habitat Areas of Particular Concern

Habitat areas of particular concern (HAPCs) are specific sites within EFH that are of particular ecological importance to the long-term sustainability of managed species, are of a rare type, or are especially susceptible to degradation or development. HAPCs are meant to provide for greater focus of conservation and management efforts and may require additional protection from adverse effects. 50 CFR 600.815(a)(8) provides guidance to the Councils in identifying HAPCs.

> FMPs should identify specific types or areas of habitat within EFH as habitat areas of particular concern based on one or more of the following considerations:
>
> (i) The importance of the ecological function provided by the habitat.
>
> (ii) The extent to which the habitat is sensitive to human-induced environmental degradation.
>
> (iii) Whether, and to what extent, development activities are, or will be, stressing the habitat type.
>
> (iv) The rarity of the habitat type.

#### 4.1.5.1 HAPC Process

The Council may designate specific sites as HAPCs and may develop management measures to protect habitat features within HAPCs.

50 CFR 600.815(a)(8) provides guidance to the Councils in identifying HAPCs. FMPs should identify specific types or areas of habitat within EFH as habitat areas of particular concern based on one or more of the HAPC considerations.

Further, any proposed HAPCs (as identified on a map) must meet at least two of the four considerations established in 50 CFR 600.815(a)(8), and rarity of the habitat is a mandatory criterion. HAPCs may be developed to address identified problems for FMP species, and they must meet clear, specific, adaptive management objectives.

The Council will initiate the HAPC process by setting priorities and issuing a request for HAPC proposals. Any member of the public may submit a HAPC proposal. HAPC proposals may be solicited every 3 years or on a schedule established by the Council. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

Criteria to evaluate the HAPC proposals will be reviewed by the Council and the Scientific and Statistical Committee prior to the request for proposals. The Council will establish a process to review the proposals and may establish HAPCs and conservation measures.

#### 4.1.5.2 HAPC Designation

In order to protect HAPCs, certain habitat protection areas and habitat conservation zones may be designated. A habitat protection area is an area of special, rare habitat features where fishing activities that may adversely affect the habitat are restricted. A habitat conservation zone is a subset of a habitat conservation area (used to protect EFH, see Section 4.1.4.4, above), in which additional restrictions are imposed on fishing beyond those established for the conservation area, in order to protect specific habitat features.

Habitat areas or types, that meet the HAPC considerations, could be considered as candidates for HAPC. Habitat-type mapping is scarce and very little information exists to determine sensitive habitat areas within Arctic waters. No specific HAPC’s currently are proposed within the FMP.

### 4.1.6 Habitat Conservation and Enhancement Recommendations for Fishing and Non-fishing Threats to Essential Fish Habitat

No adverse effects from fishing result from this FMP, thus no EFH conservation or enhancement measures are recommended for the Arctic Management Area.

### 4.1.7 Research Efforts in Support of EFH

EFH research needs are prepared through a collaborative proposal process overseen by HEPR Team at the AFSC. The process includes insight to regional EFH management needs by the Alaska Regional Office of Habitat Conservation. Major research needs are 1) to identify habitats that contribute most to the survival, growth, and productivity of managed fish and shellfish species; and 2) to determine how to best manage and protect these habitats from human disturbance and environmental change. Further information can be found at http://www.afsc.noaa.gov/HEPR/efh.htm.

## 4.2 Fishing Activities Affecting the Stocks

There are no known Indian treaty fishing rights for fish, shellfish, or other fish resources in the Arctic Management Area.

### 4.2.1 Commercial fishery

No commercial harvest of fish resources occurs in the Arctic except for a small red king crab fishery in the southern Chukchi Sea. This fishery is prosecuted during the open water season from small vessels, or in winter using snow machines or dog sleds on ice-covered waters. The fishery uses pot gear, and fishermen involved are primarily based in Kotzebue. To date, this fishery has likely had minimal impact on the red king crab stock in the southern Chukchi Sea, due to assumed low harvest amounts over many years. Fishery or stock assessment data are needed to adequately describe this stock and estimate its productivity and how a fishery may affect the stock.

State commercial fisheries occur in State waters in the Arctic. These include a small commercial fishery for chum salmon, although other fish species are incidentally harvested, in the Kotzebue Sound region. Fished from coastal set nets, salmon are sold locally and some are shipped to other markets outside the region. A commercial fishery for whitefish occurs in the delta waters of the Colville River that flows into the central Beaufort Sea. This fishery is for Arctic and least cisco, and a few other species are harvested incidentally. The market for these fish is local, although some whitefish have been marketed in the Barrow and Fairbanks area.

### 4.2.2 Subsistence Fishery

Subsistence fishing is an important part of the economic, nutritional, and cultural lifestyle of local residents of the Arctic. Subsistence fishing occurs throughout the coastal region of the Arctic Management Area by residents of villages in this region. Fishing activities occur near human settlements of Wainwright, Barrow, Nuiqsut, and Kaktovik, but also occur in all nearshore areas during open water seasons and some activities occur to a limited extent in this area during winter. In winter fishing is generally conducted by gill nets threaded through holes in the ice or by jigging. In summer, rod and reel, gill net, and jigging are techniques used to capture fish. Species harvested for subsistence purposes include Pacific herring, Dolly Varden char, whitefishes, Arctic and saffron cod, and sculpins.

### 4.2.3 Recreational Fishery

At this time, there are few recreational fisheries in the Arctic Management Area, including no catch and release fishery management programs. Personal use fisheries may occur on a variety of species, occasionally in EEZ waters, but little data are available and these probably occur on a very small scale. Personal use fisheries may more accurately be described as subsistence fisheries, although there may be some level of "sport" fishing activity near Kotzebue or Barrow. Most recreational catch in the Arctic likely would occur in state waters and thus fall under the classification of sport, subsistence or personal use fisheries and these fisheries are regulated by Alaska state law.

## 4.3 Economic and Socioeconomic Characteristics of the Fishery

Other than a small, local red king crab fishery in the southeastern Chukchi Sea, as described in Appendix A, no commercial fisheries occur in the Arctic Management Area. Coastal communities in the Arctic Management Area all may have residents that participate in fisheries, primarily for subsistence and personal use. These fisheries are almost exclusively in inland areas, or along the coast or in river delta waters, and thus would be under management authority of the State of Alaska. Regional commerce centers are in Barrow and Kotzebue, where government, commerce, and transportation support for regional communities are located.

## 4.4 Ecosystem Characteristics

### 4.4.1 Description of the Arctic Ecosystem

*Physical ecosystem characteristics*
The physical characteristics of Alaskan Arctic ecosystems arise from the larger context of their geography within the landbound Arctic region above 66.33 degrees North latitude, which include the extreme seasonality of sunlight (full sun 24 hours in summer, full darkness 24 hours in winter) and the presence of sea ice. Seasonally, winter darkness is associated with extreme cold and relatively calm weather, while light summers are cool, damp, and foggy, with more frequent rain and snow than winter. The Arctic Ocean itself is the world's smallest ocean at just over 14 million square km (a figure which includes the Barents, but not the Bering Sea, and represents an area approximately 1.5 times the size of the USA), and has limited exchange with the global ocean because it is surrounded by land masses with relatively shallow continental shelf less than 500 m deep along its entire margin. This unique "Mediterranean" sea is therefore strongly affected by land influences, including freshwater runoff (10% of worldwide runoff into 3% of total oceanic area) and the high pressure atmospheric systems and extreme cold associated with continental land masses, both of which contribute to ice formation. Another significant input into the Arctic Ocean arrives through the Bering Strait in the form of cool, low salinity Bering Sea water, which affects ecological dynamics in the Alaskan Arctic. However, 75% of the exchange between oceans occurs in the eastern Arctic with the Atlantic, with warm, high salinity water incoming and cold, lower salinity water outgoing through Fram Strait (Codispoti et al.1991, Niebauer 1991, CIA World Factbook 2008).

In addition to land and freshwater runoff, the presence of sea ice alters the structure of the ocean environment in the arctic. Ice covers the Arctic Ocean for much of the year, but it advances and retreats seasonally over the continental shelves. The wide continental shelves in the Arctic Ocean represent between one third and one half of its total area, much larger than for any other ocean basin. These wide shelves interacting with seasonal ice advance and retreat shape the water column properties in the Arctic Ocean and help maintain the more permanent ice cover found in the central basin. In turn, the advancing and retreating ice edge on the continental shelves is vitally important to the ecology of the coastal waters. There are two forms of ice in the Arctic: multi-year or perennial ice, which is more than 3 m thick and drifts throughout the central basin, and annually formed ice which is thinner (~1-2m) and covers much more area over the continental shelves, where it formed in nearshore areas by freshwater runoff and cold winds from land. Perennial ice tends to follow the general atmospheric circulation in the Arctic, moving clockwise in the Beaufort Sea for several years (westward along the northern Alaskan coast) and then joining a large general eastward flow of ice across the pole and towards the exit to the Atlantic at Fram Strait 5 to 6 years later. Perennial ice cover at the pole is maintained year-round by the stratification of the Arctic Ocean, which separates warm, salty Atlantic water deep below cooler, fresher continental shelf-derived water. Annual ice on the continental shelves forms seasonally and takes the form of bottom or land fast ice nearshore, and floating ice offshore. This ice may be blown into the central basin to contribute to perennial ice, or may melt the following summer, depending on the circulation patterns in the Arctic each year. Ice alters physical relationships on both the continental shelves and in the deep basin by altering tides, currents, mixing, and upwelling, as well as light absorption and reflection. The cycle of ice formation and retention is important to the resident and migratory inhabitants of the Arctic, and has very different patterns depending on the Arctic region (Carmack et al. 2006, Codispoti et al. 1991, Jones et al. 1991, Prinsenberg and Ingram 1991, Rigor et al. 2002).

In the Alaskan Arctic, there are three basic geographic regions, each with different ecology: two continental shelf regions, the Chukchi and Beaufort Seas, and the deep offshore region of the Beaufort Sea called the Canada Basin. We emphasize physical and ecological features of the shelf ecosystems, and not the deep basin in this description, because shelf ecosystems in general are where most fisheries take place worldwide. The wide, shallow Chukchi shelf is classified as an "inflow" shelf to the Arctic Ocean because Bering Sea water flowing through from the Pacific influences it characteristics, while the adjacent narrow Beaufort shelf is classified as an "interior" shelf, most influenced by river inputs (Carmack et al. 2006). The Chukchi and Beaufort Seas are very different physically and therefore ecologically, with differences extending to each of the major habitats in each area, including the nearshore, shelf, slope, and basin, the pelagic and benthic zones, and the ice associated habitats. The Alaskan portion of the Chukchi shelf is wide and shallow (58 m on average), similar to the Bering Sea, while the Alaskan portion of the Beaufort shelf is narrow and moderately shallow (80 m on average), dropping off steeply to the deep Canada Basin. The width of the Beaufort Sea shelf is similar to that seen in the northeastern Gulf of Alaska, but it is shallower, with barrier islands and large river deltas lining the coast (Norton and Weller 1984). Similar to the Gulf of Alaska shelf, dynamics on the Beaufort Sea shelf are affected by processes offshore in the deep basin, especially by currents there.

Although the Chukchi and Beaufort shelves are adjacent, the major currents affecting each come from opposite directions, with the exception of the Alaska Coastal Current which flows northward along the Alaskan coast of the Chukchi and continues eastward along the nearshore portions of the Alaskan Beaufort shelf (Fig 4-1; Grebmeier et al. 2006a, Woodgate et al. 2005, Aagaard 1984). Offshore, Bering Sea water generally flows northward through the Chukchi Sea from the Bering Strait, while surface flows along the outer Beaufort shelf are to the west due to the circulation of the Beaufort Gyre. Incoming waters to the Chukchi Sea from the Bering Sea are nutrient rich, especially along the Russian Coast from the Gulf of Anadyr, contributing to extremely high biological productivity in the Russian Chukchi Sea and high productivity on the Alaskan side. The incoming Alaska Coastal water is lower in both salinity and nutrients than the Bering Sea water. Some nutrients are transported around Point Barrow to the Beaufort Sea shelf in combined Bering Sea / Alaska Coastal water, and other nutrients are supplied by rivers, but in general nutrient supply to the Beaufort Sea as a whole is lower due to the dilution effect of low nutrient Atlantic origin water arriving from the north across the Arctic Ocean (McLaughlin et al. 2005).

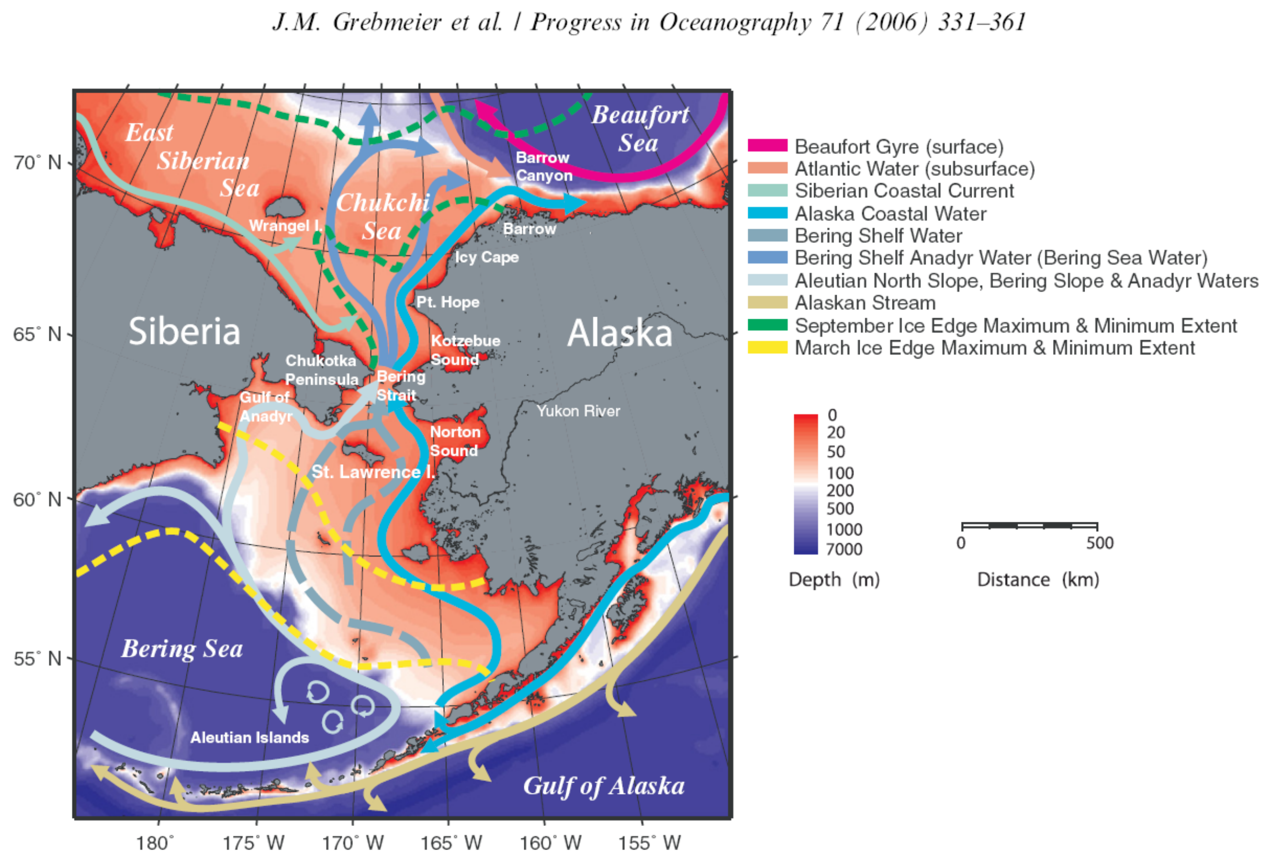


Figure 4-1 Major currents in the Alaskan Arctic region (Grebmeier et al. 2006a)

Seasonal ice formation and retreat occurs by different processes in the Chukchi and Beaufort seas, in general due to the physical differences described above. The Chukchi Sea can vary from full ice cover to full open water annually, with full ice cover typically extending for 6 months, approximately December to June (Woodgate et al. 2005). Ice cover lasts 9-10 months in the Beaufort Sea, from October through July (Norton and Weller 1984). Over the shallower Chukchi shelf, annual ice from local freezing and thawing is most common. The Beaufort Sea shelf can be affected by perennial ice from the central Arctic following the circulation of the Beaufort Gyre along the shelf break, as well as annual ice formed locally over the shelf. In both areas, remnants of annual landfast ice may remain near the coast during summer even if offshore ice is gone. There are often recurrent areas of open water (polynyas) during winter and spring along the Alaskan Chukchi coast and in the Beaufort Sea, which both alter physical characteristics by forming dense water (Carmack et al. 2006), and represent important areas of biological productivity during seasons with daylight, and therefore habitats for foraging birds and marine mammals (Stirling 1997). Ice cover's impact on biological production also makes seasonal differences in water masses flowing out of the Chukchi and into the Beaufort Sea/Canada Basin. In summer, water leaving the Chukchi shelf is relatively warmer, fresher, and depleted in nutrients but enriched in oxygen; the opposite occurs in the winter (Carmack et al. 2006, McLaughlin et al. 2005). These seasonal differences alter the eastward flowing current connecting the Chukchi and Beaufort Seas (Pickart 2004), thus changing the potential for biological production seasonally.

*Biological ecosystem characteristics*

In general, Arctic ecosystems are expected to have lower biological productivity than lower latitude ecosystems due to seasonal darkness and cold. However, there is considerable variability between Arctic systems. The physical characteristics of the Chukchi and Beaufort Seas described above lead to the distinctive ecological characteristics of each system. Overall, the combination of more time with open water and far higher nutrient inputs into the Chukchi Sea relative to the Beaufort Sea generates much higher biological productivity in the Chukchi. Estimates of primary productivity in the Arctic have wide ranges due to the extreme seasonality of production combined with high variability in conditions between years. However, the contrast between the areas remains clear despite these wide ranges: the Chukchi Sea (including the Russian portion) has a range of 20 to greater than 400 grams of carbon produced per square meter annually ($gC/m^2y$), while the Beaufort Sea (including the Canadian portion) has a narrower range of 30-70 $gC/m^2y$ (Carmack et al. 2006). This compares with the Eastern Bering Sea estimate ranging from less than 75 $gC/m^2y$ on the inner shelf to over 275 $gC/m^2y$ on the shelf break (Aydin and Mueter 2007, Springer et al. 1996), and to the Gulf of Alaska shelf estimate of 300 $gC/m^2y$ (Sambrotto and Lorenzen 1987).

Overall biological production is partitioned spatially and seasonally in the Alaskan Arctic ecosystems. Spatially, there is a clear longitudinal gradient in both benthic and primary production, with highest benthic biomass and chlorophyll observed in the Russian Chukchi Sea and progressively lower biomass observed to east towards the Alaskan coast (with the exception of the highly productive Hanna Shoal) and into the Beaufort Sea (Figs. 4-2 and 4-3; from Dunton et al. 2005).

