DRAFT

Fishery Management Plan

for Fish Resources of the Arctic Management Area

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NOTE: This is an interim draft of what the Arctic FMP will look like, and is intended for SSC review in December 2008 only. 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, and chose option 3 in the EA for setting fishery harvest levels for sustainable fisheries management. 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. This draft may 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 1990 maritime boundary line 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 (subfamily Coregoninae), Dolly Varden char, and red king crab in a red king crab fishery as described in Appendix A.

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, 16 U.S.C. 1801 et seq. (Magnuson-Stevens Act), is the primary domestic legislation governing management of the nation’s marine fisheries. The Magnuson-Stevens Act requires FMPs to be consistent with a number of provisions, including 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 laws 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, an 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 as 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. (This will be modified based on the Alternative chosen.)

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[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 Policy

The Council's policy is to proactively apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, to ensure the sustainability of fishery resources, to prevent unregulated fishing, and to protect associated ecosystems for the benefit of current users and future generations. For the past 30 years, the Council's management policy for Alaska fisheries has incorporated forward-looking conservation measures that address differing levels of uncertainty. This management policy 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 policy 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 prevent unregulated fishing, apply the Council's precautionary, adaptive management policy through community-based or rights-based management, apply ecosystem-based management principles that protect managed species from overfishing and protect the health of the entire marine ecosystem, and where appropriate and practicable include habitat protection and bycatch constraints. All management measures will be based on the best scientific information available. Given this intent, the fishery management goals are 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 policy recognizes the need to balance 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

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 1990 maritime boundary line and eastward to the U.S./Canada maritime boundary. **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, Dolly Varden char and red king crab that would be harvested in the red king crab fishery described in Appendix A.
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 fishing is authorized 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 fishing is authorized 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 fishing is authorized 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 commercial fishing is authorized in the Arctic Management Area, prohibited species are Pacific halibut, Pacific herring, Pacific salmon and steelhead, Dolly Varden char, red king crab, and whitefish. 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 fishing is authorized 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 fishing is authorized 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 fishing is authorized 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

Observer Program	In the future, if fishing is authorized 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.
Management Measures	The FMP provides management measures to prohibit commercial fishing until information is available to support sustainable management.
Monitoring and Enforcement	In the future, if fishing is authorized in the Arctic Management Area, monitoring and enforcement measures necessary and appropriate to ensure sustainable management and 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. **Management Policy**: Objectives in the management policy statement will be reviewed as determined necessary by the Council. **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 for 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 December 2008 Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis (EA/RIR/IRFA) for this FMP. Appendix D provides a description of non-fishing Effects on EFH in the Arctic Region, and Appendix E provides supplemental Arctic fish habitat descriptions.

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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
B_{msy}	Biomass at MSY
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
EC	Ecosystem component
EEZ	exclusive economic zone
EFH	essential fish habitat
ENSO	El Nino - Southern Oscillation
ESA	Endangered Species Act
F	fishing mortality rate
F_{msy}	Fishing mortality rate at MSY
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
MFMT	maximum fishing mortality threshhold
mm	millimeter(s)
MMPA	Marine Mammal Protection Act
MSY	maximum sustainable yield
Msst	minimum stock size threshhold
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

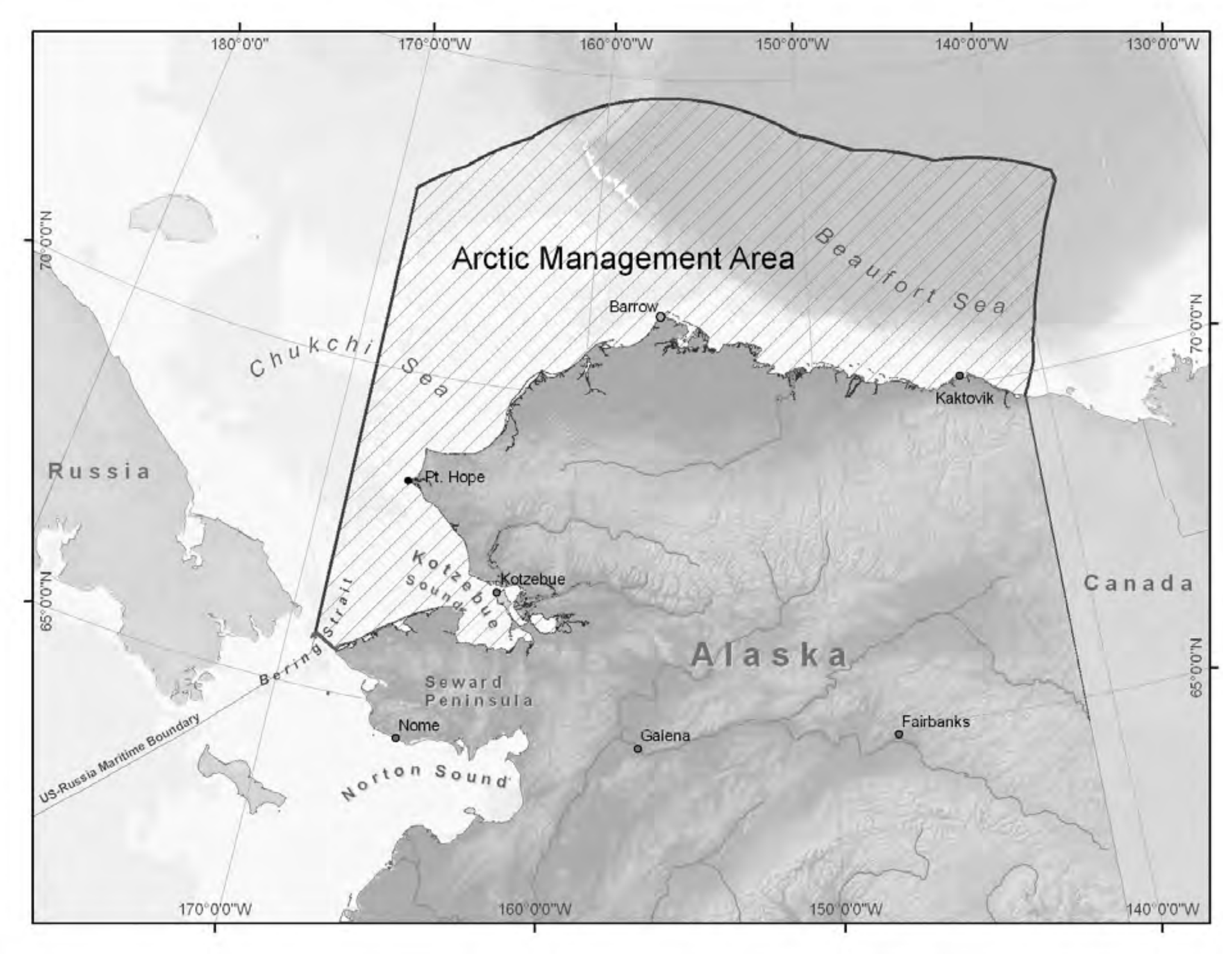
Chapter 1 Introduction

This chapter contains a description of the fishery management area covered by the FMP and addresses foreign fishing and processing in this area.

1.1 Fishery Management Area

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 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 1990 maritime boundary line 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, described in this FMP, except commercial fishing on salmonids, Pacific halibut, Pacific herring, whitefish, Dolly Varden char, and red king crab in the red king crab fishery as described in Appendix A. 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 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 Arctic Management Area is closed to commercial fishing 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 authorizing fishing in the Arctic Management Area are provided in Chapters 2 and 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 FMP and no processing capacity is needed to support commercial fishing. If in the future commercial fishing is authorized in the Arctic Management Area, the Council will specify TALFF, joint venture processing (JVP), and foreign processing at that time.

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

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 policy 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 by utilizing ecomonic and social datat that meet the requirements of paragraph (2), 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 Policy for Arctic Fisheries

The Council's policy is to proactively apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, to ensure the sustainability of fishery resources, to prevent unregulated fishing, and to protect associated ecosystems for the benefit of current users and future generations. For the past 30 years, the Council's management policy for Alaska fisheries has incorporated forward-looking conservation measures that address differing levels of uncertainty. This management policy 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 policy 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 prevent unregulated fishing, apply the Council's precautionary, adaptive management policy through community-based or rights-based management, apply ecosystem-based management principles that protect managed species from overfishing and protect the health of the entire marine ecosystem, and where appropriate and practicable include habitat protection and bycatch constraints. All management measures will be based on the best scientific information available. Given this intent, the fishery management goals are 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 policy recognizes the need to balance 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 section will be reviewed periodically by the Council. The Council will also review, modify, eliminate, or consider new measures, as appropriate, to best carry out the goals and objectives of this management policy.

To meet the goals of this management policy, 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 will follow these management objectives in carrying out the management policy:

1. Biological Conservation Objective. *Ensure the long-term reproductive viability of fish populations, by: (a) preventing unregulated fishing and 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, ecosystem component species, and non-commercial species; (d) avoiding impacts to seabirds and marine mammals; (e) incorporating ecosystem-based considerations into fishery management decisions, as appropriate; and (f) providing for an orderly process, based on best available science, to provide for the sustainable management and authorization of any future commercial fishing in the Arctic Management Area..*

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 no 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, exempted fishing for information collection, other 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 Authorizing a Commercial Fishery in the Arctic

Until sufficient information exists to authorize a sustainable fisheries management program, commercial fishing is prohibited in the Arctic Management Area. The red king crab fishery described in Appendix A is exempt from the prohibition to commercial fishing. The Council will consider the following criteria for authorizing a commercial fishery in the Arctic Management Area:

A. The Council will initially require an FMP amendment for sustainably managing a commercial fishery ensuring resource conservation, minimizing impacts on other users of the area, complying with the Magnuson-Stevens Act and its National Standards and other applicable laws, and deriving net positive benefits.

B. Any commercial fishing in the Arctic will be specified as 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 an FMP amendment that would transfer the species from the ecosystem component category to the target species category.

C. The Council will consider authorizing commercial fishing on a target species 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 Act-listed threatened or 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

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 prepare an FMP amendment, including appropriate initial review, public review, and final review and rulemaking and completion of the FMP amendment process.

E. The Council may recommend the proposed fishing 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 recommend onboard observers on fishing vessels, at shoreside processing facilities, or at harvest sites if non-vessel platforms (i.e., ice) are used for harvesting. The Council also may recommend 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 Overview

3.1 Management Area

The FMP and its management regime govern commercial fishing in the Arctic Management Area described in Section 1.1, and for those stocks listed in Sections 1.1 and 3.4. Fishing by foreign vessels is not permitted in the Arctic Management Area because no TALFF or JVP is provided by this FMP.

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 1990 maritime boundary line 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 U. S. EEZ off Alaska.

<u>Maximum sustainable yield</u> (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, and fishery technological characteristics (e. g. gear selectivity), and the distribution of catch among fleets.

<u>Optimum yield</u> (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.

<u>Overfishing level</u> (OFL) is a limit reference point set annually for a stock or stock complex during the assessment process, as described in Section 3.9, 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.

<u>Acceptable biological catch</u> (ABC) is an annual sustainable target harvest (or range of harvests) for a stock or stock complex, recommended by a Plan Team and the Scientific and Statistical Committee during the assessment process and established by the Council. It is derived from the status and dynamics of the stock, environmental conditions, other ecological factors, and the degree of scientific uncertainty, 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 biological, social, and economic factors.

3.3 Data Sources and Abundance Estimates Based on Best Available Data

3.3.1 Background

The development and implementation of the Arctic FMP is based on the best available information. The following is a summary of the information analyzed to support sustainable management of Arctic fisheries. [Update this section to incorporate 2008 Beaufort Sea survey data and biomass estimates.]

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; **Figure 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 but data were not available at the time of the development of this FMP. Data from that study may be amended to this FMP when available and in support of another action (e. g. opening a commercial fishery).

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 (**Figure 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 (**Figure 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 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). [Update with 2008 opilio size data.]

3.3.6 Forage fish species

Commercial fishing on forage fish species is prohibited. Forage fish are prey for other marine ecosystem fauna including fish, birds, and marine mammals. Forage fish are included in the "Ecosystem Component" species for which commercial fishing is prohibited.

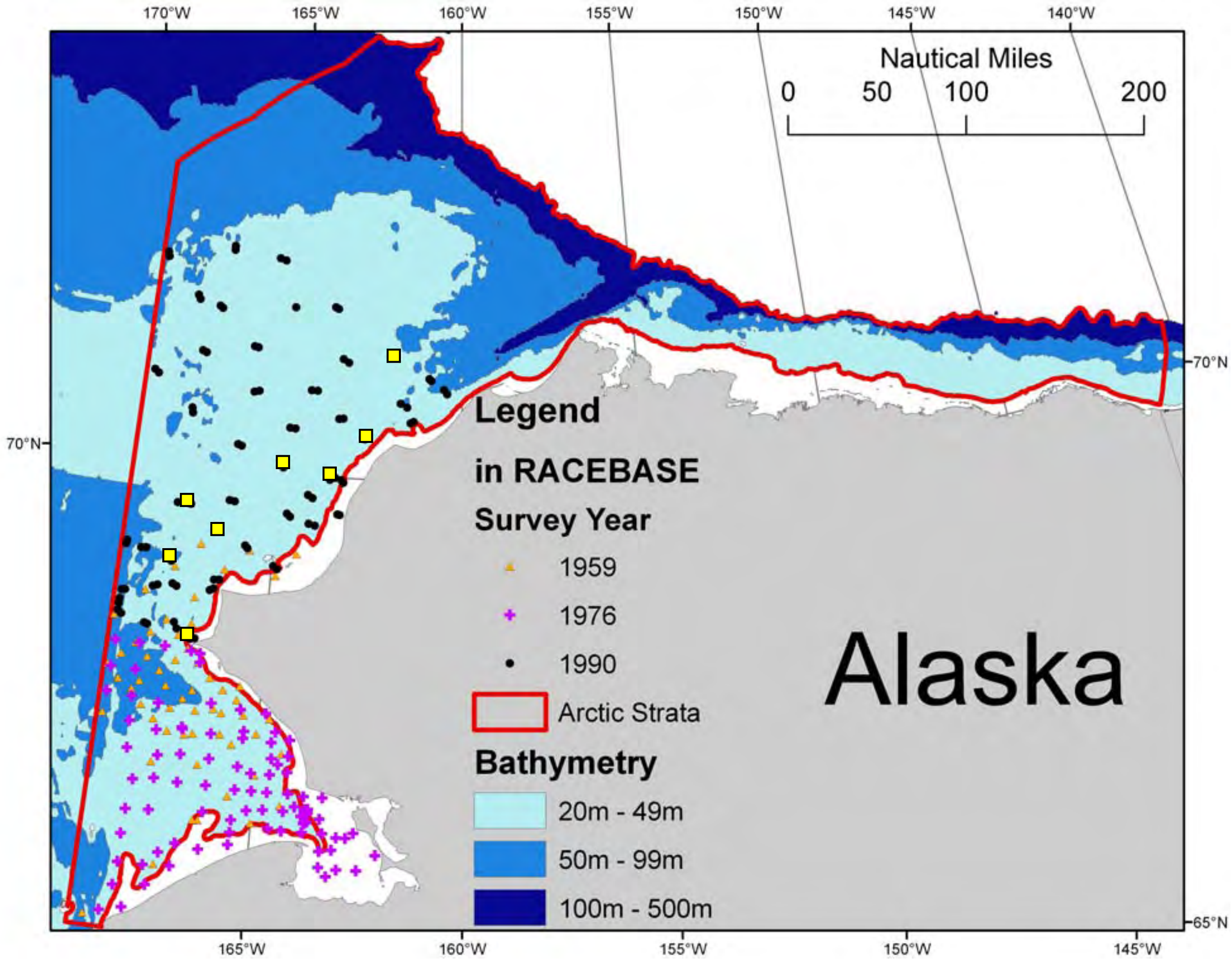

Figure 3-1 Map of the Alaskan Arctic indicating analysis area, bathymetry, and locations of survey stations. Yellow boxes indicate stations sampled in both 1990 and 1991

Table 3-1 Comparison of fish density (number of fish/km^2) in the Chukchi Sea between 1990 and 1991for eight survey stations. 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 91/90
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

3.4 Identification of FMP fisheries

The FMP manages species in the fishery to attain optimum yield of such species on an ongoing basis. In the event that information emerges in the future to indicate interest in commercial fishing for some stock not currently in the fishery, the plan may be amended to include that stock in the fishery and ensure it is managed sustainably.

The following steps are used to identify stocks in the fishery.

1. From the most recent Economic Stock Assessment and Fishery Evaluation (SAFE) Report, tabulate ex-vessel price per pound from the most recent 5 years for the following groups: pollock, Pacific cod, flatfish, rockfish, and sablefish. Convert these to metric units (dollars/kg).
2. From the most recent surveys, 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 the most recent 5 years 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, 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 species being considered for an Arctic target fishery using the best available information.
6. Account for species at the extremes of their distribution. To focus on species that might actually have self-sustaining populations in the Arctic, eliminate all species that were observed in fewer than 10% of the hauls and have total biomass estimates of less than 1,000 mt.
7. For each of the species identified in Step 6, assume that the true mean CPUE is equal to the upper 95% confidence interval of the mean. Then, for each species compute the "breakeven" price needed to achieve the cutoff RPUE value. Then, select all species with breakeven prices less than the highest price ever observed for the most recent 5 years for any groundfish listed in Step 1.
8. Of the species identified in Step 7, eliminate any for which markets appear to be nonexistent.

Based on the best available information at the development of the Arctic FMP, the results of the above algorithm are the target species shown in Table 3-3. Until information is available to support adding additional species to the fishery, the remaining Arctic fish, as defined by the Magnuson-Stevens Act, are in the ecosystem component category. Only target species are part of the fishery management unit for this FMP, requiring status determination criteria and essential fish habitat descriptions.

Table 3-3 Target Species and Ecosystem Component Species.

	Finfish	**Invertebrates**
Target Species	Arctic Cod and Safron Cod	Snow crab (*C. opilio*)
Ecosystem Component Species	All finfish other than Arctic cod, saffron cod	All marine invertebrates other than snow crab (*C. opilio*) and red king crab that would be harvested in the red king crab fishery described in Appendix A

3.5 Specification of Maximum Sustainable Yield

3.5.1 MSY Control Rule

The MSY control rule for stocks in the fishery is of the “constant fishing mortality rate” form. MSY for each stock will be calculated as though the respective stock were exploited at a constant instantaneous fishing mortality rate.

3.5.1.1 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 $0 \leq r \leq 1$ 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:

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

Determine the biomass information that provides the best representation of unfished biomass B_0. 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

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

and an estimate of MSY can be obtained as

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

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.

3.5.2 MSY for Target Species

The following descriptions of MSY for snow crab, Arctic cod, and saffron cod are based on the best available science at the time this FMP was developed. These values are examples of MSYs, which will be updated as necessary based on new information available during the stock assessment process described in Section 3.10.2. The values provided here are applicable until the FMP is amended based on new information in stock assessments sufficient to update these MSYs.

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 in the Bering Sea. 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. B_{MSY}/B_0 is equal to the fraction of unfished biomass at which fishery thresholds are typically set to close crab fisheries because of concerns about stock status. 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 saffron 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 15 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. This is an illustration of the process for deriving MSY and is based on the information available during the development of the Arctic FMP. These values will be revised through FMP amendments as appropriate, based on new information provided during the stock assessment process.

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**

3.6 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). The guidelines suggest, but do not require, that an FMP specify overfishing limit (OFL).

3.6.1 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 rate must not exceed the fishing mortality threshold 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 Arctic 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 FMP will be amended to improve the estimate of F_{MSY}. The overfishing limit for each fishery is specified as the catch that would result from fishing at the MFMT.

3.6.2 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, and it is appropriate to replace the B_{MSY} value listed in the FMP, the FMP will be amended. Also, if a future stock assessment enables estimation of rebuilding rates under an F_{MSY} exploitation strategy and it is appropriate to revise $\mathrm{F_{MSY}}$, then the FMP will be amended to revise MSST according to the National Standard Guidelines definition.

3.7 Specification of Optimum Yield

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." The recently proposed guidelines also suggest that OY be reduced from MSY to account for scientific uncertainty in calculating MSY. (73 FR 32526, June 9, 2008, 50 CFR 600.310(e)(3)(v), proposed). 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 and prevent overfishing." 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. The results shown are examples based on the information available during the development of the FMP and are applicable until the FMP is amended to incorporate new information from the stock assessment process described in Section 3.10.2.

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

3.7.1.1 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

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

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

$$Yratio_G(F) = Yratio(F \,|\, r_H) \quad .$$

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

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

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 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 μ_r=ln(5/2) and σ_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 σ_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.

3.7.1.2 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 σ_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 σ_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 σ_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.

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

3.7.2.1 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

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

3.7.2.2 Results

There are no data on the value of p_B for any of the qualifying fisheries that would be covered by the FMP. 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 target fisheries covered by the FMP. The available information pertaining to non-consumptive value therefore does not support a reduction from MSY for any of the three potential commercial fisheries.

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

3.7.3.1 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 $c_F > \mathrm{MSY} \times p_Y$ or if $c_V > B_0 \times p_Y$, 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.

3.7.3.2 Results

No significant commercial fishery currently exists for any of the three stocks to which the plan applies. Neither does there appear to have been significant commercial fisheries targeting these species, in this region, in the past. This implies that the expected costs of fishing outweigh the expected revenues, all else equal. These costs may include fuel use in remote locations, distance to processing facilities, very small CPUE in comparison to other fishing locations, lack of knowledge of profitable fishing locations, and small fish or crab size. 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 expected revenue structures remain unchanged.

3.7.4 Reductions from MSY prescribed by relevant ecological factors

3.7.4.1 Methods

The MSFCMA requires that the specification of optimum yield take “into account the protection of marine ecosystems.” 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.

3.7.4.2 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 marine mammal species 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. Arctic cod is a keystone species in the Arctic ecosystem. 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 (a keystone species) 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.

3.7.5 Conclusion: OY 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% reduction for all but the snow crab fishery.

On the basis of these analyses, OY would be an annual *de minimis* catch, sufficient only to account for bycatch in subsistence fisheries for other species. Because this FMP applies to the management of commercial fishing, the OY for each of the target species is zero based on the 100% reduction of MSY for each target 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 and the FMP amended to change OY based on the new information.

3.8 Overfishing and Acceptable Biological Catch Determination Criteria

Overfishing is defined as any amount of fishing in excess of a prescribed maximum allowable rate. For finfish species in the Target Species category, this maximum allowable rate would be prescribed through a set of five tiers which are listed in section 4.7.3.3.1 in descending order of preference, corresponding to descending order of information availability. A similar tier process for crab species follows in section 3.8.2. The tier systems for specifications ares based on best available information (section 3.3). The tier system is used to specify ABC and OFL in a manner that accounts for uncertainty in the information used. Less information leads to more conservative setting of these values, resulting in more conservation management of stocks for which less information is available or reliable. .

If OY for the Arctic fisheries is reduced to zero through the process shown in section 3.7.5, no acceptable biological catches or total allowable catches would be specified. The process described in this section applies to the appropriate fishery that has been identified through the process described in sections 2.2 and 3.4.

The Council's Scientific and Statistical Committee (SSC) will have final authority for determining whether a given item of information is "reliable," and may use either objective or subjective criteria in making such determinations.

3.8.1 Finfish Tiers

For tier (1), a “pdf” refers to a probability density function. For tiers 1 and 2, if a reliable pdf of biomass at MSY (B_{MSY}) is available, the preferred point estimate of B_{MSY} 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 α 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 B_{MSY} 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 “$F_{X\%}$” refers to the fishing mortality (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 $B_{40\%}$ refers to the long-term average biomass that would be expected under average recruitment and $F=F_{40\%}$.

Tier 1 Information available: Reliable point estimates of B and B_{MSY} and reliable pdf of F_{MSY} .
1a) Stock status: $B/B_{MSY} > 1$
$F_{OFL} = m_A$, the arithmetic mean of the pdf
$F_{ABC} \leq m_H$, the harmonic mean of the pdf
1b) Stock status: $a < B/B_{MSY} \leq 1$
$F_{OFL} = m_A \times (B/B_{MSY} - a)/(1 - a)$
$F_{ABC} \leq m_H \times (B/B_{MSY} - a)/(1 - a)$
1c) Stock status: $B/B_{MSY} \leq a$
$F_{OFL} = 0$
$F_{ABC} = 0$

Tier 2 Information available: Reliable point estimates of B, B_{MSY} , F_{MSY} , $F_{35\%}$, and $F_{40\%}$.

2a) Stock status: $B/B_{MSY} > 1$
$F_{OFL} = F_{MSY}$
$F_{ABC} \leq F_{MSY} \times (F_{40\%} /F_{35\%})$
2b) Stock status: $a < B/B_{MSY}$ # 1
$F_{OFL} = F_{MSY} \times (B/B_{MSY} - a)/(1 - a)$
$F_{ABC} \leq F_{MSY} \times (F_{40\%} /F_{35\%})\times (B/B_{MSY} - a)/(1 - a)$
2c) Stock status: $B/B_{MSY} \leq a$
$F_{OFL} = 0$
$F_{ABC} = 0$

Tier 3 Information available: Reliable point estimates of B, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$.