Seasons and the associated ice cover lead to an annual productivity/migratory cycle driven by high production during ice free seasons and characterized by short food chains and animals with high lipid storage capacity and content at all trophic levels (Grebmeier et al. 2006a, Weslawski et al. 2006). Interannual variability in primary production is high due to variability in the timing and extent of ice retreat and reformation (Wang et al. 2005). Migratory marine mammals and birds forage in the Arctic in certain areas and at certain times according to the distribution of ice, bathymetric and other physical features (Moore et al. 2000). Here we describe a generalized seasonal productivity cycle, linking benthic and pelagic primary production, secondary production, and higher trophic level production in habitats defined by ice and bathymetry: the ice undersurface, the ice edge, open water, and shallow nearshore benthic habitats. In some areas such as Simpson Lagoon on the edge of the Beaufort Sea, annual primary production may be locally high and may contribute to offshore systems because some zooplankton and fish migrate inshore to feed seasonally, returning offshore as the lagoon freezes (Craig et al. 1984). Additional benthic primary production by macroalgae is limited to shallow nearshore areas and has been best described on the Alaskan Beaufort shelf, where boulder-kelp communities prevail (Dunton 1985, Dunton and Schell 1986, Dunton and Dayton 1995). While there are potentially important linkages between some nearshore habitats and the larger offshore ecosystems, we focus below on the open shelf habitats responsible for the bulk of productivity and comparable to others under current fishery management plans, then discuss fish, macroinvertebrates, and food webs in the Alaskan Arctic.

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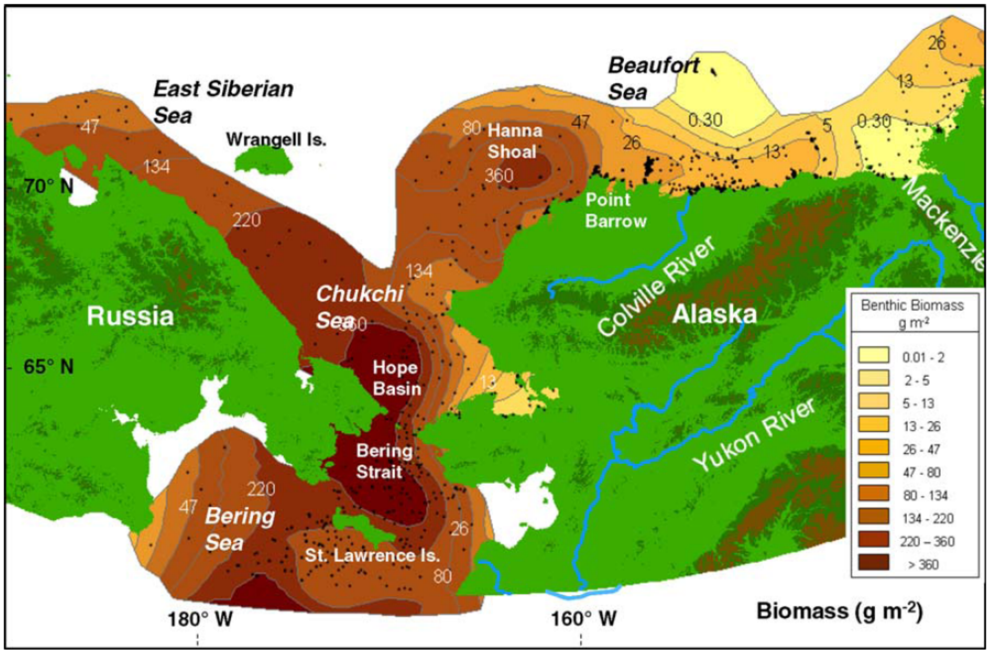


Figure 4-2 Distribution of benthic animal biomass in the Alaskan Arctic region (Dunton et. al 2005)

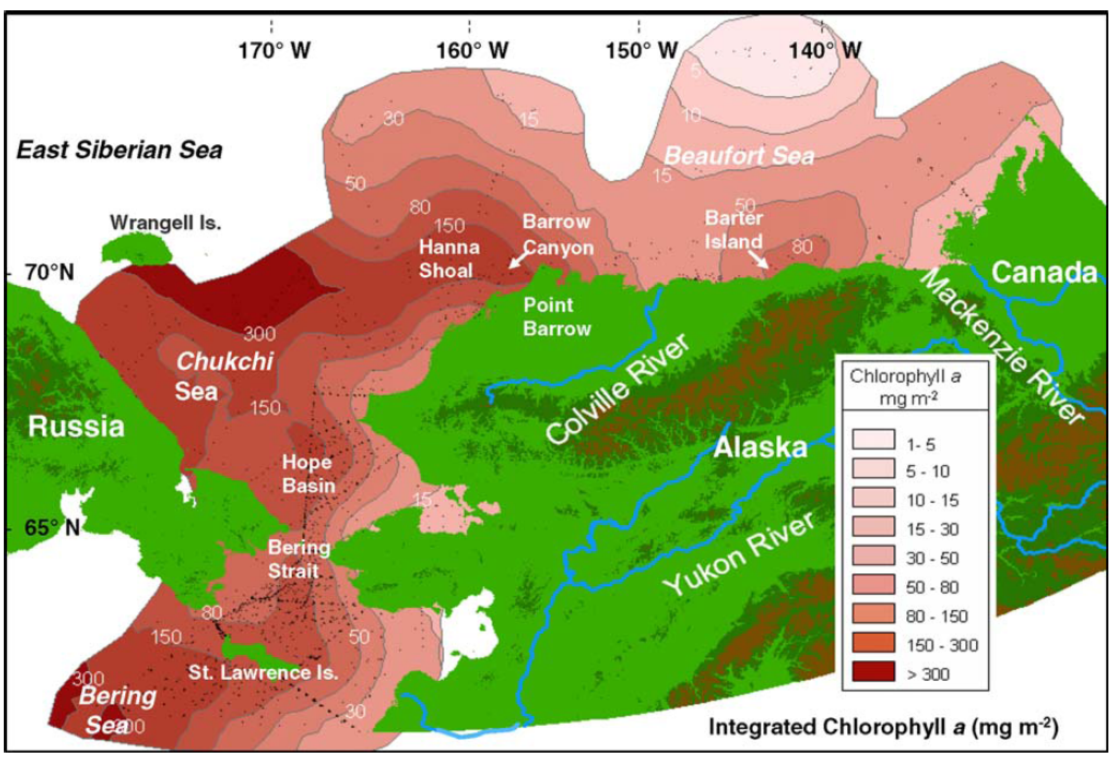


Figure 4-3 Distribution of Chlorophyll a (primary production) in the Alaskan Arctic region (Dunton et al. 2005)

Algae growing on the undersurface of the ice itself has a relatively small contribution to overall primary production in the ecosystem (4% of total production in the Chukchi and 5-10% in the Beaufort Sea; Carmack et al. 2006), but may represent a critically important forage concentration for grazers during late winter and early spring when there is little other primary production, forming an "upside-down benthos" for overwintering invertebrates (Conover and Huntley 1991). All life stages of certain amphipod and copepod species are associated with perennial ice, suggesting an ice-specific community exists in addition to open water zooplankton species feeding opportunistically on ice algae. In addition, turbellarians and nematodes are part of these perennial ice communities (Gradinger et al. 2005). Densities of these invertebrates can be locally high, in turn attracting foraging fish, most commonly the Arctic cod, *Boreogadus saida* (Gulliksen and Lonne 1991). However, most observations of Arctic cod and other larger animals are associated with the extremely productive (and more easily studied) ice edge habitat.

The ice edge habitat occurs seasonally in different areas as ice melts and moves to form cracks, leads, and polynyas in winter and spring, and eventually areas of fully open water in the summer. During light seasons, primary production is enhanced at the ice edge because fresher water from melting ice mixes with the nutrient rich water below to create a shallow, well-lit layer of nutrient rich water where large phytoplankton (diatoms) bloom at high rates relative to the surrounding water and ice (Niebauer 1991, Hill and Cota 2005, Hill et al. 2005). The ultimate fate of this high primary production depends on the ecosystem. For example, in the subarctic Bering Sea, ice edge bloom production is thought to sink to the bottom to enhance benthic production because pelagic zooplankton grow slowly and are less effective at grazing in cold water, thus they do not transfer the energy to other pelagic consumers (Mueter et al. 2006, Niebauer 1991). However, zooplankton species endemic to colder Arctic waters depend on this ice edge bloom (as well as ice algae, Conover and Huntley 1991) and there are clearly foraging predators associated with the ice edge habitat wherever it occurs, including open water zooplankton, Arctic cod, marine mammals (especially Beluga whales and ringed seals), and seabirds (murres and fulmars; Bradstreet and Cross 1982, Gulliksen and Lonne 1991, Moore et al. 2000, Gradinger and Bluhm 2004). In particular, Arctic cod fed on both ice-associated invertebrates and open water copepods and amphipods in ice edge habitats in the Canadian high Arctic, and were in turn fed on by five of six studied birds and mammals (Bradstreet and Cross 1982), suggesting that the link between ice edge primary production and pelagic zooplankton, fish, and apex predator production may be stronger in Arctic ecosystems than in the subarctic Bering Sea. The ice edge bloom on interior shelves like the Alaskan Beaufort shelf may account for half of the annual primary production (Carmack et al. 2006). Even in high Arctic areas, some of the ice edge bloom may sink to the benthos, enhancing benthic production; however, benthic biomass is relatively low on the Beaufort Sea shelf where ice edge blooms are most important (Dunton et al. 2005). There is close coupling between high benthic biomass and primary production in the Chukchi Sea, due to high primary production in nutrient rich open waters during its longer ice-free season (Grebmeier et al. 1988, Grebmeier and McRoy 1989, Dunton et al. 2005).

As open water habitat expands during the late spring (in the Chukchi Sea) and the summer (in the Beaufort Sea), different processes foster primary production away from the ice and determine its ultimate fate, depending on nutrient availability, habitat depth, and other physical features. While primary production is limited by the availability of sunlight early in the season and under the ice, in open waters later in the season there is plenty of light but primary production is limited by the availability of nutrients. Therefore, the generally high nutrient inputs into the well-mixed Chukchi Sea through the Bering Strait sustain a high level of primary production throughout the summer open water season, but these nutrients are depleted in water transported to "downstream" regions in the Beaufort Sea shelf and Canada Basin. Productivity is further limited by stratification of these deeper water columns, where intermittent mixing produces intermittent blooms (Dunton et al. 2005, Carmack et al. 2006). On the Beaufort shelf, years that had the lowest ice cover generally had higher primary productivity measurements (Horner 1984). In certain areas of the Chukchi and Beaufort shelves bathymetric features encouraging upwelling of deeper nutrient rich layers are associated with higher overall primary productivity, especially around Beaufort

Canyon in the far eastern Chukchi Sea (Hill and Cota 2005). In the south central Chukchi Sea, recurrent oceanographic fronts enhance primary and benthic productivity, attracting aggregations of gray whales (Bluhm et al. 2007). Similarly, oceanographic fronts in the Beaufort Sea concentrate pelagic phytoplankton and their grazers, copepods and euphausids, attracting foraging bowhead whales (Moore et al. 2000). The shelf break and canyon habitats of both the Chukchi and Beaufort seas are also areas of enhanced primary and secondary production where high densities of foraging birds and mammals are observed during the open water season (Harwood et al. 2005). Fish associations with these Arctic bathymetric and oceanographic features have received little study to date, although Arctic cod, one of the most common fish, feeds on similar zooplankton to bowhead whales (Frost and Lowry 1984). In the subarctic Bering Sea, open water phytoplankton blooms are thought to enhance pelagic fish (especially pollock) production at the expense of benthic production, via increased zooplankton grazing and production in the warmer open waters during early summer (Hunt et al. 2002, Mueter et al. 2006). Different mechanisms may operate on the Beaufort shelf, which appears more dependent on ice edge blooms yet has both a well developed pelagic food web (Frost and Lowry 1984, see below) and an observed decoupling of pelagic and benthic productivity (Dunton et al. 2006). The Chukchi shelf, in contrast, clearly has high benthic production directly coupled with high primary production in the open water column (Grebmeier et al. 1988, Grebmeier and McRoy 1989, Dunton et al. 1989, Dunton et al. 2005). The close coupling of high primary to high benthic productivity in the Chukchi provides the rich northern foraging grounds for migrating gray whales and other benthic feeders during the open water season (Coyle et al. 2007, Moore et al. 2000). However, the connections between primary and benthic production and fish production in the Alaskan Arctic remain less clear.

The fish and epifaunal invertebrates of the Alaskan Arctic are known mostly from the summer season open water habitat, where it is possible to use trawl survey sampling gear. In August-September of 1976-1977, 19 species of fish were found on the combined eastern Chukchi and western Beaufort Sea shelves off Alaska (Frost and Lowry 1983). The three most common species (by numbers, biomass was not reported) were Arctic cod, Canadian eelpout (*Lycodes polaris*), and twohorn sculpins (*Icelus bicornis*). Compared with the fish fauna of the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska, these most common fish were small (maximum size of 18 cm for Arctic cod, 24 cm for eelpouts, and 7 cm for sculpins). Brittle stars and crinoids were the most abundant invertebrates at most stations, often accounting for 75% or more of total trawl biomass. Larger crabs included Arctic lyre crab (*Hyas coarctatus)* and snow crab (*Chionoecetes opilio*), which were roughly equal in maximum size at 7.5 cm carapace length; however most crabs were smaller and given the size distribution observed, the number of mature individuals was expected to be low for snow crab (Frost and Lowry 1983). In an August-September 1990-1991 study restricted to the Chukchi Sea, 66 species of fish were found (Barber et al. 1997). Arctic cod was also the most common fish in this study, followed by saffron cod (*Eleginus gracilis)*; these two species combined accounted for 69% of fish biomass over the two year study. Sculpins in the genus *Myoxocephalus* were next most common. The distribution and abundance of fish between the two years studies differed widely, with much higher biomass overall recorded in 1990 and higher biomass in the southern portion of the study area in that year. No spatial trends were observed in 1991. Of 8 stations sampled in both years, little consistency was found in species biomass or composition in the same locations over time (Barber et al. 1997). Further analysis of the dataset from the Alaskan Chukchi shelf in 1990 revealed a similarly high ratio of invertebrates to fish as was found in the 1976-1977 study of Frost and Lowry (1983), with invertebrates accounting for more than 90% of total identified biomass. The top biomass invertebrate groups in 1990 were tunicates, sea stars, sea cucumbers and other echinoderms, jellyfish, snow crabs, and sponges. Snow crab biomass was more than double that recorded for Arctic cod in 1990 (data summarized by A. Greig, AFSC). Compared with 1991 trawl survey estimates of biomass in the eastern Bering Sea, the Chukchi shelf had lower fish and invertebrate biomass density overall, with the exception of tunicates, sponges, non-pandalid shrimp and small sculpins (Table 4-1, Fig 4-4). A survey is currently (August-September 2008) underway on the Alaskan Beaufort Sea shelf to update biomass estimates for the fish and invertebrate fauna there so that further comparisons with other managed Alaskan ecosystems will be possible in the future.

Table 4-1 Biomass estimates in metric tons for Chukchi Sea invertebrates and fish from a 1990 trawl survey, summarized by A. Greig (AFSC). Chukchi Density is biomass in tons divided by the estimated area of the Alaskan Chukchi shelf, 218,729 square km. E. Bering Density is tons per square km in the Eastern Bering Sea (shelf area 495,218 square km as reported in Aydin et al. 2007) for the 1991 bottom trawl survey where the comparable group had biomass estimated. In making these comparisons, we assume that survey selectivity for each group is similar between areas.

| Chukchi Group | Rank | Biomass | Chukchi Density | E. Bering Density |
|---|---|---|---|---|
| All invertebrates | | | 5.028074261 | 7.482607813 |
| All fish | | | 0.453578989 | 18.20035613 |
| | | | | |
| Tunicates | 1 | 274785 | 1.256279 | 0.3545 |
| Sea stars | 2 | 178987 | 0.818304 | 2.47136 |
| Urchins dollars cucumbers | 3 | 160230 | 0.732549 | 1.11966 |
| Scyphozoid jellies | 4 | 159982 | 0.731416 | |
| C. Opilio | 5 | 147196 | 0.67296 | 1.8667 |
| Sponges | 6 | 114997 | 0.52575 | 0.05449 |
| Arctic cod | 7 | 60042 | 0.274504 | |
| Hermit crabs | 8 | 29223 | 0.133604 | 0.889427 |
| Lg. sculpins | 9 | 12531 | 0.05729 | 0.54032 |
| Misc crabs | 10 | 11557 | 0.052837 | 0.059657 |
| Saffron cod | 11 | 10195 | 0.04661 | |
| Anemones | 12 | 10167 | 0.046482 | 0.10952 |
| Non-Pandalid shrimp | 13 | 6219 | 0.028432 | 0.00036 |
| Eelpouts | 14 | 4943 | 0.022599 | 0.074322 |
| Bering flounder | 15 | 3898 | 0.017821 | |
| Herring | 16 | 2874 | 0.01314 | 0.067143 |
| Sculpins | 17 | 2502 | 0.011439 | 0.006443 |
| Brittle stars | 18 | 2292 | 0.010479 | 0.283877 |
| Snails | 19 | 2260 | 0.010332 | 0.043351 |
| Misc Crustacean | 20 | 1305 | 0.005966 | |
| Misc. fish | 21 | 872 | 0.003987 | 0.082681 |
| Misc. worms | 22 | 460 | 0.002103 | |
| W. Pollock | 23 | 413 | 0.001888 | 10.30904 |
| Oth pel. smelt | 24 | 238 | 0.001088 | 0.003549 |
| Managed Forage | 25 | 252 | 0.001152 | 0.000149 |
| P. Cod | 26 | 199 | 0.00091 | 1.044407 |
| AK Plaice | 27 | 125 | 0.000571 | 1.0684 |
| King crab | 28 | 79 | 0.000361 | 0.21821 |
| pandalidae | 29 | 45 | 0.000206 | 0.011496 |
| YF Sole | 30 | 38 | 0.000174 | 4.83331 |
| Capelin | 31 | 34 | 0.000155 | 0.003477 |
| Gr. Turbot | 32 | 23 | 0.000105 | 0.02152 |
| Misc. Flatfish | 33 | 23 | 0.000105 | 0.145496 |
| Greenlings | 34 | 9 | 4.11E-05 | 9.58E-05 |
| Bivalves | 35 | 3 | 1.37E-05 | |

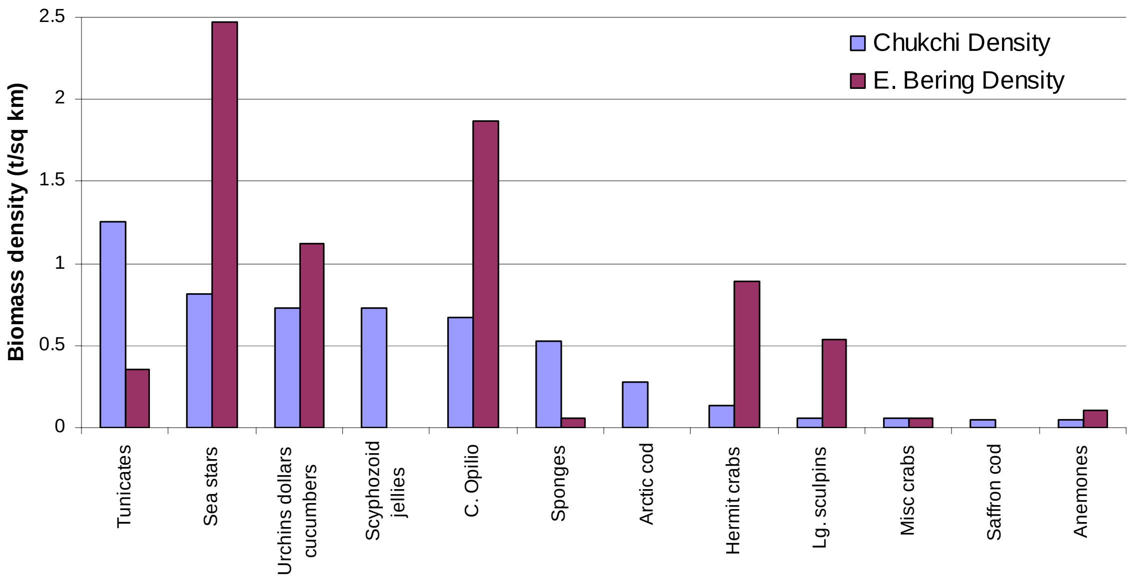


Figure 4-4 Top ranked Chukchi Sea biomass groups compared with EBS biomass for early 1990s

Both the limited available survey data and the more comprehensive Arctic marine mammal and bird literature prominently feature Arctic cod and saffron cod as locally abundant species in the Alaskan Arctic, and as critical components of pelagic food webs. In open water and/or ice edge habitats, Arctic cod are a key link converting the production of small animals (pelagic zooplankton and ice-associated small invertebrates) into useful forage for large animals (birds and mammals; Welch et al. 1993). Multiple predator diets (Beluga whales, ringed seals, ribbon seals, spotted seals, black-legged kittiwakes, glaucous gulls, ivory gulls, black guillemots, thick-billed murres, northern fulmars, and loons) are at least 50% Arctic cod in the Beaufort Sea, and over 90% Arctic cod in certain seasons and areas, especially during winter for foraging seals (Frost and Lowry 1984, Divoky 1984, Welch et al. 1993, Dehn et al. 2007, Bluhm and Gradinger 2008). Frost and Lowry (1984) estimated the consumption requirements for the most common marine mammals and birds in the pelagic food web of the Alaskan Beaufort shelf, and included Arctic cod as both forage for these predators and as a predator on zooplankton. An estimated 123,000 tons of Arctic cod were required to feed the Belugas, ringed seals, marine birds, and Arctic cod themselves in the Beaufort Sea. Belugas and ringed seals in particular were dependent on Arctic cod for a majority of their consumption, and birds for half their consumption requirements. A total of 2,000,000 metric tons of forage (copepods, euphausiids, pelagic amphipods, Arctic cod, and other prey) was required for all predators including Arctic cod, of which nearly half was copepods. The authors remarked that the level of zooplankton forage required was likely to be available in years with high primary productivity, but might not be available in low productivity years, suggesting that competition for these resources might occur between predators; specifically, between bowhead whales, ringed seals, and Arctic cod for copepods and euphausiids (Frost and Lowry 1984). The tight linkages described in this simple food web and potentially complex competitive interactions given environmental variability in primary production (which may vary with ice cover) suggest that adding another competitor (fishery) to this ecosystem could have highly unpredictable effects.

While many marine mammals and birds depend on the pelagic food web described above, others are equally dependent on the benthic food web in the Alaskan Arctic. Benthic clams and amphipods are important groups channeling the relatively high benthic production observed in the Chukchi Sea to birds and mammals, specifically walruses, bearded seals, and gray whales (Moore et al. 2000, Coyle et al.

2007, Dehn et al. 2007, Bluhm and Gradinger 2008). Quantitative consumption estimates similar to those presented above for the pelagic food web in the Beaufort Sea are not available for the benthic predators of the Chukchi (and Beaufort) shelves. Further information and work is necessary to determine the extent to which benthic and pelagic food webs may be linked in the Alaskan Arctic as they are in the Bering Sea, potentially switching between benthic and pelagic pathways (Hunt et al. 2002, Mueter et al. 2006), and/or with potentially strong flow through each pathway to predatory fish dependent on both (Aydin et al. 2007). The limited available trawl survey data reviewed above suggest that the high benthic and primary productivity observed in the Chukchi Sea may not indicate similarly high fish biomass as is observed in the Bering Sea. Some authors suggest that the close coupling of primary production with benthic invertebrate biomass results from short food chains and little grazing in the pelagic zone (Dunton et al. 1989), thus leaving little energy for high fish biomass, but considerable energy for large benthic foraging mammals.

*Human ecosystem characteristics*

Humans have inhabited the Alaskan Arctic and foraged in its marine ecosystems for thousands of years. Sea level rose to its current level between 4,500 and 4,200 years ago, at which time certain coastal areas were used seasonally for seal hunting and fishing according to archaeological sites along the Alaskan Chukchi coast. At one site (Cape Krusenstern), whaling clearly took place between 1400 and 1300 B.C., and in this same location primarily ringed seal and bearded seal bones were found in a layer dating from 0-1000 A.D. (Anderson 1984, Savinetsky et al. 2004). Off Point Barrow, whaling again took place starting around 1000 A.D. after an apparent 500 year gap; people living on this coast also hunted seals, birds, caribou, and fish and eventually lived in relatively large settlements at Point Hope and Barrow. Whaling gave way to fishing at Cape Krusenstern after 1400 A.D., apparently due to the absence of whales. While mammal and bird populations fluctuated substantially over this time period according to archaeological remains, these fluctuations appeared more driven by environmental variability than by human exploitation (Savinetsky et al. 2004). Coastal settlements and subsistence patterns remained relatively steady up until contact between the resident people and whaling ships from the east coast of the U.S. in the late 1800s (Anderson 1984).

The only large scale commercial fishery that has taken place in the Alaskan Arctic was for whales. Bowhead whales were discovered in the Bering Sea by the "Yankee whalers" around 1850 as a replacement for the dwindling Pacific right whales (Bockstoce 1978). The bowheads were heavily exploited by the Yankee whalers and were eventually pursued all the way up to their final summer refuge, feeding grounds in the Mackenzie River delta of the Beaufort Sea. During this hunt, the population of Pacific walrus was also reduced to a quarter its original size; idle whalers hunted the walrus for ivory while they waited for ice to break up or for bowheads to migrate by (Haycox 2002). Bowhead whaling eventually ended due to a combination of economic, social, and environmental forces. First, a directed Civil War attack on the Yankee whaling fleet in which 29 whaling vessels were destroyed and 38 more were captured significantly reduced fleet capacity (Mohr 1977). Then, the discovery of petroleum oil and associated invention of plastics diminished the demand for whale oil to light the lamps of Europe and America. Finally, a bad Arctic ice year (after many between 1871 and 1897) crushed a significant portion of the remaining active whaling vessels. In the end, it cost too much to catch the remaining bowhead whales for the companies to make any money on the products by the beginning of the 20$^{th}$ century (Bockstoce 1978).

Today, many of the settlements of the original Arctic Alaskans are still inhabited, and dependence on the marine ecosystem continues (Fig 4-5, from http://www.co.north-slope.ak.us/villages/barrow/). Barrow is the northernmost settlement in the United States, with a population over 4000 in 2006. The majority of Barrow residents are Inupiat Eskimos, and North Slope oil taxes fund many city services. Point Hope is the next largest community, with a population of over 700 residents, mostly Inupiat Eskimos who hunt, fish, and whale for subsistence. Wainwright is the next largest community on the North Slope, with a population of over 500 residents, including Inupiat bowhead whale and caribou hunters. Bowhead, gray, and beluga whale hunting are still community mainstays for subsistence in all of these villages, with hunters sharing catch throughout the community. However, there are modern concerns with climate change (see below) and contamination of high trophic level animals which are important to human subsistence in this region. The extreme seasonality of production and short food chains, combined with the preferential atmospheric transport of some contaminants to the Arctic may cause long-lived, lipid-rich marine mammals and birds to accumulate toxins which may threaten human health (Alexander 1995. Mallory et al. 2006). Finally, oil exploration represents the other major human activity on the North Slope, which brings both economic enrichment and the potential for contamination of ecosystems if there are spills or other industrial accidents. The community of Barrow has been active in seeking stricter environmental review of offshore oil exploration in order to preserve the offshore environment (Itta 2008).

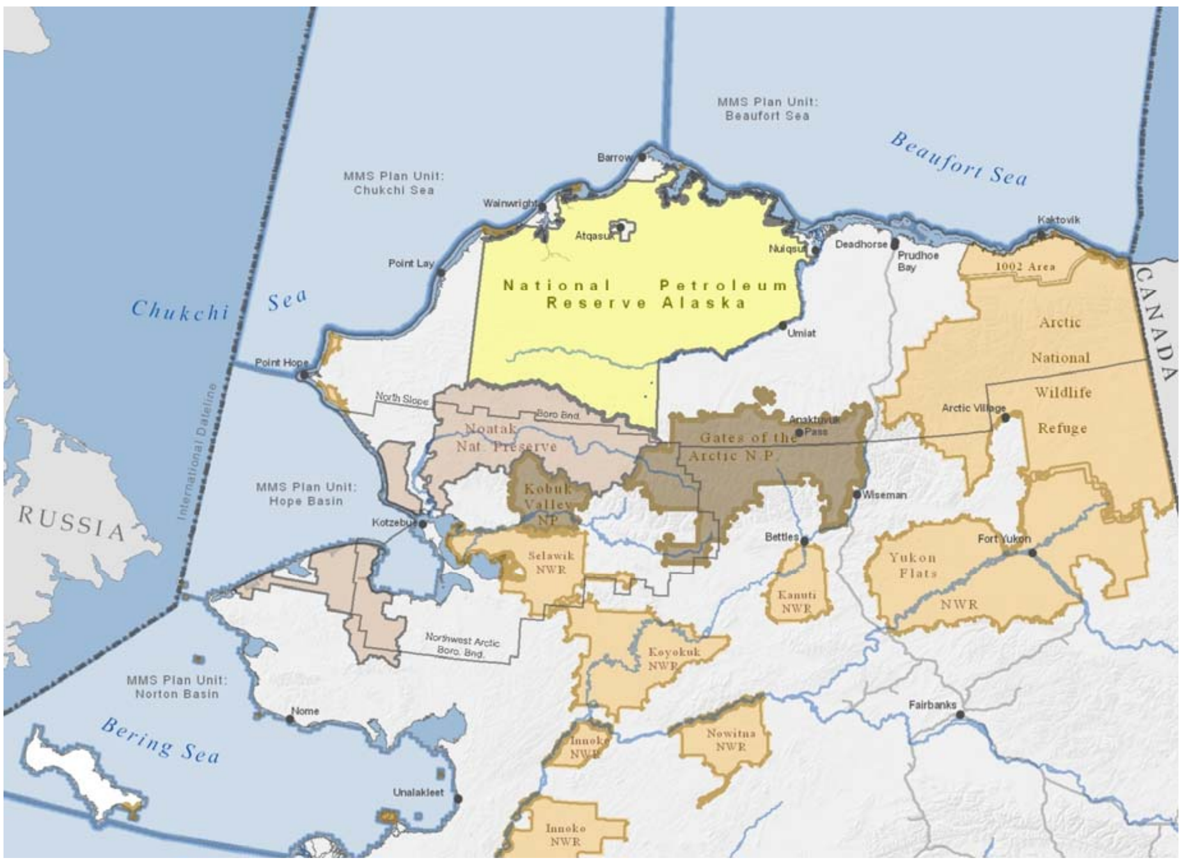

Figure 4-5 Villages and land status of the Alaska Arctic region (map by M. Geist and A. Couvillion, The Nature Conservancy).

### 4.4.2 Climate Change and the Arctic

This section describes in a general manner the climate change that is believed to be occurring in the North Pacific Ocean area and how that may be affecting the marine ecosystems of this region. Additional information on the Arctic specifically is provided in the EA/RIR/IRFA for the development of this FMP.

*The changing Arctic*

Certain aspects of the Alaskan Arctic ecosystems described above are changing rapidly; most notably, the physical attributes which drive much of the seasonal habitat availability and resultant primary production.

The most obvious change is the continuing decline in summer sea ice cover, which reached a new record minimum in September 2007 (Richter-Menge et al. 2007, Parkinson and Cavalieri 2008, Overland et al. 2008), and which has resulted in the replacement of nearly 30% of the perennial ice which existed in 1979 with annual ice (Carmack et al. 2006). Since perennial ice is generally thicker than annual ice, this suggests that annual ice may be more prone to quicker melting in the summer, both continuing the trend and perhaps increasing the overall variance of ice cover relative to past conditions. The perennial sea ice is also reportedly getting thinner overall, though measurements of ice thickness are more difficult to verify than ice coverage (Rothrock et al. 1999, Winsor 2001, Laxon et al. 2003). This reduction in ice cover is happening much faster than climate change models have predicted (Walsh 2008).

Changes in sea ice have direct effects on biological systems. Human foragers in the Arctic are immediately affected by earlier melts, thinner ice, ice further from shore, and changes in animal migratory patterns (Mallory et al. 2006, Krupnik and Ray 2007). For animals dependent on stable ice near relatively shallow areas as a foraging platform and for reproduction (polar bears, walrus, and ice seals), less ice represents less habitat and is therefore predicted to lead to range alteration, demographic effects, and population declines (Tynan and DeMaster 1997). Despite poor information on the population levels of many Arctic mammal species, this prediction appears to be validated for polar bears, which have associated changes in denning locations and body condition, and for walruses in the Chukchi Sea, where the ice edge retreated to deep water away from the continental shelf, restricting foraging and resulting in some pup abandonment (Lairdre et al. 2008). However, not all changes are predicted to have negative impacts. Bowhead whales might benefit from any increased productivity that might be associated with more open water in their current summer foraging habitats (Moore and Laidre 2006). Further, Arctic cod larval survival may increase if there are earlier melts and more open water following their winter spawning season (Fortier et al. 2006). Likewise, earlier ice breakup and more open water may benefit some marine birds (Mallory et al. 2006). However, the pelagic food web interactions described above may complicate the separate predictions for bowhead whales, marine birds, and Arctic cod, given that they may compete for any increased zooplankton production in open water systems.

An example of a more complex whole ecosystem change which may be driven by climate warming is occurring in the Northern Bering Sea, where a shift from strong benthic energy flow to one dominated by pelagic fish has been documented, in part due to range extensions into northern waters (Grebmeier et al. 2006b). Other changes in Arctic ecosystems are less directly attributable to climate change or even increased variability in physical conditions, and still others will be driven by human initiatives. For example, gray whales are now hypothesized to have exceeded their carrying capacity on the northern Bering Sea shelf, perhaps because concentrations of their primary prey, benthic amphipods, have declined (Coyle et al. 2007). While climate change was not implicated in the amphipod decline, any changes to the ecosystem resulting in lower productivity or less benthic pelagic coupling was predicted to exacerbate the decline, potentially affecting gray whales further. Finally, less ice and more open water may lead to increased human activities in the area, including oil exploration, shipping, and commercial fishing.

### *The North Pacific Ocean*

Evidence from observations during the past two decades and the results of modeling studies using historical and recent data from the North Pacific Ocean suggest that physical oceanographic processes, particularly climatic regime shifts, might be driving ecosystem-level changes that have been observed in the BSAI and GOA. Commercial fishing has not been largely implicated in BSAI and GOA ecosystem changes, but studies of other ecosystems with much larger fishing pressures indicate that fishing, in combination with climate change, can alter ecosystem species composition and productivity (Jennings and Kaiser 1998, Livingston and Tjelmeland 2000).

During 1997 and 1998, a period of warmer-than-usual ambient air temperatures (Hare and Mantua 2000), a number of unusual species occurrences were observed in the BSAI and GOA, including the following examples:

- In 1998, several warm-water fish species, including Pacific barracuda (*Sphyraena argentea*), were observed and/or caught in the GOA. Ocean sunfish (*Mola mola*) and chub mackerel (*Scomber japonicus*), occasionally recorded in southeast Alaskan waters, were documented there in unusually large numbers. Similarly, Pacific sleeper sharks (*Somniosus pacificus*) were caught (and released) in higher than normal levels in Cook Inlet, and salmon sharks (*Lamna ditropis*) were taken in fairly large numbers off Afognak Island (Kevin Brennan, ADF&G, personal communication).
- Spiny dogfish (*Squalus acanthias*) substantially increased in the Kodiak area and in Prince William Sound (Bill Bechtol and Dave Jackson, ADF&G, personal communication). In 1998, this species' inclusion in collection tows increased by more than 40 percent. A corresponding increase in spiny dogfish has been observed in the International Pacific Halibut Commission's GOA halibut longline bycatch surveys (Lee Hulbert, NMFS, personal communication).
- Individuals of several marine mammal species were seen at unusual times and/or places during 1998, including a Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) near Haines and a northern right whale (*Eubalaena glacialis*) off Kodiak Island.
- Unusual bird sightings in the GOA included a gray-tailed tattler (*Heteroscelus brevipes*) south of the Kenai Peninsula and a mallard (*Anas platyrhynchos*) several miles offshore in the open ocean. Common murre (*Uria aalge*) die-offs were reported in Cook Inlet, Kodiak, the eastern Aleutians, Resurrection Bay, and the eastern Bering Sea.
- Three northern elephant seals (*Mirounga angustirostris)* were spotted in nearshore waters around Unalaska during late June and early July, whereas they are usually found farther offshore and at a different time of year.
- There were poor returns of chinook (*Oncorhynchus tshawytscha*) and sockeye (*Oncorhynchus nerka*) salmon to Bristol Bay during both years.

Research on climate shifts as a forcing agent on species and community structure of the North Pacific Ocean can be found in Francis and Hare (1994), Klyashtorin (1998), McGowan *et al.* (1998), Hollowed *et al.* (1998), and Hare and Mantua (2000). The approach used in these studies assesses correlations between past climatic patterns and changes in biomass or recruitment rate for particular marine species. Because cause-and-effect relationships between temporal and spatial patterns of climate change and corresponding patterns of change in biological populations have not been proven for the BSAI and GOA, the correlations must be considered circumstantial. But there are reasons to expect that causal links do exist. For example, stronger recruitment would be expected under more favorable climatic conditions, because more juveniles would be likely to survive to adulthood, whereas harsh conditions would result in weak recruitment because fewer juveniles would survive. In both cases, the recruitment patterns would be reflected in the strength or weakness of the affected age groups within future fisheries.