3a) Stock status: $B/B_{40\%} > 1$
$F_{OFL} = F_{35\%}$
$F_{ABC} \leq F_{40\%}$
3b) Stock status: $a < B/B_{40\%} \leq 1$
$F_{OFL} = F_{35\%} \times (B/B_{40\%} - a)/(1 - a)$
$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - a)/(1 - a)$
3c) Stock status: $B/B_{40\%} \leq a$
$F_{OFL} = 0$

$F_{ABC} = 0$

Tier 4 Information available: Reliable point estimates of B, $F_{35\%}$, and $F_{40\%}$.

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

Tier 5 Information available: Reliable point estimates of B and natural mortality rate M.

$F_{OFL} = M$

$F_{ABC} \leq 0.75 \times M$.

3.8.2 Crab Tiers

Status determination criteria for crab stocks are calculated using a five-tier system that accommodates varying levels of uncertainty of information. The five-tier system incorporates new scientific information and provides a mechanism to continually improve the status determination criteria as new information becomes available. Under the five-tier system, overfishing and overfished criterion are formulated and assessed to determine the status of the crab stocks and whether (1) overfishing is occurring or the rate or level of fishing mortality for a stock or stock complex is approaching overfishing, and (2) a stock or stock complex is overfished or a stock or stock complex is approaching an overfished condition.

Overfishing is determined by comparing the overfishing level (OFL), as calculated in the five-tier system for the crab fishing year, with the catch estimates for that crab fishing year. For the previous crab fishing year, NMFS will determine whether overfishing occurred by comparing the previous year's OFL with the catch from the previous crab fishing year. This catch includes all fishery removals, including retained catch and discard losses, for those stocks where non-target fishery removal data are available. Discard losses are determined by multiplying the appropriate handling mortality rate by observer estimates of bycatch discards. For stocks where only retained catch information is available, the OFL will be set for and compared to the retained catch.

NMFS will determine whether a stock is in an overfished condition by comparing annual biomass estimates to the established MSST, defined as ½ B_{MSY}. For stocks where MSST (or proxies) are defined, if the biomass drops below the MSST (or proxy thereof) then the stock is considered to be overfished. MSSTs or proxies are set for stocks in Tiers 1-4. For Tier 5 stocks, it is not possible to set an MSST because there are no reliable estimates of biomass.

If overfishing occurred or the stock is overfished, section 304(e)(3)(A) of the Magnuson-Stevens Act, as amended, requires the Council to immediately end overfishing and rebuild affected stocks.

The Council, Scientific and Statistical Committee, and Crab Plan Team will review (1) the stock assessment documents, (2) the OFLs and total allowable catches or guideline harvest levels for the upcoming crab fishery, (3) NMFS's determination of whether overfishing occurred in the previous crab fishing year, and (4) NMFS's determination of whether any stocks are overfished.

3.8.2.1 Five-Tier System

The OFL for each stock is estimated for the upcoming crab fishery using the five-tier system, detailed in Table 3-4 and Table 3-5. First, a stock is assigned to one of the five tiers based on the availability of information for that stock and model parameter choices are made. Tier assignments and model parameter choices are recommended through the Crab Plan Team process to the Council's Scientific and Statistical Committee. The Council's Scientific and Statistical Committee will recommend tier assignments, stock assessment and model structure, and parameter choices, including whether information is "reliable," for the assessment authors to use for calculating the OFLs based on the five-tier system.

For Tiers 1 through 4, once a stock is assigned to a tier, the stock status level is determined based on recent survey data and assessment models, as available. The stock status level determines the equation used in calculating the F_{OFL}. Three levels of stock status are specified and denoted by “a,” “b,” and “c” (see Table 3-4). The F_{MSY} control rule reduces the F_{OFL} as biomass declines by stock status level. At stock status level “a,” current stock biomass exceeds the B_{MSY}. For stocks in status level “b,” current biomass is less than B_{MSY} but greater than a level specified as the “critical biomass threshold” (β).

Lastly, in stock status level “c,” current biomass is below β * (B_{MSY} or a proxy for B_{MSY}). At stock status level “c,” directed fishing is prohibited and an F_{OFL} at or below F_{MSY} would be determined for all other sources of fishing mortality in the development of the rebuilding plan. The Council will develop a rebuilding plan once a stock level falls below the MSST. The estimation of B_{msy}/B_0 is equal to the fraction of unfished biomass at which fishery thresholds are typically set to close crab fisheries because of concerns about stock status.

For Tiers 1 through 3, the coefficient α is set at a default value of 0.1, and β set at a default value of 0.25, with the understanding that the Scientific and Statistical Committee may recommend different values for a specific stock or stock complex as merited by the best available scientific information.

In Tier 4, a default value of natural mortality rate (M) or an M proxy, and a scalar, γ, are used in the calculation of the F_{OFL}.

In Tier 5, the OFL is specified in terms of an average catch value over an historical time period, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information.

OFLs will be calculated by applying the F_{OFL} and using the most recent abundance estimates. The Crab Plan Team will review stock assessment documents, the most recent abundance estimates, and the proposed OFLs. The Alaska Fisheries Science Center will set the OFLs consistent with this FMP and forward OFLs for each stock to the State of Alaska prior to its setting the total allowable catch or guideline harvest level for that stock’s upcoming crab fishing season.

3.8.2.1.1 Tiers 1 through 3

For Tiers 1 through 3, reliable estimates of B, B_{MSY}, and F_{MSY}, or their respective proxy values, are available. Tiers 1 and 2 are for stocks with a reliable estimate of the spawner/recruit relationship, thereby enabling the estimation of the limit reference points B_{MSY} and F_{MSY}.

Tier 1 is for stocks with assessment models in which the probability density function (pdf) of F_{MSY} is estimated.
Tier 2 is for stocks with assessment models in which a reliable point estimate, but not the pdf, of F_{MSY} is made.
Tier 3 is for stocks where reliable estimates of the spawner/recruit relationship are not available, but proxies for F_{MSY} and B_{MSY} can be estimated.

For Tier 3 stocks, maturity and other essential life-history information are available to estimate proxy limit reference points. For Tier 3, a designation of the form “F_X” refers to the fishing mortality rate associated with an equilibrium level of fertilized egg production (or its proxy) per recruit equal to X% of the equilibrium level in the absence of any fishing.

The OFL calculation accounts for all losses to the stock not attributable to natural mortality. The OFL is the total catch limit comprised of three catch components: (1) non-directed fishery discard losses; (2) directed fishery discard losses; and (3) directed fishery retained catch. To determine the discard losses, the handling mortality rate is multiplied by bycatch discards in each fishery. Overfishing would occur if, in any year, the sum of all three catch components exceeds the OFL.

3.8.2.1.2 Tier 4

Tier 4 is for stocks where essential life-history, recruitment information, and understanding are lacking. Therefore, it is not possible to estimate the spawner-recruit relationship. However, there is sufficient information for simulation modeling that captures the essential population dynamics of the stock as well as the performance of the fisheries. The simulation modeling approach employed in the derivation of the annual OFLs captures the historical performance of the fisheries as seen in observer data from the early 1990s to present and thus borrows information from other stocks as necessary to estimate biological parameters such as γ.

In Tier 4, a default value of natural mortality rate (M) or an M proxy, and a scalar, γ, are used in the calculation of the F_{OFL}. Explicit to Tier 4 are reliable estimates of current survey biomass and the instantaneous M. The proxy B_{MSY} is the average biomass over a specified time period, with the understanding that the Council's Scientific and Statistical Committee may recommend a different value for a specific stock or stock complex as merited by the best available scientific information. A scalar, γ, is multiplied by M to estimate the F_{OFL} for stocks at status levels a and b, and γ is allowed to be less than or greater than unity. Use of the scalar γ is intended to allow adjustments in the overfishing definitions to account for differences in biomass measures. A default value of γ is set at 1.0, with the understanding that the Council's Scientific and Statistical Committee may recommend a different value for a specific stock or stock complex as merited by the best available scientific information.

If the information necessary to determine total catch OFLs is not available for a Tier 4 stock, then the OFL is determined for retained catch. In the future, as information improves, data would be available for some stocks to allow the formulation and use of selectivity curves for the discard fisheries (directed and non-directed losses) as well as the directed fishery (retained catch) in the models. The resulting OFL from this approach, therefore, would be the total catch OFL.

3.8.2.1.3 Tier 5

Tier 5 stocks have no reliable estimates of biomass or M and only historical data of retained catch is available. For Tier 5 stocks, the historical performance of the fishery is used to set OFLs in terms of retained catch. The OFL represents the average retained catch from a time period determined to be representative of the production potential of the stock. The time period selected for computing the average catch, hence the OFL, would be based on the best scientific information available and provide the appropriate risk aversion for stock conservation and utilization goals. In Tier 5, the OFL is specified in terms of an average catch value over a time period determined to be representative of the production potential of the stock, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information.

For most Tier 5 stocks, only retained catch information is available so the OFL will be estimated for the retained catch portion only, with the corresponding overfishing comparison on the retained catch only. In the future, as information improves, the OFL calculation could include discard losses, at which point the OFL would be applied to the retained catch plus the discard losses from directed and non-directed fisheries.

Table 3-4 Five-Tier System for setting overfishing limits for crab stocks. The tiers are listed in descending order of information availability. Table 3-5 **contains a guide for understanding the five-tier system.**

Information available	Tier	Stock status level	F_{OFL}
B, B_{MSY}, F_{MSY}, and pdf of F_{MSY}	**1**	a. $\frac{B}{B_{msy}} > 1$	$F_{OFL} = \mu_A$ =arithmetic mean of the pdf
		b. $\beta < \frac{B}{B_{msy}} \leq 1$	$F_{OFL} = \mu_A \frac{B/B_{msy} - \alpha}{1-\alpha}$
		c. $\frac{B}{B_{msy}} \leq \beta$	*Directed fishery F = 0* $F_{OFL} \leq F_{MSY}$ †
B, B_{MSY}, F_{MSY}	**2**	a. $\frac{B}{B_{msy}} > 1$	$F_{OFL} = F_{msy}$
		b. $\beta < \frac{B}{B_{msy}} \leq 1$	$F_{OFL} = F_{msy} \frac{B/B_{msy} - \alpha}{1-\alpha}$
		c. $\frac{B}{B_{msy}} \leq \beta$	*Directed fishery F = 0* $F_{OFL} \leq F_{MSY}$ †
B, $F_{35\%}{}^{*}$, $B_{35\%}{}^{*}$	**3**	a. $\frac{B}{B_{35\%*}} > 1$	$F_{OFL} = F_{35\%}*$
		b. $\beta < \frac{B}{B_{35\%}*} \leq 1$	$F_{OFL} = F^{*}{}_{35\%} \frac{\frac{B}{B^{*}{}_{35\%}} - \alpha}{1-\alpha}$
		c. $\frac{B}{B_{35\%}*} \leq \beta$	*Directed fishery F = 0* $F_{OFL} \leq F_{MSY}$ †
B, *M*, $B_{msy^{prox}}$	**4**	a. $\frac{B}{B_{msy^{prox}}} > 1$	$F_{OFL} = \gamma M$
		b. $\beta < \frac{B}{B_{msy^{prox}}} \leq 1$	$F_{OFL} = \gamma M \frac{B/B_{msy^{prox}} - \alpha}{1-\alpha}$
		c. $\frac{B}{B_{msy^{prox}}} \leq \beta$	*Directed fishery F = 0* $F_{OFL} \leq F_{MSY}$ †
Stocks with no reliable estimates of biomass or M.	**5**		OFL = average catch from a time period to be determined, unless the SSC recommends an alternative value based on the best available scientific information.

*35% is the default value unless the SSC recommends a different value based on the best available scientific information.

† An $F_{OFL} \leq F_{MSY}$ will be determined in the development of the rebuilding plan for that stock.

Table 3-5 A guide for understanding the five-tier system.

- F_{OFL} — the instantaneous fishing mortality (F) from the directed fishery that is used in the calculation of the overfishing limit (OFL). F_{OFL} is determined as a function of:
  - F_{MSY} — the instantaneous F that will produce MSY at the MSY-producing biomass
    - A proxy of F_{MSY} may be used; e.g., $F_{x\%}$, the instantaneous F that results in x% of the equilibrium spawning per recruit relative to the unfished value
  - B — a measure of the productive capacity of the stock, such as spawning biomass or fertilized egg production.
    - A proxy of B may be used; e.g., mature male biomass
  - B_{MSY} — the value of B at the MSY-producing level
    - A proxy of B_{MSY} may be used; e.g., mature male biomass at the MSY-producing level
  - β — a parameter with restriction that $0 \leq \beta < 1$.
  - α — a parameter with restriction that $0 \leq \alpha \leq \beta$.
- The maximum value of F_{OFL} is F_{MSY}. $F_{OFL} = F_{MSY}$ when $B > B_{MSY}$.
- F_{OFL} decreases linearly from F_{MSY} to $F_{MSY} \cdot (\beta - \alpha)/(1 - \alpha)$ as B decreases from B_{MSY} to $\beta \cdot B_{MSY}$
- When $B \leq \beta \cdot B_{MSY}$, F = 0 for the directed fishery and $F_{OFL} \leq F_{MSY}$ for the non-directed fisheries, which will be determined in the development of the rebuilding plan.
- The parameter, β, determines the threshold level of B at or below which directed fishing is prohibited.
- The parameter, α, determines the value of F_{OFL} when B decreases to $\beta \cdot B_{MSY}$ and the rate at which F_{OFL} decreases with decreasing values of B when $\beta \cdot B_{MSY} < B \leq B_{MSY}$.
  - Larger values of α result in a smaller value of F_{OFL} when B decreases to $\beta \cdot B_{MSY}$.
  - Larger values of α result in F_{OFL} decreasing at a higher rate with decreasing values of B when $\beta \cdot B_{MSY} < B \leq B_{MSY}$.

[Footnote RE: ABC control rule to be provided by AFSC.]

3.9 Specification of ABC and TAC

At the time information is available to support the management of a sustainable fishery in the Arctic Management Area, the following process would be used to provide harvest specifications for the management of the target fishery(ies).

The Secretary of Commerce (Secretary), after receiving recommendations from the Council, will determine up to 3 years of TACs and apportionments thereof for each stock or stock complex in the target species categories, by January 1 of the new fishing year, or as soon as practicable thereafter, by means of regulations implementing the FMP. Notwithstanding designated stocks or stock complexes listed by category in Table 3-3, the Council may recommend splitting or combining stocks or stock complexes in the "target species" category for purposes of establishing a new TAC if such action is desirable based on commercial importance of a stock or stock complex and whether sufficient biological information is available to manage a stock or stock complex on its own merits.

Prior to making final recommendations to the Secretary, the Council will make available to the public for comment as soon as practicable after its October meeting, proposed specifications of ABC and TAC for each target stock or stock complex, and apportionments thereof.

The Council will provide proposed recommendations for harvest specifications to the Secretary after its October meeting, including detailed information on the development of each proposed specification and any future information that is expected to affect the final specifications. As soon as practicable after the October meeting, the Secretary will publish in the *Federal Register* proposed harvest specifications based on the Council's October recommendations and make available for public review and comment, all information regarding the development of the specifications, identifying specifications that are likely to change, and possible reasons for changes, if known, from the proposed to final specifications. The prior public review and comment period on the published proposed specifications will be a minimum of 15 days.

At its December meeting, the Council will review the final SAFE reports, recommendations from the Groundfish and Crab Plan Teams, SSC, the Council's Advisory Panel (AP), and comments received. The Council will then make final harvest specifications recommendations to the Secretary for review, approval, and publication. New final annual specifications will supercede current annual specifications on the effective date of the new annual specifications.

3.9.1 Setting Total Allowable Catch

Once a commercial fishery is authorized by amendment to this FMP, the Council will recommend annual harvest levels by specifying a total allowable catch for each target fishery for a three year time period. The following generally describes the procedure that will be used to determine TACs for every target stock and stock complex managed by the FMP.

1. Determine the ABC for each managed stock or stock complex. ABCs are recommended by the Council's SSC based on information presented by the Plan Teams. ABC must be set less than OFL as provided in the tier process in section 3.8.
2. Determine a TAC based on biological and socioeconomic information. The TAC must be less than or equal to the ABC. The TAC may be lower than the ABC if bycatch considerations, socioeconomic considerations, or uncertainty regarding the effectiveness of management measures or accuracy of data used to inform inseason management cause the Council to establish a lower harvest.
3. Ensure TACs are at or below the OYs specified for the fisheries in the Arctic FMP. If the TACs are above the OYs, the TACs must be adjusted equal to or below OY or the FMP amended to increase OY based on the best available information.

3.9.2 Stock Assessment and Fishery Evaluation

For purposes of supplying scientific information to the Council for use in specifying ABC, OFLs, and TACs, an Arctic *Stock Assessment and Fishery Evaluation* report will be prepared when information becomes available to support the amendment to the FMP for commercial fishing. Once commercial fishing is authorized by this FMP, a SAFE report would be developed every three years or more frequently if new information or the development of a fishery indicates a shorter time period is needed, or at a different frequency as appropriate as new scientific information is received by the Council.

Scientists from the Alaska Fisheries Science Center, the Alaska Department of Fish and Game, and other agencies and universities will prepare the Arctic *Stock Assessment and Fishery Evaluation* (SAFE) report every three years, or at a different frequency as appropriate as new scientific information is received by the Council. This document is first reviewed by the Crab and BSAI Groundfish Plan Teams, and then by the Council's SSC and AP, and the Council. Reference point recommendations will be made at each level of assessment. Usually, scientists will recommend values for ABC and OFL, and the AP will recommend values for TACs. The Council has final authority to approve all reference points, but focuses on setting TACs so that OYs are achieved and OFLs are not exceeded.

The SAFE report will, at a minimum, contain or refer to the following:

1. current status of Arctic Management Area fish resources, by major species or species group;
2. estimates of maximum sustainable yield and acceptable biological catch;
3. estimates of Arctic fishery species mortality from commercial fisheries, subsistence fisheries, and recreational fisheries, and difference between Arctic target species mortality and catch, if possible;
4. fishery statistics (landings and value) for the current year;
5. the projected responses of stocks and fisheries to alternative levels of fishing mortality;
6. any relevant information relating to changes in Arctic target species markets;
7. information to be used by the Council in establishing any prohibited species catch limits with supporting justification and rationale; and
8. any other biological, social, or economic information that may be useful to the Council.

The Council will use the following to develop its own preliminary recommendations: 1) recommendations of the Plan Teams and Council's SSC and information presented by the Plan Teams and SSC in support of these recommendations; 2) information presented by the Council's Advisory Panel and the public; and 3) other relevant information.

3.9.3 Attainment of Total Allowable Catch

The attainment of a TAC for a species will result in the closure of the target fishery for that species. That is, once the TAC is taken, further retention of that species will be prohibited. Other fisheries targeting on other species could be allowed to continue as long as the non-retainable bycatch of the closed species is found to be non-detrimental to that stock.

3.10 Accountability Measures and Mechanisms

No commercial fishing in the Arctic Management Area is authorized by this FMP, and thus, no accountability measures and mechanisms are specified in the FMP. Under this FMP, catch and/or retention of species in the ecosystem component category for commercial purposes is prohibited; it is recognized that if a target fishery is eventually authorized, some catch of ecosystem component species may occur as a result of prosecuting that target fishery; in this case, retention of ecosystem component species would be prohibited. Under this FMP catch and/or retention of species in the target category for commercial purposes is prohibited and shall remain so until the FMP is amended to authorize commercial fishing. Accountability measures and mechanisms to ensure overfishing does not occur will be amended to the FMP and adopted in regulations before commercial fishing is authorized in the Arctic Management Area. These measures and mechanisms will be tailored to the commercial fishery to ensure sufficient information can be received in a timely manner to inform decisions for the sustainable management of the commercial fishery.

3.11 Permit and Participation Restrictions

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus no permitting requirements are specified with the exception of exempted fishing permits as described below.

3.11.1 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.

3.12 Gear Restrictions

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus no authorized gear is specified. Appropriate gear types for any future fisheries may be amended to this FMP if a fishery is authorized in the Arctic Management Area.

3.13 Time and Area Restrictions

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus no time or area restrictions are specified. This FMP may be amended to provide seasons, geographic restrictions, and other related management measures if a fishery is authorized in the Arctic Management Area.

3.14 Catch Restrictions

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus no catch restrictions are specified. Catch limits, adjustments, and other catch restrictions may be amended to the FMP if a fishery is authorized in the Arctic Management Area.

3.15 Bycatch Reduction Incentive Programs

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus no bycatch limits for any fisheries are specified. This FMP may be amended to provide bycatch limits if a fishery is authorized in the Arctic Management Area.

3.16 Share-based Programs

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus no share-based programs are specified. This FMP may be amended to provide share-based programs if a fishery is authorized in the Arctic Management Area.

3.17 Flexible Management Authority

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus flexible management authority is not specified. Descriptions of management measures that provide for fixed, frameworked, or discretionary management of fisheries may be specified by the Council if a fishery is authorized in the Arctic Management Area.

3.18 Monitoring and Reporting

3.18.1 Recordkeeping and Reporting

No commercial fishing for managed species in the Arctic Management Area is authorized, and thus no recordkeeping or reporting requirements are specified. Recordkeeping and reporting requirements may be specified in an exempted fishing permit issued under authority of this FMP. This FMP may be amended to provide recordkeeping, reporting, and observer requirements, including specific data to be submitted to NMFS and the Council, to ensure effective management of the fishery.

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. If a commercial fishery is authorized, the Secretary 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.

Under MSA section 313(h)(1) for Catch Management, the Council shall, by June 1, 1997, “submit, and the Secretary may approve, consistent with the other provisions of this Act, conservation and management measures to ensure total catch measurement in each fishery under the jurisdiction of such Council. Such measures shall ensure the accurate enumeration, at a minimum, of target species, economic discards, and regulatory discards." Under this FMP, no commercial fishing is authorized. Thus, no conservation or management measures to specifically address catch accounting are included in the FMP. The Council intends that any future fisheries authorized in the Arctic Management Area will be prosecuted so that accurate catch accounting occurs, and will specify those measures necessary to ensure accurate enumeration of target species, economic discards, and regulatory discards, at a minimum in the amended Arctic FMP.

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.

3.18.2 Standardized Bycatch Reporting Methodology

No commercial fishing for managed species is authorized in the Arctic Management Area, and thus no standardized bycatch reporting methodology for any fisheries is specified. This FMP may be amended to provide a standardized bycatch reporting methodology if a fishery is authorized in the Arctic Management Area.

3.19 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 fisheries 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.

3.19.1 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.

3.19.2 Enforcement

Enforcement of the prohibition on commercial fishing will be required with the implementation of this FMP. The U. S. Coast Guard and the NOAA Office of Law Enforcement are responsible for the enforcement of regulations authorized by this FMP. Additional enforcement responsibilities may occur with the authorization of commercial fishing in the Arctic Management Area. This FMP may be amended to provide conservation and management measures necessary for the effective enforcement of the regulations implementing the FMP if commercial fishing is authorized.

3.19.3 Costs Incurred for Management

The costs to implement 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 or other actions to enforce the prohibition on commercial fishing until commercial fishing is authorized.

3.19.4 Bycatch Reduction

Section 313(f) of the MSA addresses bycatch reduction requiring the Council to "submit conservation and management measures to lower, on an annual basis for a period of not less than four years, the total amount of economic discards occurring in the fisheries under its jurisdiction." Under this FMP no commercial fishing is authorized. Thus, no conservation or management measures to specifically address bycatch are included in this FMP. The Council intends that any future fisheries authorized in the Arctic Management Area will be prosecuted so that minimal discarding occurs, and will specify those measures necessary to ensure all discards of non-target catch are minimized in the amended Arctic FMP.

3.19.5 Catch Weighing

To the extent that measures required in this FMP under MSA Section 313(h)(1) do not require U.S. fish processors and fish processing vessels to weigh fish, under Section 313(h)(2) Catch Management, the Council and the Secretary "shall submit a plan to the Congress by January 1, 1998, to allow for weighing, including recommendations to assist such processors and processing vessels in acquiring necessary equipment, unless the Council determines that such weighing is not necessary to meet the requirement of this subsection." Under this FMP, no commercial fishing is authorized in the Arctic Management Area. Thus, no conservation or management measures to specifically address weighing of catch are included in this FMP. The Council intends that any future fisheries authorized in the Arctic Management Area will be prosecuted so that accurate weighing of catch occurs, and will specify those measures necessary to ensure accurate weighing in the amended Arctic FMP.