Francis and Hare (1994) analyzed historical data supporting a climate shift that caused a precipitous decline in the sardine (*Sardinops sagax*) population off Monterey, California in the 1950s. Although it had been widely concluded that this decline resulted solely from overfishing, the data indicate instead that a change in sea surface temperature was closely correlated with the sardines' disappearance, and this related closely to patterns of sardine numbers in marine sediments off Southern California. Consequently, both climate and fishing are now recognized to be implicated in the sardine population decline.

Francis and Hare (1994) related the intensity of the Aleutian low pressure system (Aleutian low), a weather pattern, with production of salmon and zooplankton. Winter ambient air temperatures at Kodiak and the North Pacific Index, an index tracking the intensity of the Aleutian low during the winter, were used as indicators of climatic severity. Strong correlations were found between long-term climatic trends and Alaskan salmon production. Annual weather patterns were found to be closely correlated with changes in zooplankton populations.

For the northeastern North Pacific Ocean, McGowan *et al.* (1998) showed that interannual climatic variations linked to the ENSO and decadal-scale climate shifts can be detected in physical oceanographic data. For instance, the depth of the mixed layer in the California Current and GOA became shallower over time, whereas the mixed-layer depth in the Central Pacific deepened during the same period. This was not, however, reflected in the mass flow of the California Current. Greater depth of the mixed layer during elevated sea surface temperature events was correlated with decreased nutrient availability, plankton abundance, and shifts in community structure. These researchers concluded that climatic events such as ENSO are correlated with changes in biological populations associated with the California Current. Biological processes in the GOA appear to be more strongly influenced by variations in the Aleutian low.

According to McGowan *et al.* (1998), climate-related changes in the biological communities of the California Current system ranged from declines in kelp forests to shifts in the total abundance and dominance of various zooplankton species. Some fish and invertebrate populations declined, and the distributional ranges of species shifted northward. In addition, seabird and marine mammal reproduction were apparently affected by El Niño-Southern Oscillation (ENSO) conditions. Interdecadal changes in community structure also occurred, with intertidal communities becoming dominated by northward-moving southern species and changes in species proportions occurring in most other sectors of the ecosystem.

Interdecadal shifts observed in the northeastern North Pacific Ocean ecosystem have been of the opposite sign from those in the California Current system, with increases in zooplankton biomass and salmon landings observed in the GOA (McGowan *et al.* 1998, Francis and Hare 1994). These shifts have corresponded to the intensity and location of the winter mean Aleutian low, which changes on an interdecadal time scale.

Klyashtorin (1998) linked catch dynamics of Japanese sardines, California sardines, Peruvian sardines, Pacific salmon, Alaska pollock, and Chilean jack mackerel in the Pacific with an atmospheric circulation index that shows trends similar to the North Pacific Index used by other researchers. Other species, such as Pacific herring and Peruvian anchovy, are negatively associated with this index.

Hollowed *et al.* (1998) analyzed oceanographic and climatic data from the eastern North Pacific Ocean and compared those data with information on recruitment for 23 species of groundfish and five non-salmonid species and with catch data for salmon. The fish recruitment data were compared to environmental factors over various time scales and with varying time lags. Hollowed *et al.* (1998) found that, for species such as pollock, cod, and hake, recruitment was generally stronger during ENSO events. Whereas salmon and large-mouthed flatfish such as arrowtooth flounder, Greenland turbot, and Pacific halibut responded more strongly to longer-term events such as decadal-scale climatic regime shifts. Because both ENSO and decadal-scale ecosystem shifts are environmentally controlled, the results of this analysis support climate change as an important controlling factor in ecosystem dynamics.

There is considerable evidence that decadal and basin-scale climatic variability can affect fish production and ecosystem dynamics. Sudden basin-wide shifts in climatic regime have been observed in the North Pacific Ocean (Mantua *et al.* 1997), apparently due to changes in atmospheric forcing. Eastward- and northward-propagating storm systems dominate the wind stress on surface waters for short periods (less than one month), mixing the upper layers and altering sea surface temperatures (Bond *et al.* 1994). Because fish are very sensitive to ambient water temperature, even changes in surface temperature, if sufficiently frequent or prolonged, can alter fish distribution and reproductive success as well as recruitment (the number of juveniles that survive to enter the adult, reproducing portion of the population).

In a long-term trends analysis by computer, Ingraham and Ebbesmeyer (Ingraham *et al.* 1998) used the Ocean Surface Current Simulator model to simulate wind-driven surface drift trajectories initiated during winter months (December through February) for the period 1946 to present. The model-generated endpoints of the 3-month drift trajectories shifted in a bimodal pattern to the north and south around the mean. The winter flow during each year was persistent enough to result in a large displacement of surface mixed-layer water. The displacement also varied in a decadal pattern. Using the rule that the present mode is maintained until three concurrent years of the opposite mode occur, four alternating large-scale movements in surface waters were suggested: a southward mode from 1946 to 1956, a northward mode from 1957 to 1963, a southward mode from 1964 to 1974, and a northward mode from 1975 to 1994. As more northern surface water shifts southward, colder conditions prevail farther south, and as southward water moves northward, warmer conditions prevail farther north, both potentially affecting fish distribution and population dynamics.

Real-world evidence that atmospheric forcing alters sea surface temperatures comes from two principal sources: shorter-term ENSO events and longer-term Pacific Decadal Oscillations (Mantua *et al.* 1997). Temperature anomalies in the BSAI and GOA indicate a relatively warm period in the late 1950s, followed by cooling especially in the early 1970s, followed by a rapid temperature increase in the latter part of that decade. Since 1983, the BSAI and GOA have undergone different temperature changes. Sea surface temperatures in the BSAI have been below normal, whereas those in the GOA have been generally above normal. Consequently, the temperature difference between the two bodies of water has jumped from about 1.1° C to about 1.9° C (U.S. GLOBEC 1996).

Subsurface temperatures, potentially an even more important influence on biological processes, have been documented to change in response to climatic drivers. There was a warming trend in subsurface temperatures in the coastal GOA from the early 1970s into the 1980s similar to that observed in GOA sea surface waters (U.S. GLOBEC 1996).

In addition, seawater temperature changes in response to ENSO events occurred, especially at depth, in 1977, 1982, 1983, 1987, and in the 1990s. The 1997-1998 ENSO event, one of the strongest recorded in the twentieth century, substantially changed the distribution of fish stocks off California, Oregon, Washington, and Alaska. The longer-term impacts of the 1997-1998 ENSO event remain to be seen. Francis *et al.* (1998) reviewed the documented ecological effects of this most recent regime shift through lower, secondary, and top trophic levels of the North Pacific Ocean marine ecosystem. Some of the following impacts on higher trophic levels are based on this review:

- Parker *et al*. (1995) demonstrated marked similarities between time series of the lunar nodal tidal cycle and recruitment patterns of Pacific halibut.
- Hollowed and Wooster (1995) examined time series of marine fish recruitment and observed that some marine fish stocks exhibited an apparent preference (measured by the probability of strong year and average production of recruits during the period) for a given climate regime.
- Hare and Francis (1995) found a striking similarity between large-scale atmospheric conditions and salmon production in Alaska.
- Quinn and Niebauer (1995) studied the Bering Sea pollock population and found that high recruitment coincided with years of warm ocean conditions (above normal air and bottom temperatures and reduced ice cover). This fit was improved by accounting for density-dependent processes.

Additional evidence of marine ecosystem impacts linked to climatic forcing comes from Piatt and Anderson (1996), who provided evidence of possible changes in prey abundance due to decadal-scale climate shifts. These authors examined relationships between significant declines in marine birds in the northern GOA during the past 20 years and found that statistically significant declines in common murre populations occurred from the mid- to late 1970s into the early 1990s. They also found a substantial alteration in the diet composition of five seabird species collected in the GOA from 1975 to 1978 and from 1988 to 1991, changing from a capelin-dominated diet in the late 1970s to a diet in which capelin was virtually absent in the later period.

The effects of ten-year regime shifts on the inshore GOA were analyzed using data from 1953 to 1997 (Anderson and Piatt 1999). Three taxonomic groups dominated (approximately 90 percent) the biomass of commercial catches during this period: shrimp, cod and pollock, and flatfish. When the Aleutian low was weak, resulting in colder water, shrimp dominated the catches. When the Aleutian low was strong, water temperatures were higher, and the catches were dominated by cod, pollock, and flatfish. Similar results were reported in very nearshore areas of lower Cook Inlet (Robards *et al.* 1999).

Few patterns were seen in the less-common species over the course of the study. Generally, the transitions in dominance lagged behind the shift in water temperature, strengthening the argument that the forcing agent was environmental. However, different species responded to the temperature shift with differing time lags. This was most evident for species at higher trophic levels, which are typically longer-lived and take longer to exhibit the effects of changes. The evidence suggests that the inshore community was reorganized following the 1977 climate regime shift. Although large fisheries for pandalid shrimp may have hastened the decline for some stocks (Orensanz *et al.* 1998), unfished or lightly fished shrimp stocks showed declines. Both Orensanz *et al.* (1998) and Anderson and Piatt (1999) concluded that the large geographic scale of the changes across so many taxa is a strong argument that climate change is responsible.

Other studies have linked production, recruitment, or biomass changes in the BSAI with climatic factors. For example, a climate regime shift that might have occurred around 1990 has been implicated in a large increase in gelatinous zooplankton in the BSAI (Brodeur *et al.* 1999). Recruitment in both crabs and groundfish in the BSAI has been linked to climatic factors (Zheng and Kruse 1998, Rosenkranz *et al.* 1998, Hollowed *et al.* 1998, Hare and Mantua 2000). Irons et al. (2008) reported correlations between murre population declines or increases in polar regions in synchrony with climate regime shifts in 1977 and 1989. They suggested the murre population declines were presumably linked to changes in the underlying food base associated with the climate changes.

There are indications from several studies that the BSAI ecosystem responds to decadal oscillations and atmospheric forcing, and that the 1976-1977 regime shift had pronounced effects. A peak in chlorophyll concentrations in the late 1970s was closely correlated with an increase in summer mixed-layer stability documented at that time (Sugimoto and Tadokoro 1997). Also, on a decadal time scale, chlorophyll concentrations in the summer were positively correlated with winter wind speeds, indicating a positive response of BSAI phytoplankton to stronger Aleutian lows (Sugimoto and Tadokoro 1997).

Evidence of biological responses to decadal-scale climate changes are also found in the coincidence of global fishery expansions or collapses of similar species complexes. Sudden climate shifts in 1923, 1947, and 1976 in the North Pacific Ocean substantially altered marine ecosystems off Japan, Hawaii, Alaska, California, and Peru. Sardine stocks off Japan, California, and Peru exhibited shifts in abundance that appear to be synchronized with shifts in climate (Kawasaki 1991). These historical 60-year cycles are seen in paleo-oceanographic records of scales of anchovies, sardines, and hake as well. Other examples are salmon stocks in the GOA and the California Current whose cycles are out of phase. When salmon stocks do well in the GOA, they do poorly in the California Current and vice-versa (Hare and Francis 1995, Mantua *et al.* 1997).

In addition to decadal-scale shifts, interannual events such as the ENSO can have significant impacts on fish distribution and survival, and can affect reproduction, recruitment, and other processes in ways that are not yet understood. This is particularly true for higher-latitude regions such as the northern California Current and GOA. As noted above, the 1997-1998 ENSO event significantly changed the distribution of fish stocks off California, Oregon, Washington, and Alaska. A change that has persisted to the present. Predicting the implications of this trend for future fishery management is problematic, in part because ENSO signals propagate from the tropics to high latitudes through the ocean as well as through the atmosphere, and it is difficult to separate these two modes of influence. Information on the dynamics of North Pacific Ocean climate and how this is linked to equatorial ENSO events is not adequate to adjust fisheries predictions for such abrupt, far-reaching, and persistent changes. Warm ocean conditions observed in the California Current during the present regime may be due, in large part, to the increased frequency of ENSO-like conditions.

In conclusion, evidence from past and present observations and modeling studies at the community and ecosystem levels for the BSAI and GOA suggest that climate-driven processes are responsible for a large proportion of the multi-species and ecosystem-level changes that have been documented. Modeling studies have been a valuable tool for elucidating the possible long-term implications of various fishing strategies. As with all computer-based models, these have been sensitive to unproven assumptions about recruitment and its relationship to climate. As the preceding discussion suggests, the models could be improved by incorporating components that include climatic effects on species, particularly with respect to recruitment. However, this approach has not been widely applied yet to species in the BSAI and GOA ecosystems.

### 4.4.3 Interactions Among Climate, Commercial Fishing, and Ecosystem Characteristics

Commercial fishing and climate-driven physical oceanographic processes interact in complex ways to affect the marine ecosystem. To characterize these interactions, it is necessary to distinguish, where feasible, the separate effects of fishing and climate on biological populations. At this time, the Council intends to prohibit commercial fishing in the Arctic Management Area. Should the Council in the future decide to consider a commercial fishery, an analysis of this fishery's interactions with the Arctic ecosystem and its components will be completed. That analysis would be part of the planning process undertaken by the Council to fully evaluate potential fishery effects on the Arctic, including analyses of the synergistic effects of fishing under climate change scenarios.

# Chapter 5 Relationship to Applicable Law and Other Fisheries

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) is the primary domestic legislation governing management of the U.S. marine fisheries. The relationship of the Fishery Management Plan (FMP) for Fish Resources of the Arctic Management Area with the Magnuson-Stevens Act and other applicable Federal law is discussed in Section 5.1. The relationship of the FMP to international conventions is addressed in Section 5.2. The relationship of the FMP to other federal fisheries is addressed in Section 5.3, and to State of Alaska fisheries in Section 5.4.

## 5.1 Relationship to the Magnuson-Stevens Act and Other Applicable Federal Law

The Arctic FMP is consistent with the Magnuson-Stevens Act (16 USC 1851), including the ten National Standards, and other applicable law.

## 5.2 Relationship to International Conventions

The U.S. is party to many international conventions. One that directly or indirectly addresses conservation and management needs of fish resources of the Arctic Management Area is the Convention for the Preservation of the Halibut Fishery of the North Pacific Ocean and the Bering Sea (basic instrument for the International Pacific Halibut Commission – IPHC).

The IPHC was created to conserve, manage, and rebuild the halibut stocks in the Convention Area to those levels which would achieve and maintain the maximum sustainable yield from the fishery. The halibut resource and fishery have been managed by the IPHC since 1923. The IPHC was established by a Convention between the United States and Canada, which has been revised several times to extend the Commission's authority and meet new conditions in the fishery. "Convention waters" are defined as the waters off the west coasts of Canada and the United States, including the southern as well as the western coasts of Alaska, within the respective maritime areas in which either Party exercises exclusive fisheries jurisdiction. Under the Protocol to the Convention, the Commission retains a research staff and recommends, for the approval of the Parties, regulations regarding: 1) the setting of quotas in the Convention Area, and 2) joint regulation of the halibut fishery in the entire Convention Area under Commission regulations. Neither U.S. nor Canadian halibut fishing vessels are presently allowed to fish in the waters of the other country.

Halibut may occur in U. S. EEZ waters of the Arctic, although no commercial harvests have occurred in the region. Some experimental fishing for halibut has occurred in the past. No known or anticipated issues associated with halibut management between the Council and the IPHC are likely in the Arctic.

## 5.3 Relationship to Other Federal Fisheries

The North Pacific Fishery Management Council (Council) has implemented five other FMPs in the U.S. EEZ off Alaska. These FMPs govern groundfish fishing in the Gulf of Alaska (GOA), groundfish fishing in the Bering Sea/Aleutian Islands (BSAI), king and tanner crab fishing in the BSAI, scallop fishing in the U. S. EEZ off Alaska, and salmon fishing in the U. S. EEZ off Alaska. The relationship of the Arctic FMP with these other management plans is discussed below.

### 5.3.1 Gulf of Alaska and Bering Sea/Aleutian IslandsGroundfish FMPs

The BSAI and GOA groundfish fisheries are managed in close connection with one another. While many of the same groundfish species occur in both the BSAI and GOA management areas, they are generally considered to be separate stocks. There is some overlap between participants in the BSAI and GOA groundfish fisheries. Many of the management measures and much of the stock assessment science are similar for the two areas. Management measures proposed for the BSAI groundfish fisheries are analyzed for potential impacts on GOA fisheries, and vice versa. Where necessary, mitigation measures are adopted to protect one area or the other (for example, sideboard measures in the AFA pollock cooperatives). The BSAI groundfish FMP terminates at Bering Strait; although the FMP and implementing regulations specify a Chukchi Sea reporting area, this area is not part of the BSAI groundfish management area. The Arctic FMP manages commercial fisheries in the Arctic, and if stocks of groundfish harvested under authority of the BSAI groundfish FMP move northward, conceivably the Arctic FMP could be amended to provide for fishing on these stocks. Under this condition, the Council would coordinate management measures between the BSAI region and the Arctic Management Area to ensure consistent management of fisheries on fish stocks that may occur in both regions.

### 5.3.2 BSAI King and Tanner Crab FMP

Domestic fishing for crab for the most part predates the domestic groundfish fishery, and since the inception of the BSAI and GOA Groundfish FMPs the consideration of crab bycatch in the groundfish fisheries has been paramount. The crab species are considered prohibited in the BSAI and GOA groundfish fisheries, with any catch required to be returned immediately to the sea with a minimum of injury so as to discourage targeting on those species. Directed fishing for crab harvests occurs only in the BSAI and to a very limited extent in the southeastern Chukchi Sea.

Prior to implementation of the Arctic FMP, the Council's crab management extended northward from the BSAI management area into the southern Chukchi Sea to the latitude of Point Hope. The crab FMP has been amended to terminate its coverage at Bering Strait so that the Council may implement a comprehensive multi-species FMP for all Arctic waters. The Arctic FMP now governs any crab fishing that may occur in the southern Chukchi Sea, which currently is limited to an exempted red king crab fishery described in Appendix A whose management is deferred to the State of Alaska. No commercial crab fishery is authorized under the Arctic FMP. Any other crab fishery that may develop in the future would be managed under the Arctic FMP.

### 5.3.3 Scallop FMP

Scallop management extends northward from the BSAI management area to Bering Strait. No commercial scallop fishery is authorized under the Arctic FMP. Any scallop fishery that may develop in the future would be managed under the Arctic FMP.

### 5.3.4 Salmon FMP

Pacific salmon are a prohibited species in the BSAI and GOA groundfish FMPs, and Pacific salmon are categorized as a prohibited species in the Arctic FMP under option 2. There is no fishing for salmon allowed in the U. S. EEZ off Alaska except for several small areas where traditional State salmon fisheries extended into Federal waters and are thus exempt from this prohibition (Copper River flats, Cook Inlet, the Southeast troll fishery, and Area M in the western GOA). The BSAI and GOA groundfish FMPs include management measures to reduce the bycatch of salmon in federal waters, including catch limits and area closures. No commercial salmon fishery is authorized under the Arctic FMP.