3.19.6 Full Retention/Full Utilization

Under MSA Section 313(i) Full Retention and Utilization the Council is required to report to the Secretary "on the advisability of requiring the full retention by fishing vessels and full utilization by United States fish processors of economic discards in fisheries under its jurisdiction if such economic discards, or the mortality of such economic discards, cannot be avoided." This report must outline impacts of such a requirement on fishery participants and the measures already in place. The report also must address minimizing processing waste. Under this FMP, no commercial fishing is authorized in the Arctic Management Area. Thus, no conservation or management measures to specifically address full retention or utilization are included in this FMP. The Council intends that any future fisheries authorized in the Arctic Management Area will be prosecuted so that full retention and utilization of catch is required to the extent possible, and will specify those measures necessary to ensure full retention and utilization to the extent possible in the amended Arctic FMP.

3.20 Council Review of the Fishery Management Plan

3.20.1 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 and management.
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.

3.20.2 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 Policy

Objectives identified in the management policy statement (Section 2.2) will be reviewed as determined to be necessary by the Council. The Council will also review, modify, eliminate, or consider new isuues and consider information, 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.

3.21 Research

Under MSA Section 302(h)(7) the Council shall "develop, in conjunction with the scientific and statistical committee, multi-year research priorities for fisheries, fisheries interactions, habitats, and other areas of research that are necessary for management purposes" for 5-year periods and update this list of research priorities as necessary and submit the list to the Secretary and the NMFS Alaska Fisheries Science Center for consideration in developing research priorities and budgets for the Alaska Region. The Council annually develops a list of research needs based on recommendations from its SSC. The list contains both short-term (for the immediate year ahead) and long-term (for the next 5 years) research needs, and is provided annually to the Secretary, NMFS, and other agencies entities. While no fisheries are authorized under this FMP, the Council, in conjunction with its SSC and at its discretion and as appropriate, may develop short-term and long-term research needs for the Arctic Management Area that may improve scientific understanding of fish stocks and environmental parameters that may be important in considering fishery development in the future.

Chapter 4 Description of Habitat, Fisheries, and Ecosystem

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 km², 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 km², 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 shipping lanes open.

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 and plankton 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 eastern portion of the National Petroleum Reserve-Alaska and the Colville River and Delta eastward to the Sagavanirktok River, and in recent years further to the east. 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 km^2 (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 1990 line of agreement extending through the middle of Bering Strait northward at 169 degrees West longitude.

4.1.3 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 sections and in Appendix B and C, as they apply to the Arctic Management Area and the fisheries currently in this area. Because this FMP prohibits commercial fishing in the Arctic Management Area for managed species, no impacts on EFH are expected and therefore no cumulative impacts on EFH are expected. In addition, the prohibition on commercial fishing ensures no effects on prey resources for FMP managed species. At the time this FMP may be amended to provide for a commercial fishery in the Arctic Management Area, the cumulative effects on EFH and the effects on prey resources for FMP managed species will be addressed in the FMP amendment.

4.1.3.1 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 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 Area (FMA) for the FMP and the target fisheries within the FMA as the fishery management unit (FMU). EFH must be described for the FMU. The Arctic FMP FMA 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 1990 maritime boundary line and eastward to the U.S. Canada maritime boundary. The fisheries within this unit are those listed in the target category in **Table 3-3**.

FMPs 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 for the target species are in Appendices B and C. Appendix E contains additional habitat information for several ecosystem component species. This supplemental habitat information is provided to assist the Council in its ecosystem approach to management in the Arctic Management Area.

Appendix D provides information on non-fishing Effects on EFH in the Arctic Region.

4.1.3.2 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. If commercial fishing is authorized, EFH habitat conservation measures may be amended to the FMP to protect EFH.

4.1.3.3 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.

4.1.3.4 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.

4.1.3.5 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 because no HAPC has been identified through the process described in section 4.1.5.1.

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

Because no commercial fishing for species managed under the FMP is conducted and the gear types and magnitude of other fisheries are not likely to impact EFH (section 4.2), no actions are necessary to minimize the effects of MSA fishing on EFH.

4.1.5 Research Efforts in Support of EFH

See section 3.17. EFH research needs are prepared through a collaborative proposal process overseen by Habitat and Ecological Process Research (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 www.afsc.noaa.gov/HEPR/efh.htm.

4.1.6 Fishing and Non-fishing Activities Affecting the Stocks or EFH

There are no known Indian treaty fishing rights for fish, shellfish, or other fish resources in the Arctic Management Area; and therefore, no know effects on EFH from Indian Treaty fishing. Non-fishing activities that may affect EFH are in Appendix D of the FMP. This section describes the MSA and non-MSA fishing activities that may affect EFH. Commercial fishery

4.1.6.1 Commercial Fishery

No commercial fishing occurs in the Arctic except for a small red king crab fishery in the southern Chukchi Sea as described in Appendix A. 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 areas.

4.1.6.2 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.

4.1.6.3 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.

4.2 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 recreational 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.

4.3 Ecosystem Characteristics

4.3.1 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 (**Figure 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).

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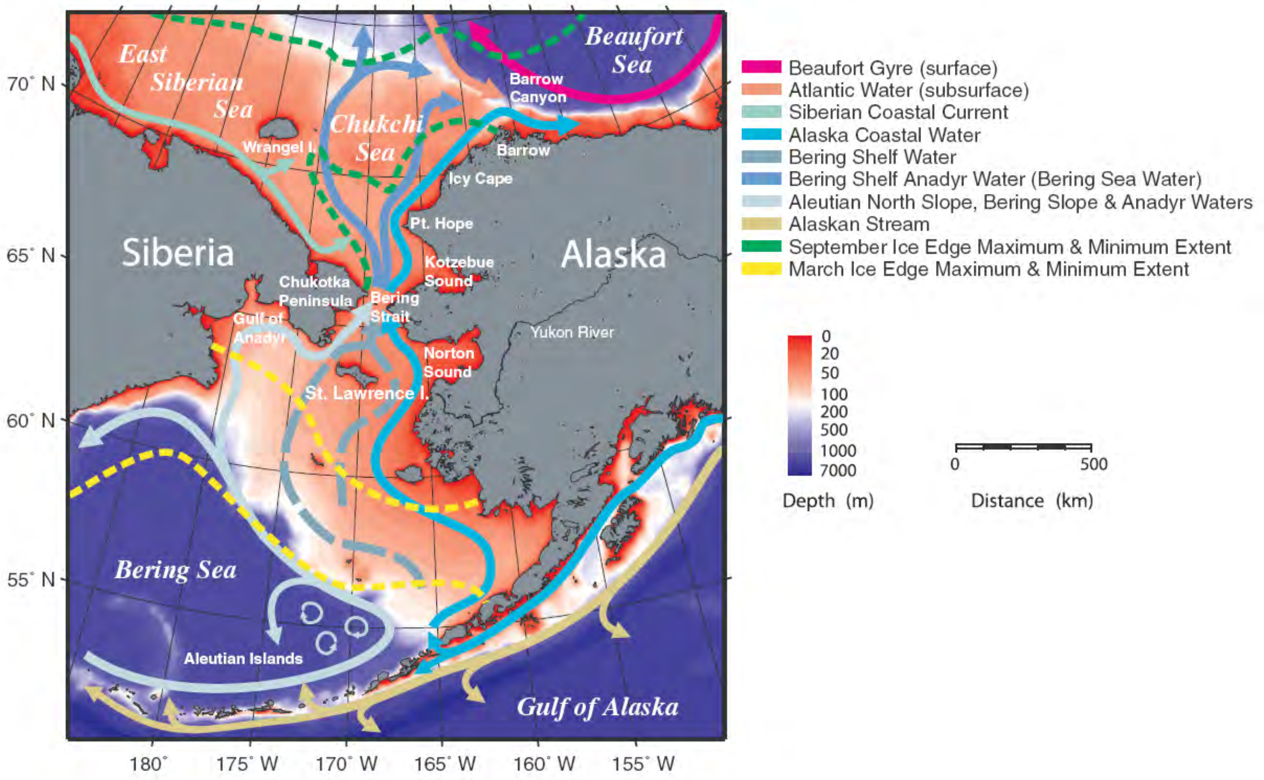

Figure 4-1 Major currents in the Alaskan Arctic region (Grebmeier et al. 2006a)

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.

4.3.2 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 (**Figure 4-2**, and **Figure 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, this section first focuses on the open shelf habitats responsible for the bulk of productivity and comparable to others under current fishery management plans, then discuses fish, macroinvertebrates, and food webs in the Alaskan Arctic.

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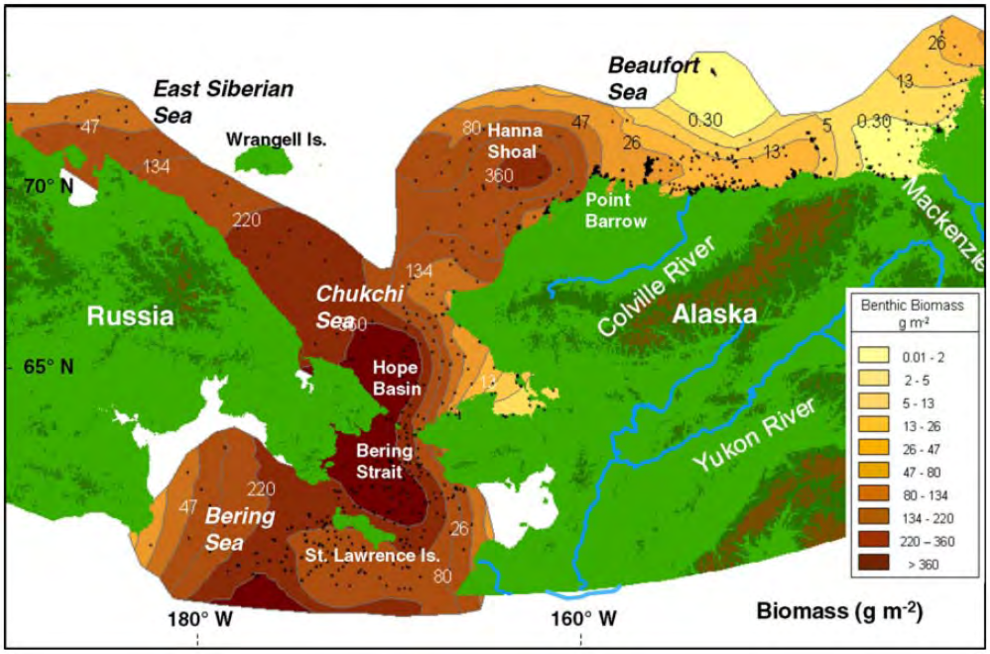

Figure 4-2 Distribution of benthic animal biomass in the Alaskan Arctic region (Dunton et. al 2005)

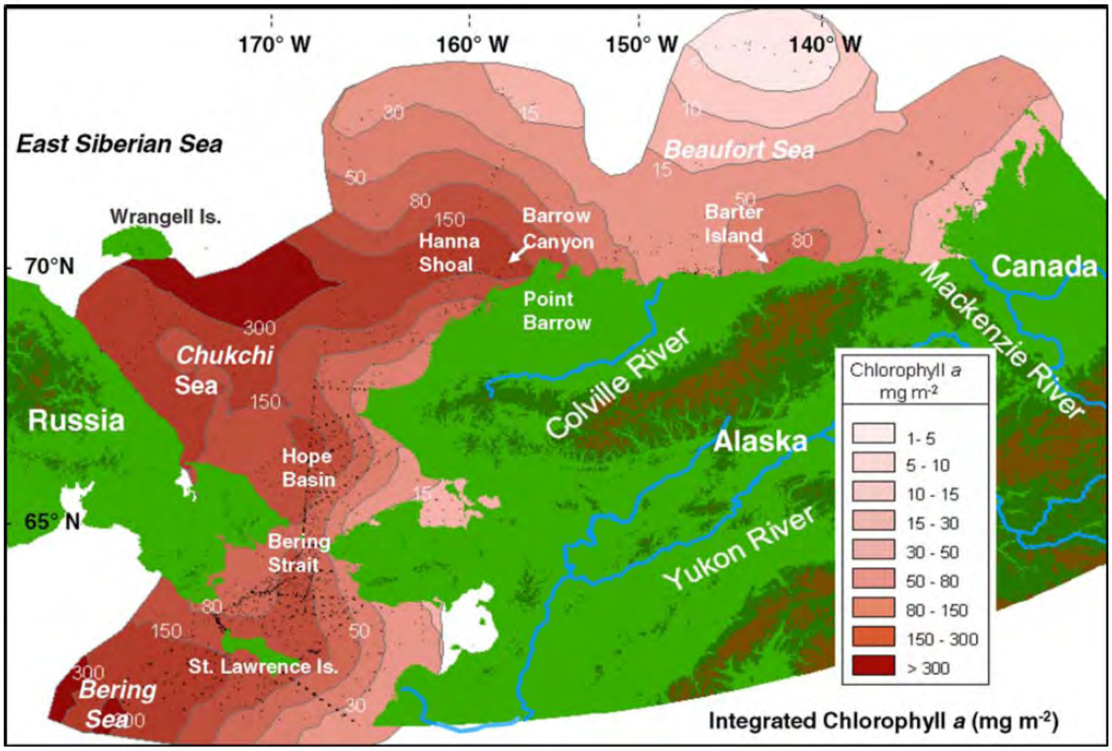

Figure 4-3 Distribution of Chlorophyll a (primary production) in the Alaskan Arctic region (Dunton et al. 2005)

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, Figure 4-4). A survey was recently (August-September 2008) completed on the Alaskan Beaufort Sea shelf to update biomass estimates for the fish and invertebrate fauna. These data will facilitate further comparisons with other managed Alaskan ecosystems in the future. [Update with 2008 Beaufort survey data.]

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	

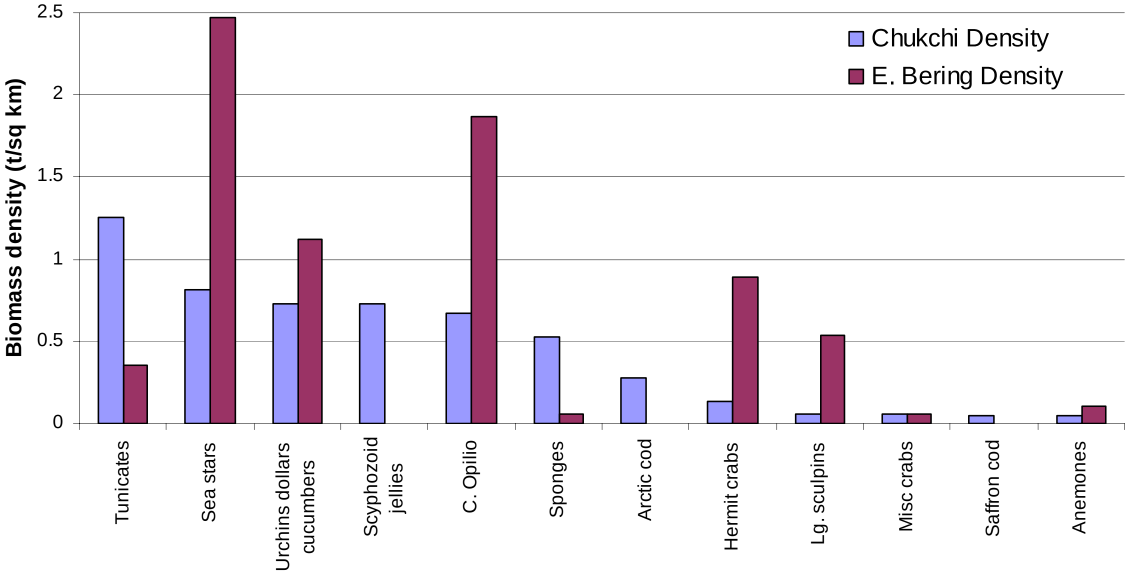

Figure 4-4 Top ranked Chukchi Sea biomass groups compared with EBS biomass for early 1990s

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. Because of the broad occurrence of Arctic cod throughout the Arctic Management Area and dependence of many marine mammal and seabird species on Arctic cod, Arctic cod is considered a keystone species in the Arctic ecosystem.

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.

4.3.3 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 20th century (Bockstoce 1978).

Today, many of the settlements of the original Arctic Alaskans are still inhabited, and dependence on the marine ecosystem continues (Figure 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).

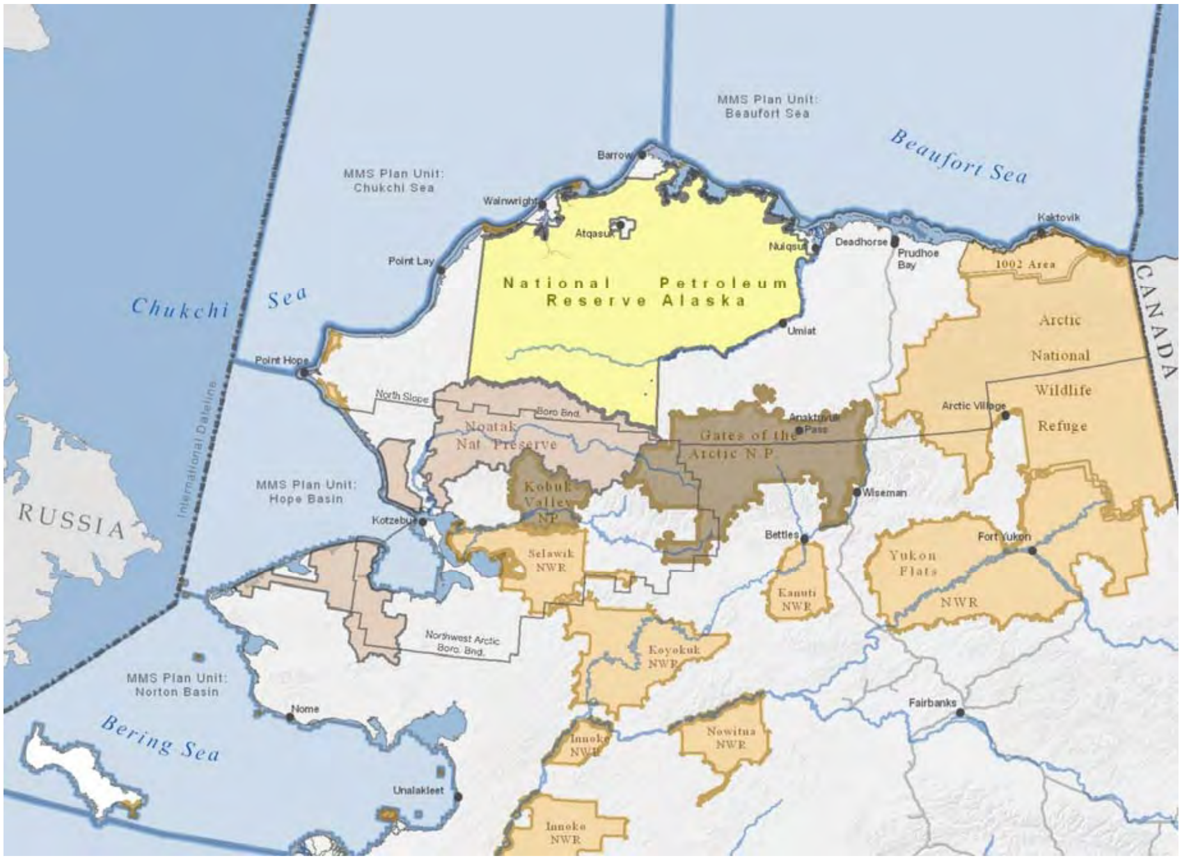

Figure 4-5 Villages and land status of the Alaska Arctic region (map by M. Geist and A. Couvillion, The Nature Conservancy).

4.3.4 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.

4.3.4.1 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.

4.3.4.2 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 Interactions Amoung 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 commercially 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 Islands Groundfish 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 excluded from this FMP and are managed by the State of Alaska. 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.

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.

5.4.3 State salmon fishery

Pacific salmon are a prohibited species in the BSAI and GOA groundfish FMPs. 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. The State may allow a Pacific salmon fishery in other Arctic State waters in the future.

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. The State may allow a Pacific herring fishery in other Arctic 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; many of these fisheries 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.

Chapter 6 Fishery Impact Statement

A fishery impact statement (FIS) is required by the MSA, section 303(a)(9). The FIS must assess, specify and analyzed the likely effects, including cumulative conservation, economic, and social impacts, of the conservation and management measures on and possible mitigation measures for-

(A) participants in the fisheries and fishing communities affected by the plan or amendment;

(B) participants in the fisheries conducted in adjacent areas under the authority of another Council, after consultation with such Council and representatives of those participants; and

(C) the safety of human life at sea, including whether and to what extent such measures may affect the safety of participants in the fishery.

Because the Arctic FMP does not authorize any commercial fishing and no commercial fishing 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 fishery 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 7.1 describes the sources of available data regarding U. S. EEZ in the Arctic and adjacent fisheries, including annually updated reference material. A list of the literature cited in the FMP is included in Section 7.2.

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 and the Crab Plan Team, which are 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 reports 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 reports provides information on the historical catch trend, estimates of the maximum sustainable yield of the crab and 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 crab and 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 reports 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 reports are available online (see below), and by request from the North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, Alaska, 99501.

As information on Arctic species becomes available, SAFE reports specific to certain Arctic species may be developed by a Council Plan Team. Information from such reports will be used in the sustainable management of Arctic species managed under this FMP.

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/

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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).

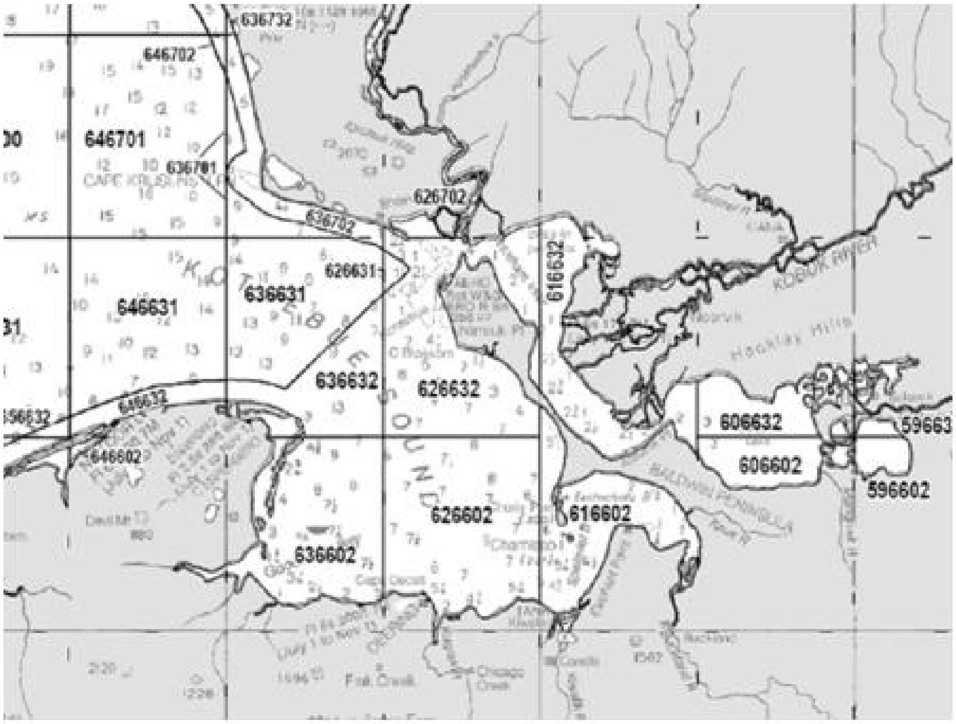

Figure A-1 State Statistical Areas of Kotzebue Sound. Red king crab fishery exemption from the Arctic FMP is limited to fishing in state statistical areas 626701, 646631, 646641, and 636631.

APPENDIX B. EFH Text Descriptions

This appendix contains EFH descriptions for fish species within the fishery management unit.

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.

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 as the Arctic Management Area and the fisheries managed by 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 1990 maritime boundary line and eastward to the U.S. Canada maritime boundary and the target species listed in **Table 3-3**.

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.

Objective

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. (See Table 1. EFH Information Levels)

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.

Rationale

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.

Methodology

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. EFH cannot be described for many species and life history stages and is not described for ecosystem component species

Arctic EFH Text Descriptions

EFH Description for Arctic Cod

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.

EFH Description for Saffron Cod

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.

EFH Description for Snow Crab (*C. opilio)*
Eggs
Essential fish habitat of snow crab eggs is inferred form the general distribution of egg-bearing female crab (see also Adults).

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

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.