## 5.4 Relationship to State of Alaska Fisheries

The Constitution of the State of Alaska states the following in Article XIII:

Section 2 General Authority. The legislature shall provide for the utilization, development, and conservation of all natural resources belonging to the State, including land and waters, for the maximum benefit of the people.

Section 4 Sustained Yield. Fish, forest, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the sustained yield principle, subject to preferences among beneficial uses.

Section 15 No Exclusive Right of Fishery, has been amended to provide the State the power "to limit entry into any fishery for purposes of resource conservation" and "to prevent economic distress among fishermen and those dependent upon them for a livelihood".

The relationship of the Arctic FMP with State of Alaska fisheries is discussed below.

### 5.4.1 State whitefish fishery

A small State water fishery for whitefish is permitted in the central Alaskan Beaufort Sea in the area of the Colville River delta. This fishery occurs partly in brackish marine waters in the delta or in more fresh waters in the lower Colville River. This fishery does not extend offshore into, or even close to, Federal EEZ waters. Under option 2, whitefish are considered a prohibited species, and must be immediately returned to the sea with a minimum of injury.

### 5.4.2 State shellfish fishery

This Arctic FMP exempts the red king crab fishery of the size and scope of the historic fishery in the geographic area where the fishery has historically occurred in the southeastern Chukchi Sea and defers its management to the State of Alaska. The closest crab fishery authorized under the Council's crab FMP occurs in the Norton Sound area; management of this fishery is largely deferred to the State, although the Council retains oversight and principal aresponsibility for management of this fishery. This fishery does not extend northward of Bering Strait. Under option 2, red king crab are considered a prohibited species, and must be immediately returned to the sea with a minimum of injury.

### 5.4.3 State salmon fishery

Pacific salmon are a prohibited species in the BSAI and GOA groundfish FMPs, and Pacific salmon are categorized as a prohibited species under option 2 and must be immediately returned to the sea with a minimum of injury. There is a commercial salmon fishery managed by the State of Alaska and prosecuted in the Kotzebue Sound region, but no salmon fishery is authorized in the Arctic FMP for the Arctic Management Area.

### 5.4.4 State herring fishery

Pacific herring are harvested in State waters in parts of Alaska, but no commercial harvest of herring occurs in the Arctic Management Area. Under option 2 Pacific herring are considered a prohibited species, and must be immediately returned to the sea with a minimum of injury. The State may allow a Pacific herring fishery in State waters in the future.

### 5.4.5 State water subsistence fishery

Subsistence fisheries in Alaska are managed by the State or through the Federal Subsistence Board if occurring on Federal lands, and take place primarily in state waters. While subsistence fishing is an important sociocultural activity in Arctic waters, the Arctic FMP would not affect these fisheries. As mentioned above, many subsistence species such as Pacific salmon, Pacific herring, whitefish, and Dolly Varden char are considered prohibited species under option 2, and must be immediately returned to the sea with a minimum of injury.

# Chapter 6 Fishery Impact Statement

A fishery impact statement is required by the MSA, section 303(a)(9). Because the Arctic FMP does not authorize any commercial fishery and no commercial fishery currently occurs in the Arctic, except as described in Appendix A, no fishery impact is expected. No participants or communities in a fishery would be affected. By prohibiting commercial fishing, the FMP provides protection to marine resources that may be used by those living in the Arctic region, particularly those dependent on marine resources for subsistence. No fisheries are conducted in adjacent areas that are under the authority of another regional management council. This FMP prevents fishing activities that may pose a safety risk and is therefore protective of human life at sea.

# Chapter 7 References

This chapter contains references for the Arctic FMP. Section 6.1 describes the sources of available data regarding U. S. EEZ in the Arctic and adjacent fisheries, including annually updated reference material. Section 6.2 provides management and enforcement considerations for the Arctic fisheries. A list of the literature cited in the FMP is included in Section 6.3.

## 7.1 Sources of Available Data

The Council developed the Arctic FMP based on the best available scientific information. Any amendments to the FMP would be based on the best available scientific information at the time. Unless a sufficient biomass of a commercially-desirable stock is determined to warrant a fishery, it is unlikely that this FMP will be frequently updated with new stock information. However, the North Pacific Fishery Management Council (Council) (Section 7.1.1), the NMFS Alaska Fisheries Science Center (AFSC) (Section 7.1.2), and the NMFS Alaska Region office (Section 7.1.3) each produce an abundance of reference material that is useful for understanding U. S. EEZ off Alaska fisheries. The sections below provide an overview of the types of reports and data available through the various organizations and their websites.

### 7.1.1 North Pacific Fishery Management Council

#### 7.1.1.1 Stock Assessment and Fishery Evaluation Report

The *Stock Assessment and Fishery Evaluation* (SAFE) report is compiled annually by the BSAI Groundfish Plan team, which is appointed by the Council. The sections are authored by AFSC and State of Alaska scientists. As part of the SAFE report, a volume assessing the *Economic Status of the Groundfish Fisheries off Alaska* is also prepared annually, as well as a volume on *Ecosystem Considerations*. The SAFE report may contain information on species of fish or shellfish, or related ecosystem information, that may be relevant to the adjacent Arctic since many BSAI species occur in waters of the Chukchi Sea, and in some cases the Beaufort Sea.

The SAFE report provides information on the historical catch trend, estimates of the maximum sustainable yield of the groundfish complex as well as its component species groups, assessments on the stock condition of individual species groups; assessments of the impacts on the ecosystem of harvesting the groundfish complex at the current levels given the assessed condition of stocks, including consideration of rebuilding depressed stocks; and alternative harvest strategies and related effects on the component species groups.

The SAFE report annually updates the biological information base necessary for multispecies management. It also provides readers and reviewers with knowledge of the factual basis for total allowable catch (TAC) decisions, and illustrates the manner in which new data and analyses are used to obtain individual species groups' estimates of acceptable biological catch and maximum sustainable yield.

Copies of the most recent SAFE report are available online (see below), and by request from the North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, Alaska, 99501.

#### 7.1.1.2 Council Website

Much of the information produced by the Council can be accessed through its website, to be found at:

http://www.fakr.noaa.gov/npfmc

The information available through the website includes the following.

- FMPs: summaries of the FMPs as well as the FMPs themselves are available on the website.
- Meeting agendas and reports: annual harvest specifications, amendments to the FMPs or implementing regulations, and other current issues are discussed at the five annual meetings of the Council. Meeting agendas, including briefing materials where possible, and newsletter summaries of the meeting are available on the website, as well as minutes from the meetings.
- Current issues: the website includes pages for issues that are under consideration by the Council, including amendment analyses where appropriate.

### 7.1.2 NMFS Alaska Fisheries Science Center

Much of the information produced by the AFSC can be accessed through its website, to be found at:

http://www.afsc.noaa.gov/

The information available through the website includes the following.

- Species summaries: a summary of each groundfish species is available online, including AFSC research efforts addressing that species where applicable.
- Issue summaries: a summary of major fishery issues is also available, such as bycatch or fishery gear effects on habitat.
- Research efforts: a summary of the research efforts for each of the major AFSC divisions is provided on the website.
- Observer Program: the homepage describes the history of the program and the sampling manuals that describe, among other things, the list of species identified by observers.
- Survey reports: the groundfish stock assessments are based in part on the independent research surveys that are conducted annually, biennially, and triennially in the management areas. Reports of the surveys are made available as NMFS-AFSC National Oceanic and Atmospheric Administration (NOAA) Technical Memoranda, and are available on the website; the data maps and data sets are also accessible.
- Publications: the AFSC Publications Database contains more than 4,000 citations for publications authored by AFSC scientists. Search results provide complete citation details and links to available on-line publications.
- Image library: the website contains an exhaustive library of fish species.

### 7.1.3 NMFS Alaska Region

#### 7.1.3.1 Programmatic SEIS for the Alaska Groundfish Fisheries

Published in 2004, the *Final Programmatic Supplemental Environmental Impact Statement for the Alaska Groundfish Fisheries* (NMFS 2004) is a programmatic evaluation of the BSAI and GOA groundfish fisheries.

The document contains a detailed evaluation of the impact of the groundfish FMPs on groundfish resources, other fish and marine invertebrates, habitat, seabirds, marine mammals, economic and socioeconomic considerations, and the ecosystem as a whole. The impacts are evaluated in comparison to a baseline condition (for most resources this is the condition in 2002) that is comprehensively summarized and includes the consideration of lingering past effects. Additionally, sections of the document describe the fishery management process in place for the Alaska federal fisheries, and the changes in management since the implementation of the FMPs in the 1980s.

An EA/RIR/IRFA was prepared to accompany this Arctic FMP. That document contains a summary of existing knowledge of the fish resources of the Arctic Management Area, a summary of knowledge of the bird and marine mammal species of the Arctic Management Area, and an ecosystem description of the Arctic. The Council may periodically update the information with amendments to this FMP or otherwise provide periodic reports on the Arctic Management Area.

#### 7.1.3.2 EIS for Essential Fish Habitat Identification and Conservation in Alaska

In 2005 NMFS and the Council completed the Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS) (NMFS 2005). The EFH EIS provided a thorough analysis of alternatives and environmental consequences for amending the Council's FMPs to include EFH information and conservation measures pursuant to Section 303(a)(7) of the Magnuson-Stevens Act and 50 CFR 600.815(a). Specifically, the EFH EIS examined three actions: (1) describing and identifying EFH for Council managed fisheries, (2) adopting an approach to identify HAPCs within EFH, and (3) minimizing to the extent practicable the adverse effects of fishing on EFH. The Council's preferred alternatives from the EFH EIS were implemented through Amendment 78 to the BSAI Groundfish FMP and corresponding amendments to the Council's other FMPs. Habitat conservation measures for the Bering Sea were implemented in 2008 with Amendment 89 to the BSAI groundfish FMP.

#### 7.1.3.3 NMFS Website

Much of the information produced by NMFS Alaska region can be accessed through its website, to be found at:

http://www.fakr.noaa.gov/

The information available through the website includes the following.

- Regulations: the FMP's implementing regulations can be found on the Alaska region website, as well as links to the Magnuson-Stevens Act, the American Fisheries Act, the International Pacific Halibut Commission, and other laws or treaties governing Alaska's fisheries
- Catch statistics: inseason and end of year catch statistics for the groundfish fisheries can be found dating back to 1993, or earlier for some fisheries; annual harvest specifications and season opening and closing dates; and reports on share-based fishery programs (such as the individual fishing quota program for fixed-gear sablefish)
- Status of analytical projects: the website includes pages for the many analytical projects that are ongoing in the region
- Habitat protection: maps of essential fish habitat, including a queriable database; status of marine protected areas and habitat protections in Alaska
- Permit information: applications for and information on permits for Alaska fisheries; data on permit holders
- Enforcement: reports, requirements, and guidelines

- News releases: recent information of importance to fishers, fishery managers, and the interested public.

The NMFS Alaska region website also links to the national NMFS website, which covers national issues. For example, NMFS-wide policies on bycatch or improving stock assessments, may be found on the national website. Also, NMFS produces an annual report to Congress on the status of U.S. fisheries, which can be accessed from this website.

### 7.1.4 State of Alaska

The State of Alaska maintains a comprehensive website containing information on all fisheries prosecuted in State waters or under State management authority. Information on sport, commercial, and susbsitence/personal use fisheries may be accessed at that site:

http://www.adfg.state.ak.us/

## 7.2 Management and Enforcement Considerations

The Council and NMFS, in concert with NOAA Office of Law Enforcement and the U.S. Coast Guard, as well as the Alaska Department of Public Safety, provide management and enforcement capabilities for all fisheies prosecuted in Federal waters and under Federal authorization If the Council authorizes a commercial fishery in the Arctic Management Area in the future, management and enforcement responsibilities will include the following:

- Data collection, research, and analysis to prepare annual stock assessments;
- The annual harvest specifications process through which total allowable catch (TAC) limits and prohibited species catch (PSC) limits are established;
- The ongoing process of amending the FMP and regulations to implement fishery management measures recommended by the Council or NMFS;
- Monitoring of commercial fishing activities to estimate the total catch of each species and to ensure compliance with fishery laws and regulations;
- Actions to close commercial fisheries once catch limits have been reached; and
- Actions taken by NMFS Enforcement, the U.S. Coast Guard (USCG), and NOAA General Counsel to identify, educate, and, in some cases, penalize people who violate the laws and regulations governing the groundfish fisheries.

Management of the groundfish fisheries in the BSAI and enforcement of management measures governing those fisheries comprise a complex system for overseeing fisheries that range geographically over an extensive area of the North Pacific Ocean and Bering Sea. Monitoring and enforcement provisions would be part of the management program for a commercial fishery in the Arctic Management Area.

NMFS manages the fisheries off Alaska based on TAC amounts for target species and PSC amounts for species that may not be retained. No TAC allocations are authorized in the Arctic for any species of fish.

A key component of management and enforcement is education and outreach. Complex management programs are accompanied by a regulatory structure that can be difficult for the fishing industry to understand and comply with. This is exacerbated when regulations change rapidly. When fishermen believe that regulations are unduly burdensome or unnecessary, they are less likely to comply voluntarily. Thus, successful implementation of the regulations is dependent on outreach programs that explain the goal of regulations and why they are necessary. NMFS Management, NMFS Enforcement, and the USCG all conduct extensive outreach and education programs that seek not only to explain the regulations, but to help the fishing industry understand the rationale for those regulations. In addition, the Council and

NMFS would work with the fishing industry and enforcement agencies to develop practical monitoring and enforcement provisions.

### 7.2.1 Expected costs of management

If the Council authorizes a commercial fishery in the Arctic Management Area in the future, information on the costs to manage such fishery or fisheries will be collected and provided in an amended Arctic FMP. Costs to manage fisheries in the Council's BSAI and GOA groundfish fishery FMPs can be reviewed in those documents.

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# APPENDIX A. Description of red king crab fishery exempted from the Arctic FMP.

A distinct Kotzebue Sound fishing district including the waters of ADF&G Registration Area Q north of 66° N. lat. was created by the Alaska Board of Fisheries in March 2005.[3] This action was taken to consolidate management boundaries for stocks south of Bering Strait, and create a distinct area in the southern Chukchi Sea in case a crab fishery ever emerged there. The northern boundary of Area Q, at the latitude of Point Hope (68°, 21' N. lat.), is the northern boundary of the Kotzebue District. At the same meeting, the Board changed the start date for commercial fishing from August 1 to June 15. Fishermen may take red and blue male crab (ADF&G, 2005; Lean, pers. comm.).

Commercial crab fishing in the region would be conducted under the State of Alaska's K09X interim use permit. Prior to 2005, these authorized harvests occurred from an area that included the St. Lawrence Island; following the Board of Fish action in 2005, permits only authorized harvest from the southern Chukchi Sea between Bering Strait and Point Hope. Prior to 2002 no more than one of these was issued in any year; none were issued from 1980 to 1993. In 2002, the year following the test fishery, the number jumped to four, and fluctuated between two and four through 2007. A total of 21 K09X annual interim use permits were issued between 2002 and 2008. Eighteen of these were issued to four residents of Kotzebue (permit data obtained from the Alaska Commercial Fisheries Entry Commission web site; Lean, pers. comm.).

There is little documented evidence for commercial harvests of red king crab in this area. A review of the State of Alaska's fish ticket data base back to 1985 turned up one crab ticket recording harvest in July 2005 (review conducted by ADF&G staff). The ticket only indicated that a small amount of crab had been landed.[4] Although a complete review of ADF&G management reports has not been done for this analysis, the ADF&G Annual Management Report for 1992 does report a small sale of 16 crab. It is very likely, however, that in this area not all crab landings are recorded on fish tickets. There have been fish ticket compliance problems in this area in the past, notably for sheefish harvests; there may well be compliance problems in the crab fishery as well (Lean, pers. comm.). Fishery observers believe that king crab are harvested in the EEZ in the outer part of Kotzebue Sound for subsistence, personal use, and commercial purposes (Menard pers. comm.; Lean, pers. comm.; Pungowiyi, pers. comm.).[5] It is possible that some subsistence and personal use harvest may have been sold.

Although crab fishing apparently takes place, few individuals have participated in it, and it is characterized as a local, small-vessel fishery operated by small skiffs. The gear used is small crab pots that are locally manufactured by participants in the fishery or purchased from vendors. The only species targeted is the red king crab, although some blue king crab may be present. It is believed that these crabs mature in the southern Chukchi Sea area, possibly seeded by larval crabs that originate in the Bering Sea and are transported through Bering Strait into the Chukchi Sea. Since so few individuals have participated in this fishery, almost no revenues have accrued to individuals.

In summary, the red king crab fishery exempt from this FMP is very small scale, poorly documented, and possibly intermittent fishery in the outer waters of Kotzebue Sound. To the extent that this fishery occurs, it takes place in the summer. Any harvests in the winter are likely to be taken within Alaska's internal waters; a winter fishery may be affected, however, by harvest of what are likely the same stocks in the immediately adjacent waters of the EEZ.

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[3] This is designated the "Q4" district of the Bering Sea Registration Area Q.

[4] While this ticket reported a landing from state internal waters, it may have been in error. July landings are very unlikely to have come from inshore waters. (Lean, pers. comm.)

[5] Pungowiyi, Caleb. Kotzebue. Personal communication.

To establish the scope and size for the exemption of the Kotzebue red king crab fishery from the Arctic FMP, the fishery would be limited to no more than 1,000 lbs annually and limited to fishing in state statistical areas 646701, 646631, 646641, and 636631 (Figure A-1).

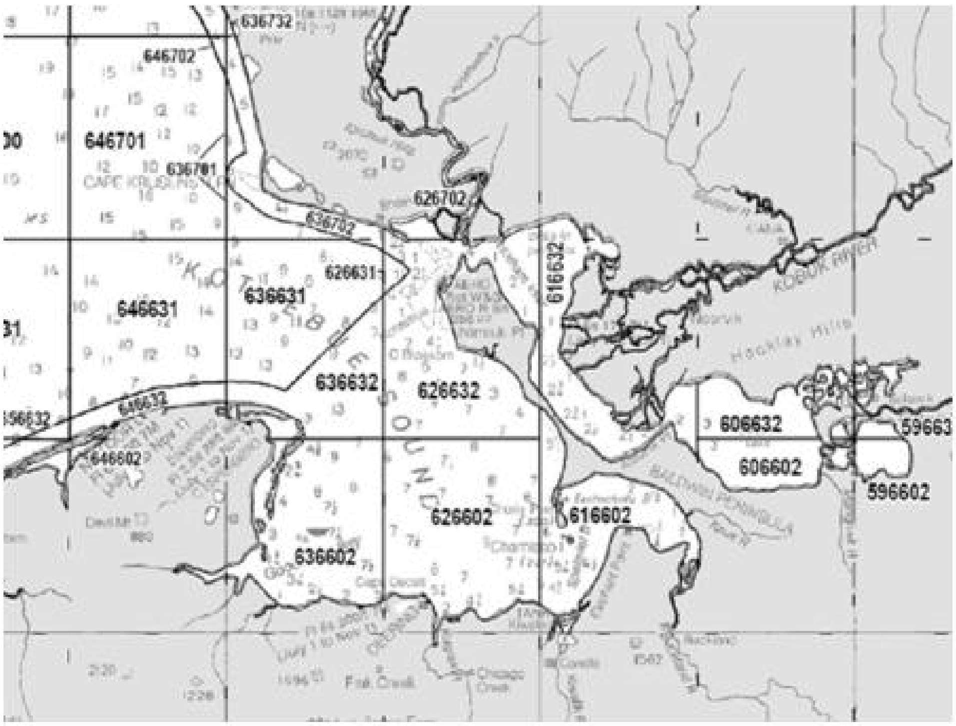


**Figure A-1** State Statistical Areas of Kotzebue Sound. Red king crab fishery exemption from the Arctic FMP is limited to fishing in state statistical areas 626701, 646631, 646641, and 636631.