Table 1. EFH Information Levels

Arctic FMP EFH Species	**Life History Stage**			
	Eggs	**Larvae**	**Late Juvenile**	**Adult**
Arctic cod	-	-	1	1
Saffron cod	-	-	1	1
Snow crab	1	-	1	1

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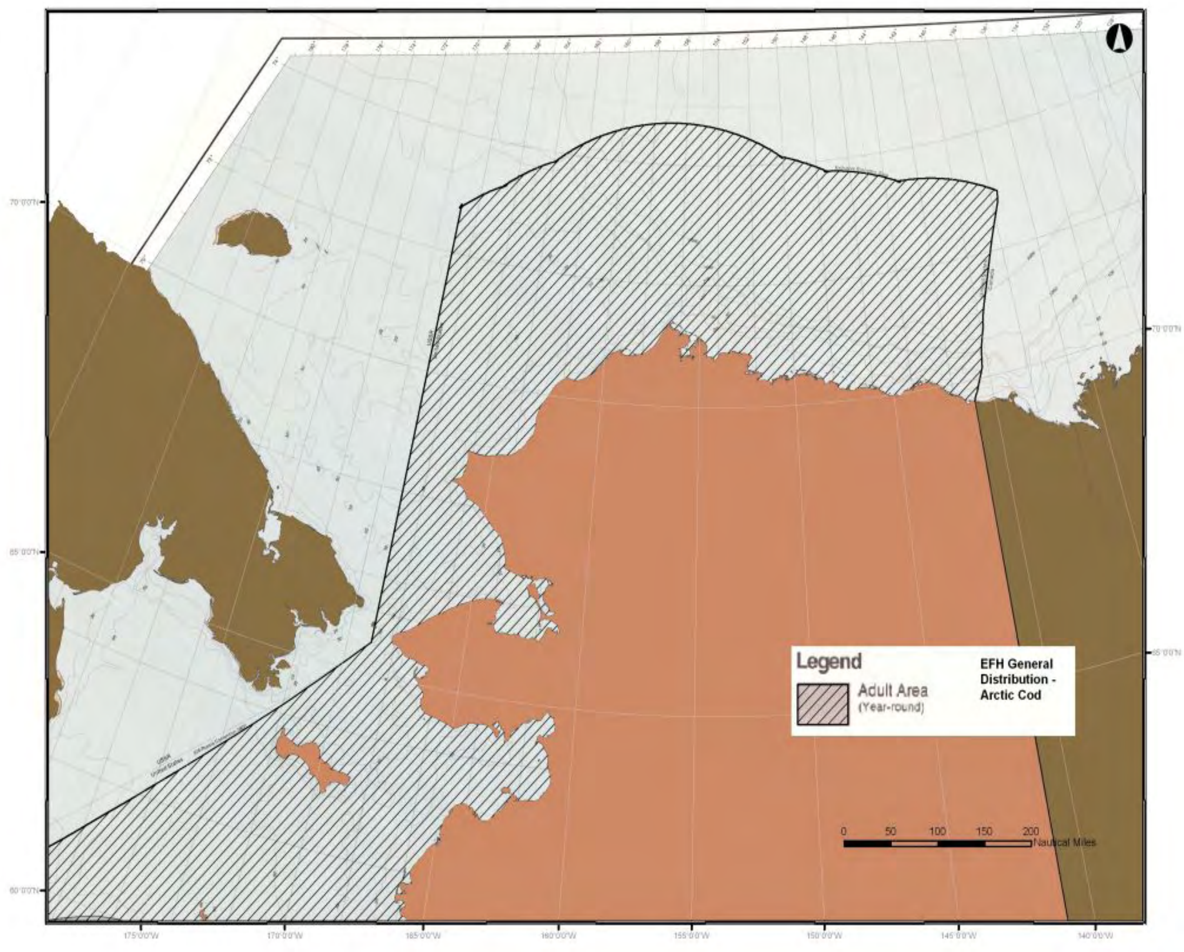
NPFMC. 2005a. Essential fish habitat assessment report for the groundfish resources of the Bering Sea and Aleutian Islands regions. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

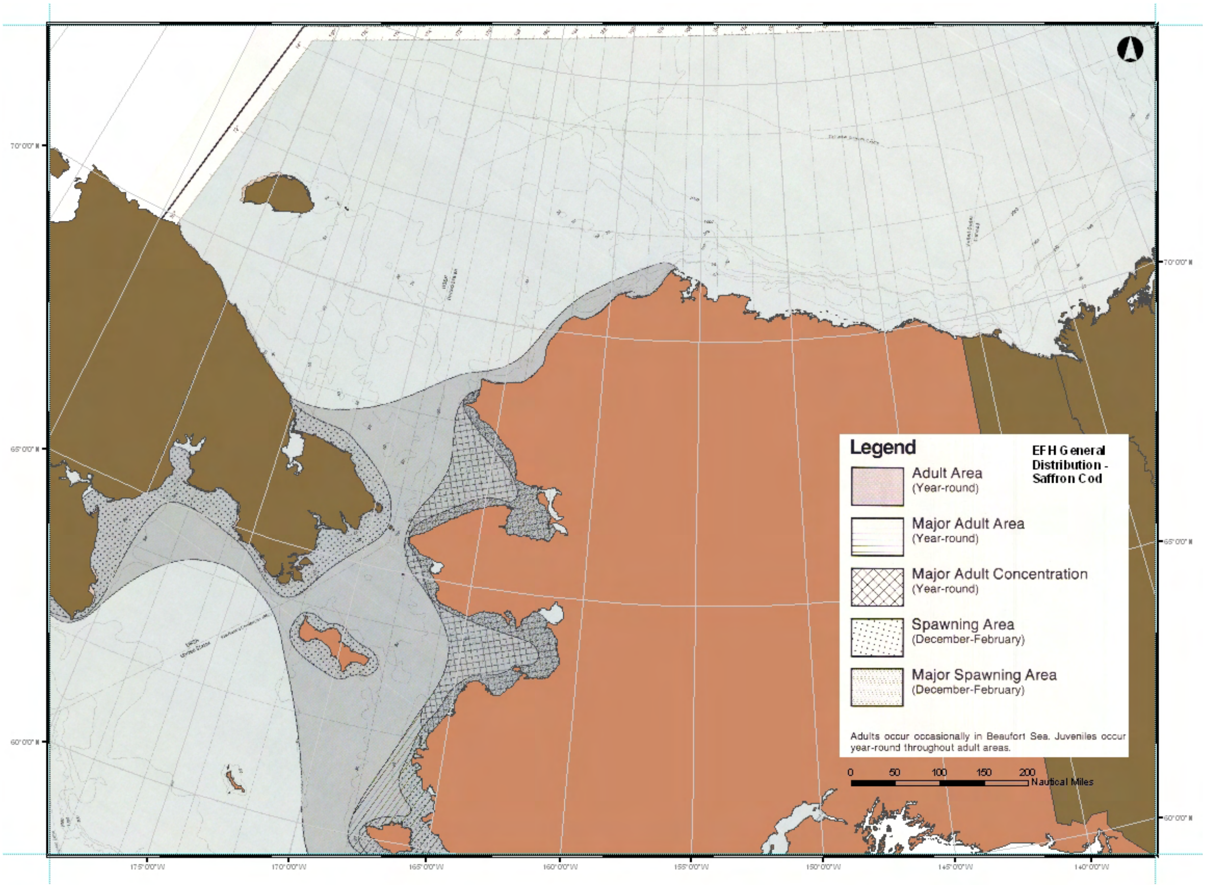
APPENDIX C. EFH Map Descriptions

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. A GIS system was used to re-create best information available for this analysis. EFH descriptive maps depict, and are complimentary to, each life history EFH text description, if known. Thus, EFH is to be interpreted using EFH species habitat requirements (text) together with spatial delineations (map).

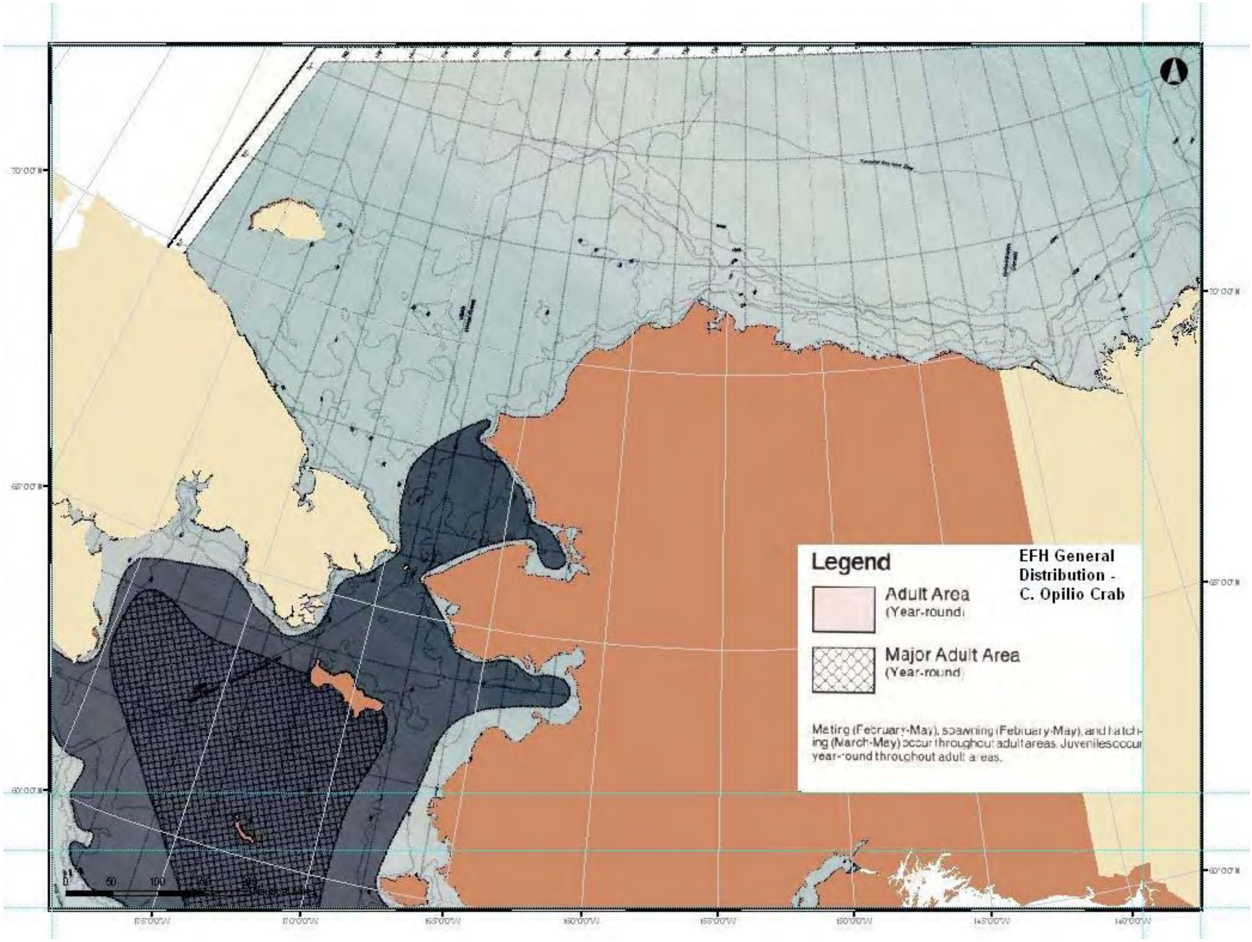
EFH Map Description for Arctic Cod



EFH Description for Saffron Cod



EFH Description for Snow Crab (*C. opilio*)



EFH General Distribution - C. Opilio Crab

Mating (February-May), spawning (February-May), and hatching (March-May) occur throughout adult areas. Juveniles occur year-round throughout adult areas.

APPENDIX D. Non-fishing Effects on EFH in the Arctic Region

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), the federal law that governs U.S. marine fisheries management, contains provisions to identify Essential Fish Habitat (EFH) for federally managed species and consider measures to conserve and enhance the habitat necessary for these species throughout their life cycles. The Magnuson-Stevens Act also requires NMFS to recommend conservation measures to those federal and state agencies whose actions may adversely affect EFH. EFH conservation recommendations are advisory, not mandatory, and may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects to EFH.

The April 2005 EFH FEIS contains a thorough discussion of non-fishing activities in *Appendix G Non-Fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures* (EFH FEIS Appendix G) at http://www.fakr.noaa.gov/habitat/seis/efheis.htm. EFH FEIS Appendix G details numerous activities that could have adverse affects on EFH and offers EFH Conservation Recommendations for actions throughout Alaska. Due to the large size and scale of actions within EFH FEIS Appendix G, the following non-fishing activities discussion is a summary of actions that could be expected to occur in the Arctic Region and not all-inclusive. The intent is to provide an accurate description of those non-fishing activities and offer general recommendations to conserve and protect EFH. Each of the following non-fishing activities within the Arctic Region will be discussed:

- Oil and Gas Exploration, Development and Production
- Fish Processing Waste—Shoreside and Vessel Operation
- Water Intake Structures/Discharge Plumes
- Vessel Operations and Marine Transportation
- Introduction of Exotic Species
- Road Construction and Maintenance
- Point-source Discharges
- Persistent Organic Pollutants
- Mining
- Dredging
- Disposal of Dredged Material
- Fill Material
- Dock Construction and Pile Driving
- Overwater Structures
- Flood Control and Shoreline Protection
- Utility Lines, Cables, and Pipelines
- Urban Development
- Fish Habitat Restoration and Enhancement

Oil and Gas Exploration, Development, and Production

Offshore exploration, development, and production of natural gas and oil reserves have been, and continue to be, an important aspect of the U.S. economy. As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue. Projections indicate that U.S. demand for oil will increase by 1.3 percent per year between 1995 and 2020. Gas consumption is projected to increase by an average of 1.6 percent during the same time frame (Waisley 1998). Much of the 1.9 billion acres within the offshore jurisdiction of the U.S. remains unexplored (Oil and Gas Technologies for the Arctic and Deepwater 1985). Some of the older oil and gas platforms in operation will probably reach the end of their productive life in the near future, and decommissioning them is also an issue.