# APPENDIX B. EFH descriptions.

**Highlighted items will be edited when option is selected.**

**Background**

In 1996, the Sustainable Fisheries Act amended the Magnuson-Stevens Act to require the description and identification of EFH in FMPs, adverse impacts on EFH, and actions to conserve and enhance EFH. Guidelines were developed by NMFS to assist Fishery Management Councils in fulfilling the requirements set forth by the Act.

EFH means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of essential fish habitat: "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

With respect to type, the information available for almost all species is primarily broad geographic distributions based on specific samples from surveys, which have not been linked with habitat characteristics. Furthermore, our ability to precisely define the habitat (and its location) of each life stage of each managed species in terms of its oceanographic (temperature, salinity, nutrient, current), trophic (presence of food, absence of predators), and physical (depth, substrate, latitude, and longitude) characteristics is very limited. Consequently, the information is restricted primarily to their position in the water column (e.g., demersal, pelagic), broad biogeographic and bathymetric areas (e.g., 100-200 m zone), and occasional references to known bottom types associations.

Identification of EFH for some species includes historical range information. Traditional knowledge and sampling data have indicated that fish distributions may contract and expand due to a variety of factors including, but not limited to, temperature changes, current patterns, changes in population size, and changes in predator and prey distribution.

The Council first identified EFH in 1998. In preparation of the 1999 EFH Environmental Assessment, EFH Technical Teams comprised of stock assessment authors, compiled scientific information and prepared the 1999 Habitat Assessment Reports. These reports provided the scientific information baseline to describe EFH. However, where new information does exist, new data helps to fill information gaps in the region's limited habitat data environment.

EFH descriptions were updated in 2005 for the Bering Sea and Aleutian Islands management area and for the Gulf of Alaska. Stock assessment authors reviewed information contained in the 1999 summaries and applied stock expertise, along with data contained in reference atlases (ADFG 2007; Council 2005; NOAA 1988 and 1990), fishery and survey data (NOAA 1998), and fish identification books (Hart 1973; Eschmeyer and Herald 1983; Mecklenburg and Thorsteinson 2002), to describe EFH for each life stage using best scientific judgment and interpretation.

In 2005, EFH text and map descriptions for most Council managed species were revised using an analytical approach. The approach focused on fish survey and fishery observer data. For adult and late juvenile life stages, each data set was analyzed for 95 percent of the total accumulated population for the species using GIS. For eggs and larvae, the EFH description is based on presence/absence data from surveys. Where information existed, the area described by these data is identified as EFH. The analyzed EFH data and area were further reviewed by scientific stock assessment authors for accuracy. This review ensures that any outlying areas not considered were included and gaps in the data were considered.

The EFH section of the Arctic FMP will undergo similar but simpler review. Fish survey and observer data is not available to analyze in this same manner. However, information does exist to describe EFH in the same manner as was completed for other Council FMPs in 1999 and as revised in 2005. Thus, Arctic EFH for each species by life stage will be described as a general distribution using the best scientific information available.

**EFH Descriptive Information Levels**

EFH is defined in the Magnuson-Stevens Act as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. The regulations specify the following requirements for EFH description. "FMPs must describe and identify EFH in text that clearly states the habitats or habitat types determined to be EFH for each life stage of the managed species. FMPs should explain the physical, biological, and chemical characteristics of EFH and, if known, how these characteristics influence the use of EFH by the species/life stage. FMPs must identify the specific geographic location or extent of habitats described as EFH. FMPs must include maps of the geographic locations of EFH or the geographic boundaries within which EFH for each species and life stage is found....[also] FMPs must demonstrate that the best scientific information available was used in the description and identification of EFH, consistent with national standard 2" (50 CFR 600.815(a)).

The EFH Final Rule (50 CFR 600.815(a)) specifies the following approach to gather and organize the data necessary for identifying EFH. Information is to be described using levels of information and all levels should be used to identify EFH, if information exists. The goal of this procedure is to include as many levels of analysis as possible within the constraints of the available data. Councils should strive to obtain data sufficient to describe habitat at the highest level of detail (i.e., Level 4).

> Level 1: Distribution data are available for some or all portions of the geographic range of the species. At this level, only distribution data are available to describe the geographic range of a species (or life stage). Distribution data may be derived from systematic presence/absence sampling and/or may include information on species and life stages collected opportunistically. In the event that distribution data are available only for portions of the geographic area occupied by a particular life stage of a species, habitat use can be inferred on the basis of distributions among habitats where the species has been found and on information about its habitat requirements and behavior. Habitat use may also be inferred, if appropriate, based on information on a similar species or another life stage.
>
> Level 2: Habitat-related densities of the species are available. At this level, quantitative data (i.e., density or relative abundance) are available for the habitats occupied by a species or life stage. Because the efficiency of sampling methods is often affected by habitat characteristics, strict quality assurance criteria should be used to ensure that density estimates are comparable among methods and habitats. Density data should reflect habitat utilization, and the degree that a habitat is utilized is assumed to be indicative of habitat value. When assessing habitat value on the basis of fish densities in this manner, temporal changes in habitat availability and utilization should be considered.
>
> Level 3: Growth, reproduction, or survival rates within habitats are available. At this level, data are available on habitat-related growth, reproduction, and/or survival by life stage. The habitats

> contributing the most to productivity should be those that support the highest growth, reproduction, and survival of the species (or life stage).
>
> Level 4: Production rates by habitat are available. At this level, data are available that directly relate the production rates of a species or life stage to habitat type, quantity, quality, and location. Essential habitats are those necessary to maintain fish production consistent with a sustainable fishery and the managed species' contribution to a healthy ecosystem.

The regulations specify that Level 1 information, if available, should be used to identify the geographic range of the species at each life stage. If only Level 1 information is available, distribution data should be evaluated (e.g., using a frequency of occurrence or other appropriate analysis) to identify EFH as those habitat areas most commonly used by the species. Levels 2 through 4 information, if available, should be used to identify EFH as the habitats supporting the highest relative abundance; growth, reproduction, or survival rates; and/or production rates within the geographic range of a species.

**EFH Scientific Information**

EFH descriptions are interpretations of the best scientific information. In support of this information, a review of FMP species is contained in Chapter 4 of the EA/RIR/IRFA supporting the development of this FMP.

Another important reference is the State of Alaska's *Catalogue of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes*. The catalogue is specific to freshwater fishes, including Dolly Varden char, whitefish and rainbow smelt, and focuses on freshwater and estuarine areas used by anadromous fishes throughout Alaska. The catalogue is divided into six regional areas: Arctic, Interior, Southcentral, Southeast, Southwestern, and Western. There are limitations to the catalogue, and many areas in Alaska have not been completely surveyed.
[http://www.sf.adfg.state.ak.us/SARR/FishDistrib/FDD_intro.cfm]

**EFH Text Descriptions**

The EFH Final Rule (50 CFR 600.815(a)(1)(iv)(B)) states the following:

> FMPs must describe EFH in text, including reference to the geographic location or extent of EFH using boundaries such as longitude and latitude, isotherms, isobaths, political boundaries, and major landmarks. If there are differences between the descriptions of EFH in text, maps, and tables, the textual description is ultimately determinative of the limits of EFH...the boundaries of EFH should be static.

The vastness of Alaska, our increasing knowledge of habitat and its use in the Arctic, and the large number of individual fish species managed by FMPs make it challenging to describe EFH by text using static boundaries. To address this challenge, NMFS refers to the boundaries as defined by a Fishery Management Unit (FMU) for the FMP. The Arctic FMP FMU would be all marine waters in the EEZ of the Chukchi and Beaufort Seas from 3 nautical miles offshore the coast of Alaska to 200 nautical miles offshore, north of Bering Strait (from Cape Prince of Wales to Cape Dezhneva) and westward to the U.S./Russia Convention Line of 1867 and eastward to the U.S. Canada maritime boundary. The FMU southern boundary of the Arctic management area would be changed to Pt. Hope for crab species under Alternative 4.

## EFH Map Description

FMPs must include maps that display, within the constraints of available information, the geographic location of EFH or the geographic boundaries within which EFH for each species and life stage is found. A GIS system was used to delineate EFH map descriptions for this analysis. EFH descriptive maps depict, and are complimentary to, each life history EFH text description, if known. Maps are labeled and compiled at the end of this text description section.

## EFH General Distribution

EFH is described as the general distribution for a species life stage, for all information levels and under all stock conditions. For Arctic EFH, general distribution is the area where presence has been documented by research effort and confirmed by species experts. Confirmation is achieved by review of each EFH description to ensure the area allows for stock and natural condition variances. Further, as specified in the EFH regulations, if little or no information exists for a given species life history stage, and habitat use cannot be inferred from other means, EFH should not be described (50 CFR 600.815(a)(1)(iii)(B)). This includes areas without systematic sampling and those areas where a species may have recruited to opportunistic sampling efforts in small numbers.

<u>Objective</u>
Describe EFH for Arctic stocks by each life history stage, where information exists. In those areas where information does not exist, then EFH will not be described.

EFH descriptions were analyzed through a process that met the objectives of the Magnuson-Stevens Act and EFH Final Rule. Specifically, the objective was to identify EFH for each FMP species, by particular life stage and using best scientific information and technology, as only those waters and substrates necessary to the species.

<u>Rationale</u>
Basic Rationales for Arctic EFH General Distribution:

- Adequately addresses unpredictable annual differences in spatial distributions of a life stage and changes due to long-term shifts in oceanographic regimes;
- Account for habitat production and contribution at some level;
- Allows for a stock's long-term productivity, based on both high and low levels of abundance;
- Reflects the habitat required to maintain healthy stocks within the ecosystem;
- Provides for changes in the natural environmental condition, such as prey movements and areas needed for growth, maturation, and diversity;
- Offers a risk-averse approach and employs an additive ecosystem approach to suggest that, unless the information indicates otherwise, a more inclusive general distribution should describe EFH.

<u>Methodology</u>
The analysis examined available information and major data sources for the Arctic: Bering, Chukchi, and Beaufort Seas Coastal and Ocean Zones Strategic Assessment: Data Atlas (DOC/NOAA. Ehler, Ray, Fay, Hickok. 1988); Fishery observer and catch data for the BSAI Groundfish, BSAI Crab, and Scallop FMP fisheries (Fritz et al. 1998), NMFS survey records (Fair and Nelson 1999), USDOI Minerals Management Service studies, and, where appropriate, ADF&G survey information to select occurrences where one would reasonably (with high probability) expect to find a certain life stage of that species. Where this information exists, text describes EFH by life history stage. EFH descriptions underwent scientific stock

assessment expert review for accuracy. Note: Information is limited for the Arctic Region; the Arctic lacks systematic fisheries stock survey assessments.

For rainbow smelt, the analysis focused on two areas: marine and freshwater. EFH was generally described to include all marine waters from the mean higher high water line to the limits of the EEZ, since scientific information indicates this species is: 1) distributed throughout all marine waters during late juvenile and adult life stages and 2) found nearshore and along coastal migration corridors as early juvenile life stages out-migrate and adult life stages return to and from freshwater areas, respectively. Freshwater areas used by egg, larvae, juvenile, and returning adults will be described as those areas indexed by the state of Alaska's *Catalog of Waters Important for the Spawning, Rearing, or Migration of Anadromous Fishes*. Specifically, these systems are generally defined as those areas above mean higher tide to the upper limits of the freshwater system that supports these fish and includes rivers, streams, and those hydrologically connected waters of the main source, such as estuaries, sloughs, channels, contiguous wetlands, and connected lakes and ponds.

Notes:

1. Species listed in this section are known to have been commercially harvested or recruited to scientific sampling gear in the Arctic Region. Incidental or occasional occurrences of a species does not transpose to:
    a. A larger EFH Description for the species;
    b. A higher knowledge of this species range or habitat requirements.
2. EFH cannot be described for many species and life history stages:
    a. Species general distribution is not within Arctic Management Area.
    b. Information may be site specific and does not depict a general distribution. Simply, the scale may not allow for a refinement of the area. All waters are not considered EFH for every species and life stage.
3. Late Juvenile and Adult EFH Descriptions are often repetitive:
    a. Life stages are hard to discern.
    b. Individual life stage recruits the same to sampling effort.
4. Crab EFH descriptions exist for the Arctic and are within the current BSAI Crab FMP (EFH FEIS April 2005). The BSAI crab fishery descriptions would change under Alternative 2 and 3. Under these alternatives, the crab descriptions north of the Bering Straight would be part of the Arctic FMP. Crab descriptions south of Bering Strait would remain in the BSAI Crab FMP. Under Alternatives 1 and 4, crab EFH up to Pt. Hope would remain in the crab FMP.
5. Scallop EFH descriptions exist within the current Scallop FMP (EFH FEIS April 2005). Scallop EFH descriptions north of Bering Strait would be part of the Arctic FMP.
6. Salmon EFH descriptions exist for the Arctic within the current Salmon Fisheries FMP (EFH FEIS April 2005).
7. The ADF&G Anadromous Fish Catalog identifies fresh water areas used by smelt. Thus, the ADF&G catalogue is the primary reference source for this species.

Table 1. Arctic Fish and Fish Habitat References (See references)

| Arctic FMP Species | Information Sources | | | | | |
|---|---|---|---|---|---|---|
| | Fishes of Alaska Mecklenburg;Thorsteinson | NOAA 1990 | NOAA 1998 | NOAA 1988 Bering, Chukchi, and Beaufort Seas Data Atlas | Council 2005 | ADFG Catalogue of Anadromous Fish Waters |
| Pacific halibut | X | | | | | |
| Pacific herring | X | | | | | X |
| Pacific salmon | X | | | | X | X |
| Dolly Varden char | X | | | | | X |
| Red king crab | | | | X | X | |
| Whitefish[a] | X | | | | | X |
| Arctic cod | X | | | | | |
| Saffron cod | X | | | X | | |
| Yellowfin sole | X | | X | X | X | |
| Alaska plaice | X | | X | X | X | |
| Other flatfish | | | | | | |
| Flathead sole/Bering flounder | X | X | X | X | X | |
| Starry flounder | X | | X | X | | |
| Walleye pollock | X | X | X | X | X | |
| Other gadids | | | | | | |
| Pacific Ocean perch | X | | | | X | |
| Capelin | X | | | X | X | |
| Rainbow smelt | X | | | X | X | |
| Eulachon | X | | | | | X |
| Pacific sand lance | X | | | X | | |
| Skates | X | | X | X | X | |
| Sharks | X | | X | X | X | |
| Gunnels | X | | | X | X | |
| Pricklebacks | X | | | X | X | |
| Eelpouts | X | | | | X | |
| Sailfishes | X | | | X | X | |
| Lumpsuckers | X | | | | | |
| Poachers | X | | | | | |
| Sculpin[b] | X | | X | X | X | |
| Laternfishes | X | | | | X | |
| Sticklebacks | X | | | | X | |
| Greenling | X | | | | | |
| Squid | | | | | X | |
| Blue king crab | | | | X | X | |
| Opilio tanner crab | | | | X | X | |
| Scallops | | | | X | X | |

[a] Includes inconnu; Arctic, Bering, and least ciscoes; and broad, humpback, and round whitefishes

[b] Includes spatulate (0 to 400m), Arctic staghorn (0 to 250), ribbed (20 to 150m), fourhorn (0 to 25m), shorthorn (0 to 500m), Arctic (0 to 25m), and great sculpin (0 to 200) and the hamecon (0 to 500m)

Table 2. EFH Information Levels for Arctic Fish

| Arctic FMP Species | | Life History Stage | | | |
|---|---|---|---|---|---|
| | | Eggs | Larvae | Juvenile | Adult |
| P | Pacific halibut | Not Described | | | |
| P | Pacific herring | | | | |
| P | Pacific salmon | | | | |
| P | Dolly Varden char | | | | |
| P | Red king crab | | | | |
| P | Whitefish[a] | | | | |
| E | Arctic cod | - | - | 1 | 1 |
| E | Saffron cod | - | - | 1 | 1 |
| E | Yellowfin sole | - | - | 1 | 1 |
| E | Alaska plaice | - | - | 1 | 1 |
| E | Other flatfish | | | | |
| E | Flathead sole/Bering flounder | - | - | 1 | 1 |
| E | Starry flounder | - | - | 1 | 1 |
| E | Walleye pollock | - | - | - | - |
| E | Other gadids | - | - | - | - |
| E | Pacific Ocean perch | - | - | - | - |
| E | Capelin | - | - | - | 1 |
| E | Rainbow smelt | - | - | - | 1 |
| E | Eulachon | - | - | - | - |
| E | Pacific sand lance | - | - | - | 1 |
| E | Skates | - | - | - | - |
| E | Sharks | - | - | - | - |
| E | Gunnels | - | - | - | - |
| E | Pricklebacks | - | - | - | - |
| E | Eelpouts | - | - | - | - |
| E | Sailfishes | - | - | - | - |
| E | Lumpsuckers | - | - | - | - |
| E | Poachers | - | - | - | - |
| E | Sculpin[b] | - | - | - | - |
| E | Laternfishes | - | - | - | - |
| E | Sticklebacks | - | - | - | - |
| E | Greenling | - | - | - | - |
| E | Squid | - | - | - | - |
| E | Blue king crab | 1 | - | 1 | 1 |
| E | Opilio tanner crab | 1 | - | 1 | 1 |
| E | Scallops | - | - | - | - |
| Arctic FMP Species | | Eggs | Larvae | Juvenile | Adult |

| | |
|---|---|
| P | Prohobited Species |
| E | Ecosystem Component Species |
| 1 | Level of EFH Information where distribution data is avlaible for some or all of the species goeprahpic range (General Distribution). In many instances, one map describes EFH for both late juvenile and adult life stages; both life stages often recruit to the same sampling method and are difficult to distinguish. See specific EFH Text for any specific differences. |
| a | Includes inconnu; Arctic, Bering, and least ciscoes; and broad, humpback, and round whitefishes |
| b | Includes spatulate (0 to 400m), Arctic staghorn (0 to 250), ribbed (20 to 150m), fourhorn (0 to 25m), shorthorn (0 to 500m), Arctic (0 to 25m), and great sculpin (0 to 200) and the hamecon (0 to 500m) |

## Arctic EFH Text Descriptions

### <u>Prohibited Species Category For option 2</u>

The Prohibited Species category includes Pacific halibut, Pacific herring, Pacific salmon, Dolly Varden char, and whitefish. EFH will not be described for Pacific halibut, Pacific herring, Pacific salmon, whitefish, and Dolly Varden char because these species are not managed under the FMP.

### <u>Ecosystem Component Species For option 2</u>

### <u>EFH Description for Arctic Cod For option 1 or 2</u>

Insufficient information is available to determine EFH for Eggs, Larvae, and Early Juveniles.

**Late Juveniles**
EFH for late juvenile Arctic cod is the general distribution areas for this life stage located in pelagic and epipelagic waters from the nearshore to offshore areas along the entire shelf (0-200m) and upper slope (200-500m) throughout Arctic waters and often associated with ice floes.

**Adults**
EFH for adult Arctic cod is the general distribution area for this life stage located in pelagic and epipelagic waters from the nearshore to offshore areas along the entire shelf (0-200m) and upper slope (200-500m) throughout Arctic waters and often associated with ice floes.

### <u>EFH Description for Saffron Cod for option 1 or 2</u>

Insufficient information is available to determine EFH for Eggs, Larvae, and Early Juveniles.

**Late Juveniles**
EFH for late juvenile Saffron cod is the general distribution area for this life stage, located in pelagic and epipelagic waters along the coastline, within nearshore bays, and under ice along the inner (0 to 50 m) shelf throughout Arctic waters and wherever there are substrates consisting for sand and gravel.

**Adults**
EFH for adult Saffron cod is the general distribution area for this life stage, located in pelagic and epipelagic waters along the coastline, within nearshore bays, and under ice along the inner (0 to 50 m) shelf throughout Arctic waters and wherever there are substrates consisting for sand and gravel.

### <u>EFH Description for Yellowfin Sole</u>

Insufficient information is available to determine EFH for Eggs, Larvae, and Early Juveniles.

**Late Juveniles**
EFH for late juvenile yellowfin sole is the general distribution area for this life stage, located in the lower portion of the water column within nearshore bays and along the entire shelf (0 to 200 m), mostly in Arctic waters south of Point Barrow, and wherever there are soft substrates consisting mainly of sand.

**Adults**
EFH for adult yellowfin sole is the general distribution area for this life stage, located in the lower portion of the water column within nearshore bays and along the entire shelf (0 to 200 m), mostly in Arctic waters south of Point Barrow, and wherever there are soft substrates consisting mainly of sand.

## EFH Description for Alaska Plaice

Insufficient information is available to determine EFH for Eggs, Larvae, and Early Juveniles.

**Late Juveniles**
EFH for late juvenile Alaska plaice is the general distribution area for this life stage, located in the lower portion of the water column along the inner (0 to 50 m) and middle (50 to 100 m) shelf in Arctic waters south of Point Barrow mainly in areas consisting of sand and silt and known to migrate in association with seasonal ice movements (deeper in winter, shallower in summer).

**Adults**
EFH for adult Alaska plaice is the general distribution area for this life stage, located in the lower portion of the water column along the inner (0 to 50 m) and middle (50 to 100 m) shelf in Arctic waters south of Point Barrow mainly in areas consisting of sand and silt and known to migrate in association with seasonal ice movements (deeper in winter, shallower in summer).

## EFH Description for Flathead Sole / Bering Flounder

Note: Flathead sole and Bering flounder are grouped together due to similarity of these two species and habitat associations. Generally, flathead sole are located south of Bering Strait, while Bering flounder range throughout the Bering and Chukchi Seas to Point Barrow.

Insufficient information is available to determine EFH for Eggs, Larvae, and Early Juveniles.

**Late Juveniles**
EFH for late juvenile flathead sole/Bering flounder is the general distribution area for this life stage, located in the lower portion of the water column within nearshore bays and along the inner (0 to 50 m) and middle (50 to 100 m) shelf mostly in Arctic waters south of Point Barrow and wherever there are soft substrates consisting mainly of sand and mud.

**Adults**
EFH for adult flathead sole/Bering flounder is the general distribution area for this life stage, located in the lower portion of the water column within nearshore bays and along the inner (0 to 50 m) and middle (50 to 100 m) shelf mostly in Arctic waters south of Point Barrow and wherever there are soft substrates consisting mainly of sand and mud.

## EFH Description for Starry Flounder

Insufficient information is available to determine EFH for Eggs, Larvae, and Early Juveniles.

**Late Juveniles**
EFH for late juvenile starry flounder is the general distribution area for this life stage, located in the lower portion of the water column within nearshore bays, estuaries, and river mouths and along the inner (0 to 50 m) and middle (50 to 100 m) shelf in Arctic waters south of Point Barrow and wherever there are soft substrates consisting mainly of sand, silt, and mud.

**Adults**
EFH for adult starry flounder is the general distribution area for this life stage, located in the lower portion of the water column within nearshore bays, estuaries, and river mouths and along the inner (0 to

50 m) and middle (50 to 100 m) shelf in Arctic waters south of Point Barrow and wherever there are soft substrates consisting mainly of sand, silt, and mud.

### EFH Description for Walleye Pollock

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

### EFH Description for Other Gadids

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

### EFH Description for Pacific Ocean Perch

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

### EFH Description for Capelin

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, and Late Juveniles.

**Adults**
EFH for adult capelin is the general distribution area for this life stage, located in epipelagic and epibenthic waters along the coastline, within nearshore bays, and along the inner (0 to 50 m) shelf throughout Arctic waters with spawning occurring in intertidal and subtidal shallow areas consisting of sand and gravel.

### EFH Description for Rainbow Smelt

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, and Late Juveniles.

**Adults**
EFH for adult rainbow smelt is the general distribution area for this life stage, located in epipelagic and epibenthic waters along the nearshore throughout Arctic waters in areas mainly consisting of sandy gravel and cobbles with spawning occurring in coastal freshwater streams.

### EFH Description for Eulachon

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

### EFH Description for Pacific Sand Lance

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Skates**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Sharks**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Gunnels (Pholidae)**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Pricklebacks (Stichaedae)**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Eelpouts (Zoarcidae)**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Snailfishes (Liparidae)**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Lumpsuckers (Cylcopteridae)**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Poachers (Agonidae)**

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

**EFH Description for Sculpins (Cottidae)**
Species group includes the spatulate (0 to 400m), Arctic staghorn (0 to 250), ribbed (20 to 150m), fourhorn (0 to 25m), shorthorn (0 to 500m), Arctic (0 to 25m), and great sculpin (0 to 200) and the hamecon (0 to 500m).

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

## EFH Description for Laternfishes (Myctophidae)

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

## EFH Description for Sticklebacks (Gasterosteridae)

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

## EFH Description for Greenling

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

## EFH Description for Squid

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

## EFH Description for Blue King Crab

**Eggs**
Essential fish habitat of the blue king crab eggs is inferred from the general distribution of egg-bearing female crab (see also Adults).

**Larvae—No EFH Description Determined**
Insufficient information is available.

**Early Juveniles—No EFH Description Determined**
Insufficient information is available.

**Late Juveniles**
EFH for late juvenile blue king crab is the general distribution area for this life stage, located in bottom habitats along the nearshore (spawning aggregations) and the inner (0 to 50 m) and middle (50 to 100 m) shelf in Arctic waters, with local distributions surrounding St. Lawrence Island extending northward into Bering Strait, and wherever there are rockier substrates areas and shell hash.

**Adults**
EFH for adult blue king crab is the general distribution area for this life stage, located in bottom habitats along the nearshore (spawning aggregations) and the inner (0 to 50 m) and middle (50 to 100 m) shelf in Arctic waters, with local distributions surrounding St. Lawrence Island extending northward into Bering Strait, and wherever there are rockier substrates areas and shell hash.

## EFH Description for Opilio Tanner Crab (*C. opilio*) (For option 1 and 2)

**Eggs**
Essential fish habitat of Tanner crab eggs is inferred form the general distribution of egg-bearing female crab (see also Adults).

**Larvae—No EFH Description Determined**
Insufficient information is available.

**Early Juveniles—No EFH Description Determined**
Insufficient information is available.

**Late Juveniles**
EFH for late juvenile tanner crab is the general distribution area for this life stage, located in bottom habitats along the inner (0 to 50 m) and middle (50 to 100 m) shelf in Arctic waters south of Cape Lisburne, wherever there are substrates consisting mainly of mud.

**Adults**
EFH for adult tanner crab is the general distribution area for this life stage, located in bottom habitats along the inner (0 to 50 m) and middle (50 to 100 m) shelf in Arctic waters south of Cape Lisburne, wherever there are substrates consisting mainly of mud.

## EFH Description for Weathervane Scallops

Insufficient information is available to determine EFH for Eggs, Larvae, Early Juveniles, Late Juveniles, and Adults.

### *Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures*

The EFH FEIS (NMFS 2005) describes non-fishing activities within Appendix G - Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures for the Bering Sea and Aleutian Islands management area and for the Gulf of Alaska. The appendix offers thorough discussion of many anthropogenic activities such as mining, oil exploration and production, port developments, dredging, and fill that may affect EFH and offers EFH Conservation Recommendations to minimize any affect. Similar activities in the Arctic management area may have similar effects on EFH. See online at http://www.fakr.noaa.gov/habitat/seis/final/Volume_II/Appendix_G.pdf. The EA/RIR/IRFA developed for this FMP contains non-fishing activities and impacts in the cumulative effects section that are specific to the Arctic Management Area. The mitigation measures described in the EFH EIS for these types of activities would be similar to mitigation used for the same activities in the Arctic and therefore are adopted by reference for this FMP.

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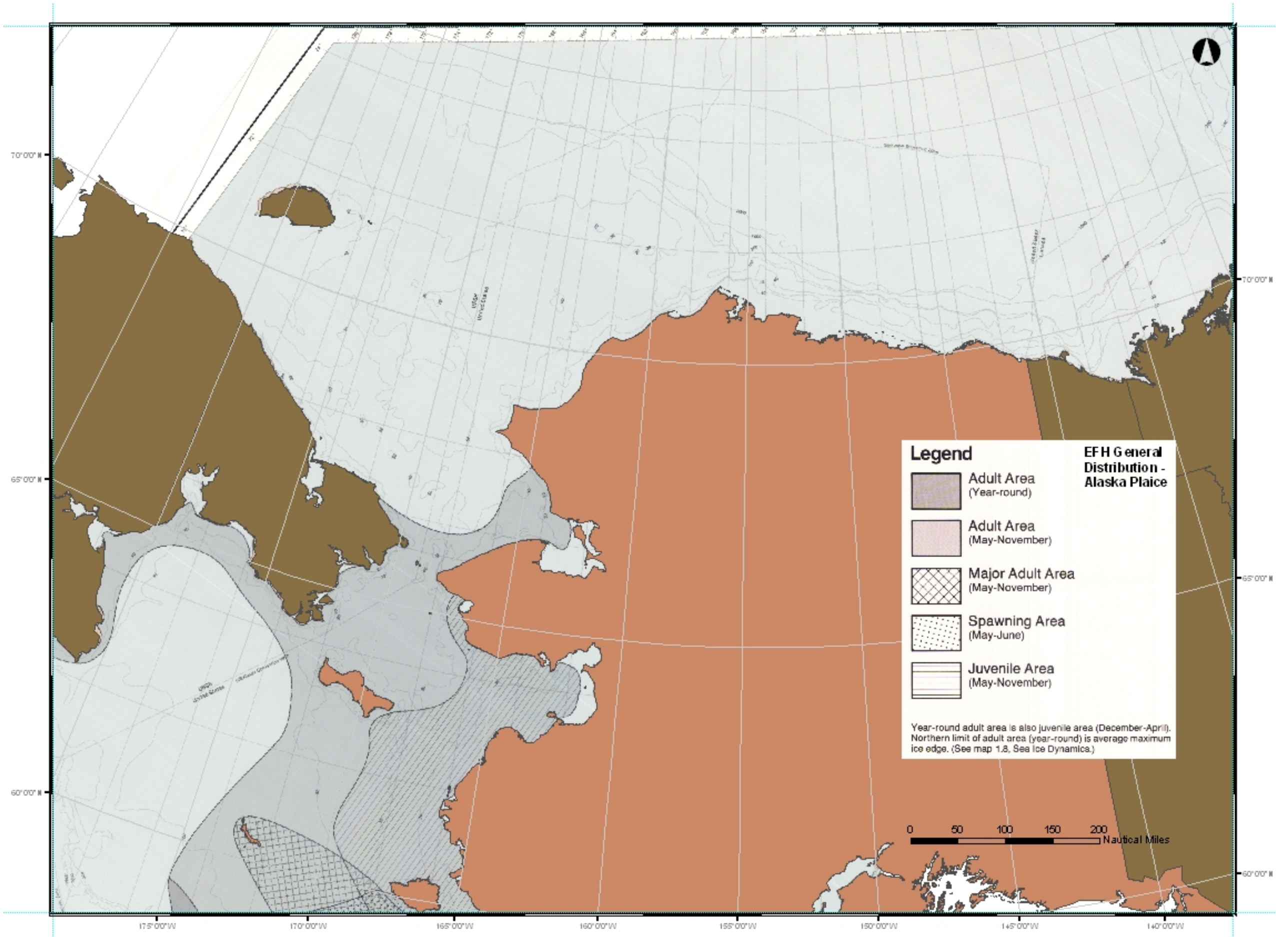
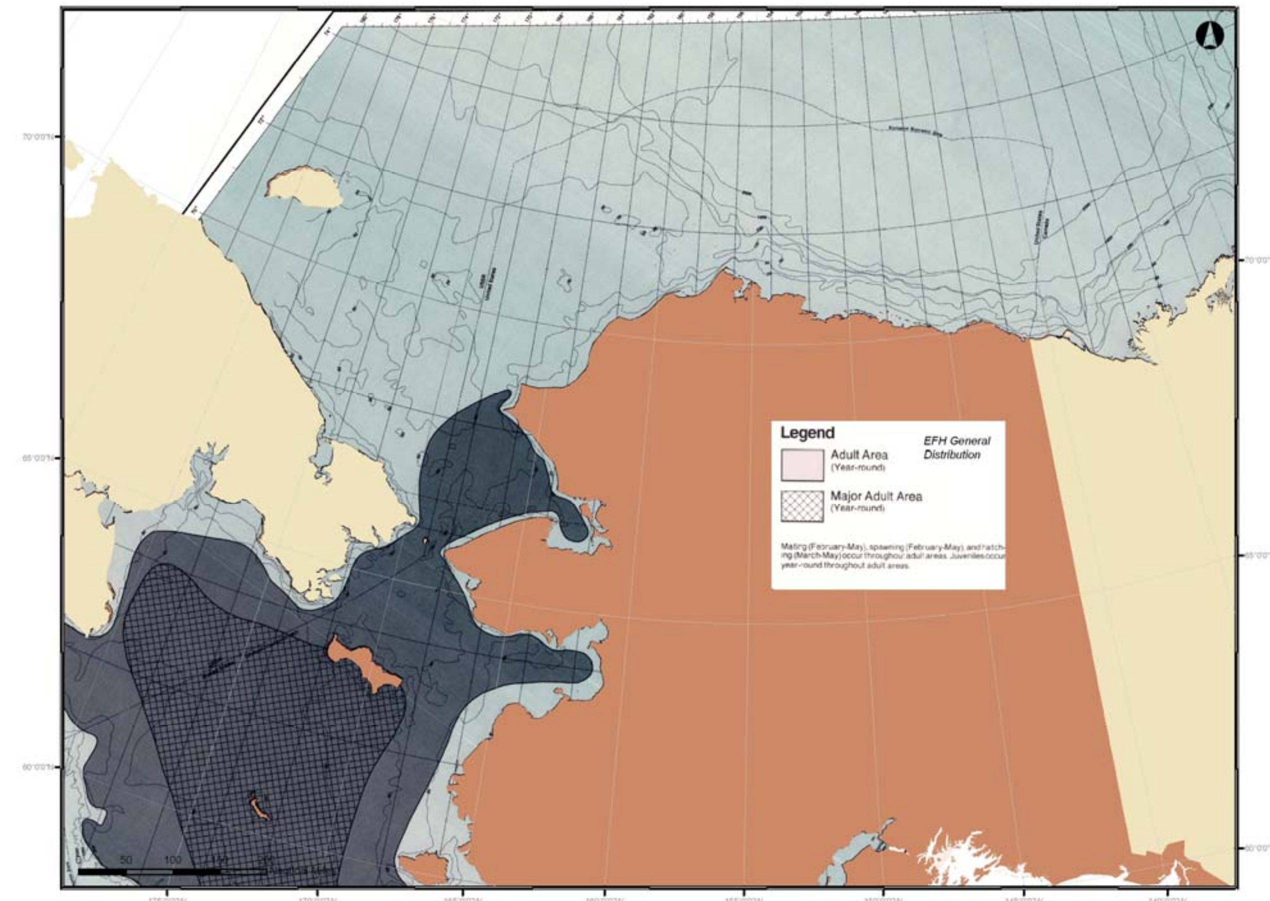
NPFMC. 2005a. Essential fish habitat assessment report for the groundfish resources of the Bering Sea and Aleutian Islands regions. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

# APPENDIX C:  Maps of essential fish habitat

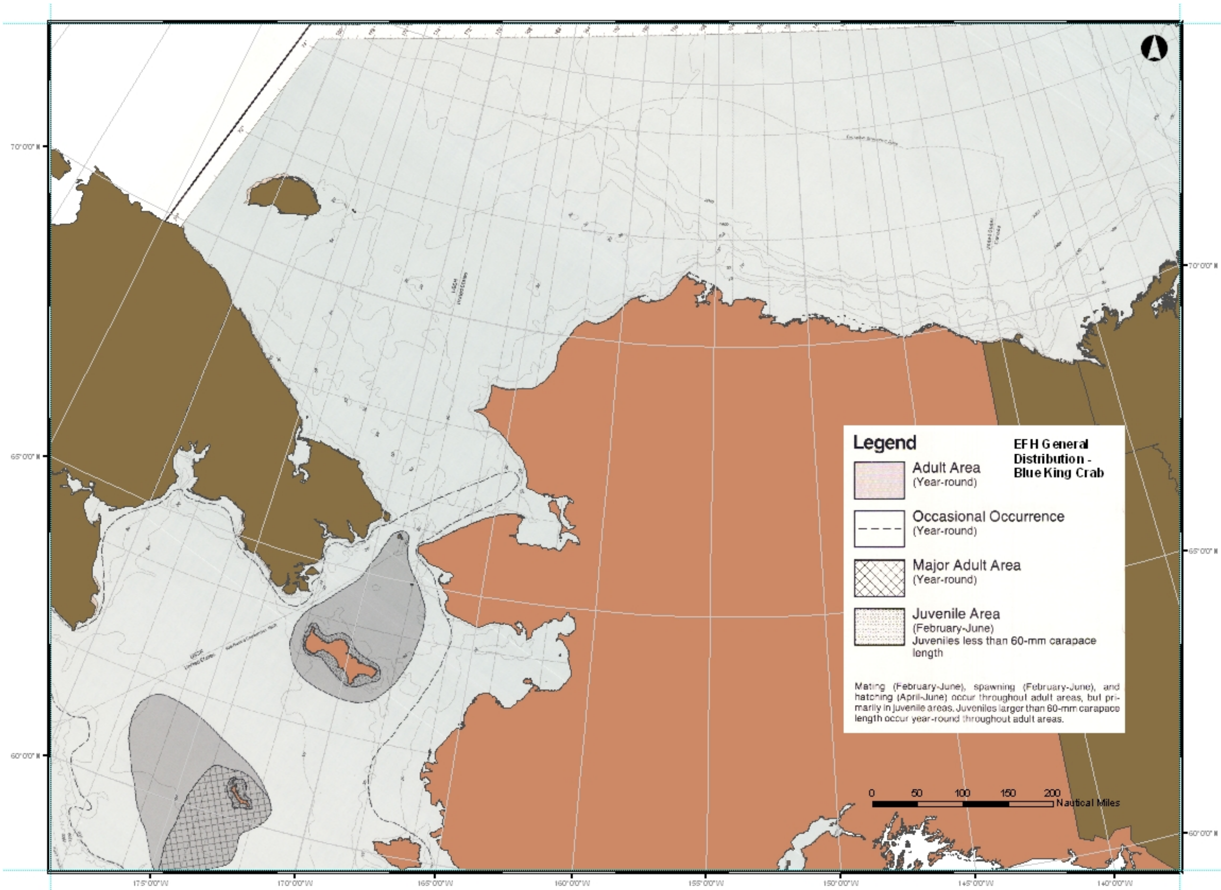
Alaska Plaice EFH Map



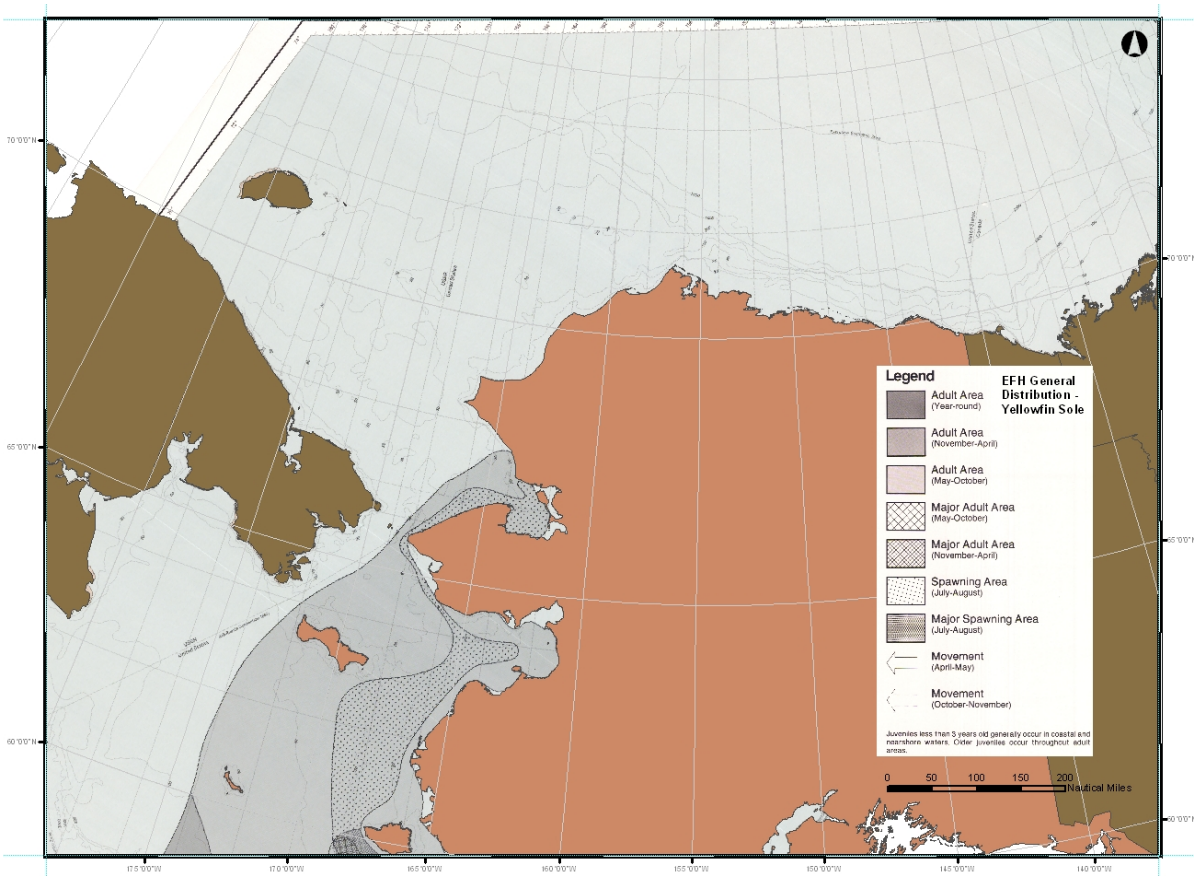
C. Opilio Snow Crab



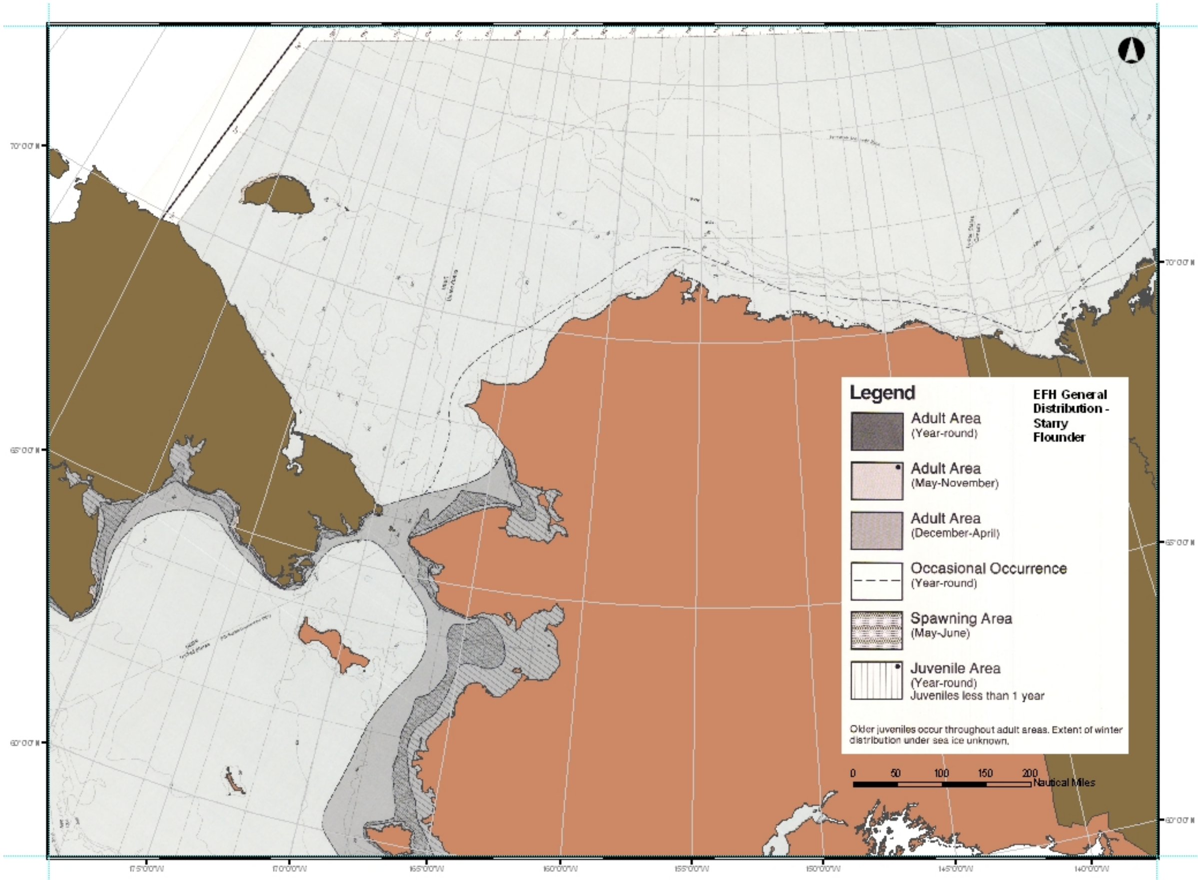
Blue King Crab EFH map



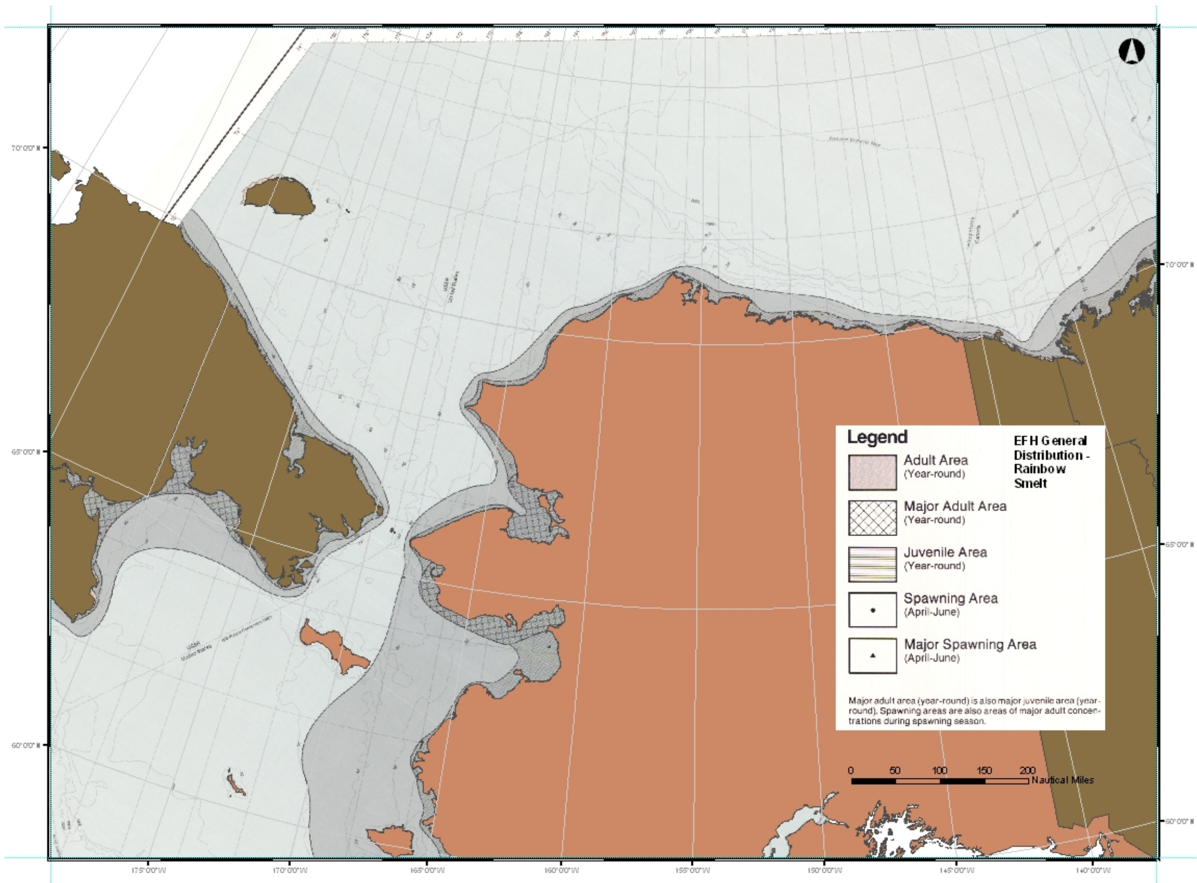
## Yellowfin Sole EFH Map



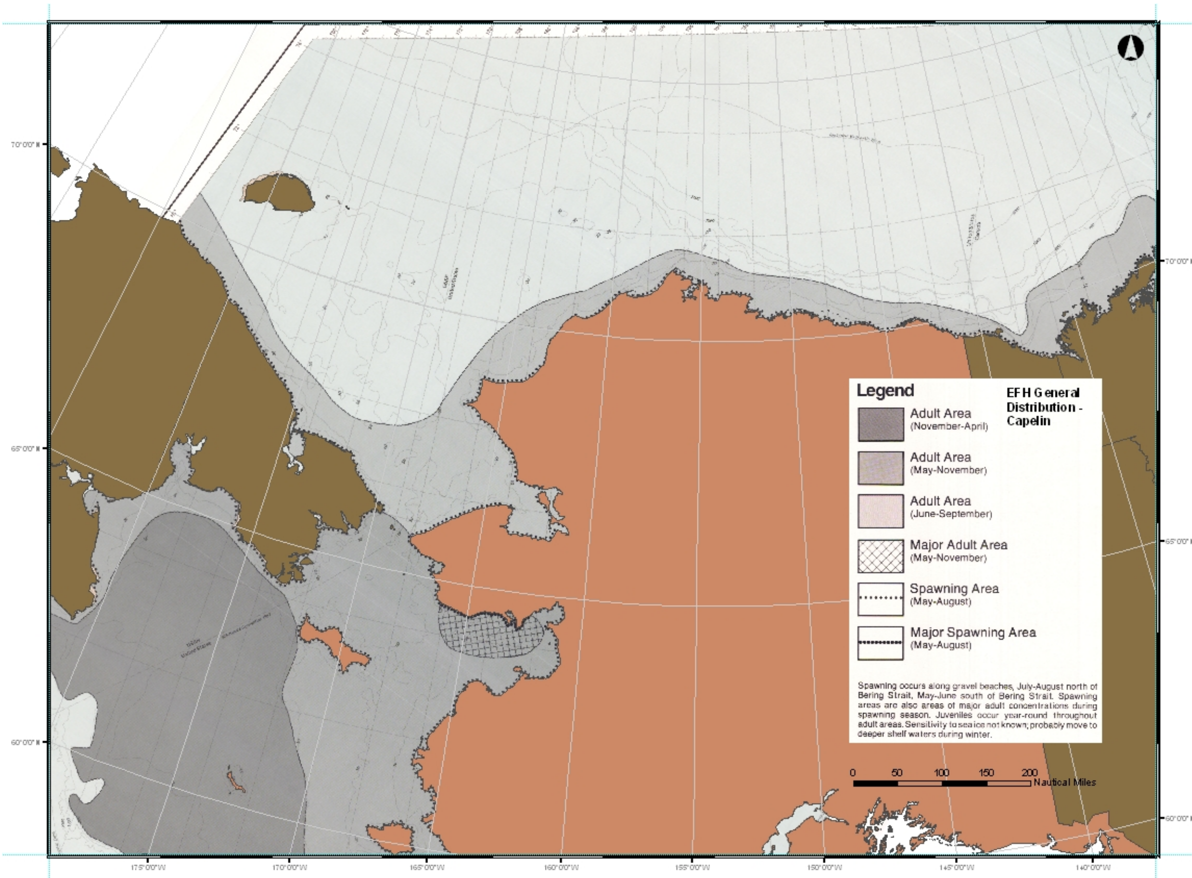
Starry Flounder EFH Map



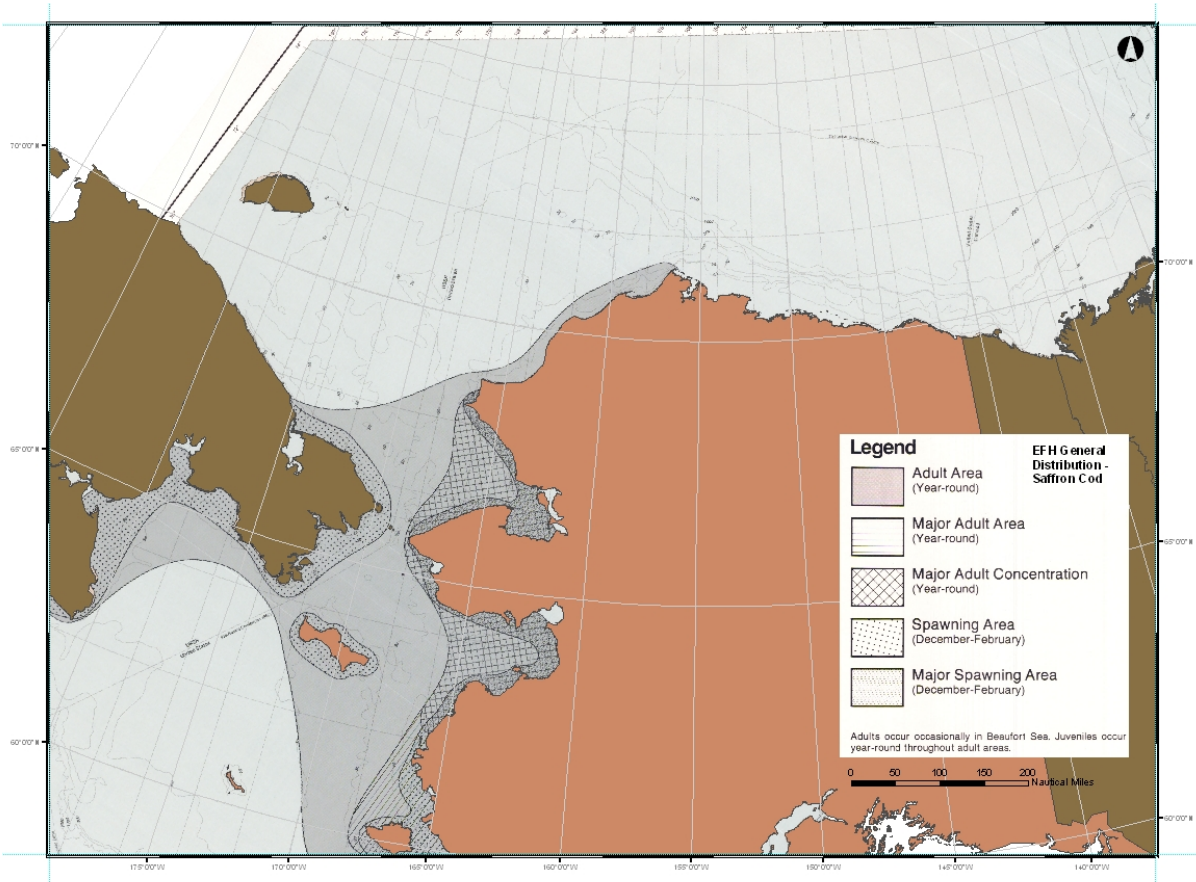
Rainbow Smelt EFH Map



# Capelin EFH Map



Saffron Cod EFH Map



Flathead Sole/Bering Flounder EFH Map

Place holder for map

Arctic Cod EFH Map