Offshore oil and gas operations can be classified into exploration, development, and production activities (which includes transportation). These activities occur at different depths in a variety of habitats. These areas are subject to an assortment of physical, chemical, and biological disturbances, including the following (Council 1999, Helvey 2002):

- Exploration. Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands.
- Physical alterations to habitat. Construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries.
- Discharges. Waste discharge, including well drilling fluids, produced waters, deck surface runoff, drainage, domestic waste water, solid waste from wells (i.e., cuttings), and other debris from human activities associated with the facility.
- Oil spills. Spill events, dispersion tactics, clean-up efforts and other response activities.

Not all of the potential disturbances in this list apply to every type of activity.

Underwater noise generates sound pressure waves that may disrupt or damage marine life. Oil and gas activities generate noise from drilling activities, construction, production facility operations, seismic exploration, and supply vessel and barge movements. Research suggests that the noise from seismic surveys associated with oil exploration may cause fish to move away from the acoustic pulse and display an alarm response (McCauley et. al. 2000). This affects both fish distribution and catch rates (Engas et. al 1996). However, while there are few disagreements that noise from seismic surveys affects the behavior of fish, there are differences of opinion regarding the magnitude of those effects (McCauley et. al 2003, Gausland 2003, Wardle 2001).

Activities such as vessel anchoring, platform or artificial island construction, pipeline laying, dredging, and pipeline burial can change bottom habitat by altering substrates used for feeding or shelter. Disturbances to the associated epifaunal communities, which may provide feeding or predator escape habitat, may also result. Benthic organisms, especially prey species, may recolonize disturbed areas, but this may not occur if the substrate composition is drastically changed or if facilities are left in place after production ends. Dredging, trenching, and pipelaying generate spoils that may be disposed of on land or in the marine environment where sedimentation may smother benthic habitat and organisms. Most activities associated with oil and gas operations are, however, conducted under permits and regulations that require companies to minimize impacts or to avoid construction or other disturbances in sensitive marine habitats.

EPA and the state of Alaska issue permits for discharge of drilling muds and cuttings to ensure the activities meet Alaska water quality standards. Potentially, the discharge of muds and cuttings from exploratory and construction activities may, change the sea floor and suspend fine-grained mineral particles in the water column. This may affect feeding, nursery, and shelter habitat for various life stages of managed species. Drilling muds and cuttings may adversely affect bottom-dwelling organisms at the site by covering immobile forms or forcing mobile forms to migrate. Suspended particulates may reduce light penetration and lower the rate of photosynthesis and the primary productivity of the aquatic area, especially if suspended for long intervals. High levels of suspended particulates may reduce feeding ability for groundfish and other fish species, leading to limited growth. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion. In addition, the discharge of oil drilling muds can change the chemical and physical characteristics of benthic sediments at the disposal site by introducing toxic chemical constituents. Changes in water clarity and the addition of contaminants may reduce or eliminate the suitability of water bodies as habitat for fish species and their prey (NMFS 1998, a,b).

Federal and state laws and regulations require oil spill prevention and cleanup response measures (http://dec.alaska.gov/spar/perp/grs/home.htm). The industry takes the initiative to prevent oil spills and uses state-of-the-art technology in oil spill prevention and response. Spills from oil and gas development remain a potential source of contamination to the marine environment. Offshore oil and gas development actions result in some amount of oil entering the environment. Most spills are small, although large spills sometimes occur. Many factors determine the degree of damage from a spill, including the type of oil, size and duration of the spill, its geographic location, and the season. Oil is toxic to all marine organisms at high concentrations, but certain species are more sensitive than others. In general, the early life stages (eggs and larvae) are most sensitive, juveniles are less sensitive, and adults are least sensitive (Rice et al. 2000).

Both large and small quantities of oil can affect habitats and living marine resources. In addition, oil spills may interrupt commercial or subsistence fishing activities. For example, the *Exxon Valdez* oil spill redirected the fishing fleet from actively fishing to oil recovery. Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the outer continental shelf (OCS) or in nearshore coastal areas. Sources include equipment malfunction, ship collisions, pipeline breaks, other human error, or severe storms. Support activities associated with product recovery and transportation may also contribute to oil spills. In addition to crude oil, chemical, diesel, and other contaminant spills, accidental discharge can also occur (Council 1999).

Chronic small oil spills are a potential problem because residual oil can build up in sediments and affect living marine resources. Low levels of petroleum components (e.g., PAHs) from such chronic pollution may accumulate in fish tissues and cause lethal and sublethal effects, particularly during embryonic development. Low-level chronic exposure alters embryonic development in fish, resulting in reductions in growth and subsequent marine survival (Carls et al. 1999, Heintz et al. 1999, 2000).

A major oil spill (e.g., 50,000 barrels) can produce a surface slick covering several hundred square kilometers. If the oil spill moves toward land, habitats and species could be affected by oil reaching the near-shore environment. Immediately after a large spill, aromatic hydrocarbons would be toxic to some organisms. Waters beneath and surrounding the surface slick would be oil-contaminated. Physical and biological forces act to reduce oil concentrations with depth and distance (Council 1999); generally the lighter-fraction aromatic hydrocarbons evaporate rapidly, particularly during high winds and wave activity. Heavier oil fractions may settle through the water column. Suspended sediment can adsorb and carry oil to the seabed. Hydrocarbons may be solubilized by wave action, which may enhance adsorption to sediments. The sediments then sink to the seabed, contaminating benthic sediments.

Carls et al. (2003) demonstrated that tides and the resultant hydraulic gradients move groundwater containing soluble and slightly soluble contaminants (such as oil) from beaches surrounding streams into the hyporheic zone (the region beneath and next to streams where surface and groundwater mix) where pink salmon eggs incubate. Oil reaching nearshore areas will affect productive nursery grounds or areas containing high densities of fish eggs and larvae. An oil spill near an especially important habitat (e.g., a gyre where fish or invertebrate larvae are concentrated) could cause a disproportionately high loss of a population of marine organisms. Other aquatic biota at risk would be eggs, larvae, and planktonic organisms in the upper seawater column. Because they are small, they absorb contaminants quickly. They are also at risk because they cannot actively avoid exposure. Their proximity to the seasurface may make them vulnerable to photo-enhanced toxicity effects, which can multiply the toxicity of hydrocarbons (Barron et al. 2003). Population reductions due to delayed and indirect effects of PAH in tidal sediments postponed recovery among some species for more than a decade following the *Exxon Valdez* oil spill (Peterson et al. 2003).

Habitats that are susceptible to damage from oil spills include not just the low-energy coastal bays and estuaries where oil may accumulate, but also high-energy cobble environments where wave action drives oil into sediments. Many of the beaches in Prince William Sound with the highest persistence of oil following the *Exxon Valdez* oil spill were high-energy environments containing large cobbles overlain with boulders. These beaches were pounded by storm waves that drove the oil into and well below the surface (Michel and Hayes 1999). Oil that mixes into bottom sediments may persist for years. Subsurface oil was still detected in beach sediments of Prince William Sound 12 years after the *Exxon Valdez* oil spill, much of it unweathered and more prevalent in the lower intertidal biotic zone than at higher tidal elevations (Short et al. 2002, 2004). The unknown impact of an oil-related event near and within ice is an added concern. Should oil become trapped in ice, it could affect habitat for months or years after the initial event. It could also move into a different region (Council 1999).

Oil and gas platforms may consist of a lattice-work of pilings, beams, and pipes that support diverse fish and invertebrate populations and are considered de facto artificial reefs (Love and Westphal 1990, Love et al. 1994, Love et al. 1999, Helvey 2002). Because decommissioning includes plugging and abandoning all wells and removing the platforms and associated structures from the ocean, impacts to EFH are possible during removal. The demolition phase may generate underwater sound pressure waves, impacting on marine organisms. Taking out these midwater structures may remove habitat for invertebrates and fish that associate with them. In some areas of the U.S., offshore oil and gas platforms are left in place after decommissioning, thereby providing permanent habitat for some organisms.

The potential disturbances and associated adverse impacts on the marine environment have been reduced through operating procedures required by regulatory agencies and, in many cases, self-imposed by facilities operators. Most of the activities associated with oil and gas operations are conducted under permits and regulations that require companies to minimize impacts or avoid construction in sensitive marine habitats. For example, the discharge of muds and cuttings is subject to EPA environmental standards, effluent limitations, and related requirements. New technological advances in operating procedures also reduce the potential for impacts.

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

1. As part of pre-project planning, identify all species of concern regulated under federal or state fishery management plans that inhabit, spawn, or migrate through areas slated for exploration, development, or production. Pay particular attention to critical life stages, and develop options that avoid and minimize adverse effects from any associated activities. Modify the project design, timing, or location and use adaptive management.

2. Avoid the discharge of produced waters into marine waters and estuaries. Re-inject produced waters into the oil formation whenever possible.
3. Avoid discharge of muds and cuttings into the marine and estuarine environment. Use methods to grind and re-inject such wastes down an approved injection well or use onshore disposal wherever possible. When not possible, provide for a monitoring plan to ensure that the discharge meets EPA effluent limitations and related requirements.
4. To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
5. As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas. Identify appropriate cleanup methods and response equipment.
6. To the extent practicable, use methods to transport oil and gas that limit the need for handling in environmentally sensitive areas, including EFH.
7. Ensure that appropriate safeguards have been considered before drilling the first development well into the targeted hydrocarbon formations whenever critical life history stages of federally managed species are present.
8. Ensure that appropriate safeguards have been considered before drilling exploration wells into untested formations whenever critical life stages of federally managed species are present. If possible, avoid such work entirely during those time frames.
9. Oil and gas transportation and production facilities should be designed, constructed, and operated in accordance with applicable regulatory and engineering standards.
10. Evaluate impacts to EFH during the decommissioning phase of oil and gas facilities, including possible impacts during the demolition phase. Minimize such impacts to the extent practicable.

Fish Processing Waste—Shoreside and Vessel Operation

Seafood processing facilities are either shore-based facilities discharging through stationary outfalls or mobile vessels engaged in the processing of fresh or frozen seafood (Science Applications International Corporation 2001). Discharge of fish waste from shoreside and vessel processing has occurred in marine waters since the 1800s (Council 1999). With the exception of fresh market fish, some form of processing involving butchering, evisceration, precooking, or cooking is necessary to bring the catch to market. Precooking or blanching facilitates the removal of skin, bone, shell, gills, and other materials. Depending on the species, the cleaning operation may be manual, mechanical, or a combination of both (EPA 1974). Seafood processing facilities generally consist of mechanisms to offload the harvest from fishing boats; tanks to hold the seafood until the processing lines are ready to accept them; processing lines, process water, and waste collection systems; treatment and discharge facilities; processed seafood storage areas; and necessary support facilities such as electrical generators, boilers, retorts, water desalinators, offices, and living quarters. In addition, marinas that cater to patrons who fish a large amount can produce an equally large quantity of fish waste at the marina from fish cleaning.

Generally, seafood processing wastes consist of biodegradable materials that contain high concentrations of soluble organic material. Seafood processing operations have the potential to adversely affect EFH through (1) direct and/or nonpoint source discharge, (2) particle suspension, and (3) increased turbidity and surface plumes.

Seafood processing operations have the potential to adversely affect EFH through the direct and/or nonpoint source discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). EPA investigations show that impacts affecting water quality are direct functions of the receiving waters. In areas with strong currents and high tidal ranges, waste materials disperse rapidly. In areas of quieter waters, waste materials can accumulate and result in shell banks, sludge piles, dissolved oxygen depressions, and associated aesthetic problems (Stewart and Tangarone 1977). If adequate disposal facilities are not available at marinas that generate a large amount of fish waste, there is a potential for disposal of fish waste in areas without enough flushing to prevent decomposition and the resulting dissolved oxygen depression (EPA 1993).

Processors discharging fish waste are required to have EPA-issued NPDES permits. Various water quality standards, including those for BOD, total suspended solids, fecal coliform bacteria, oil and grease, pH, and temperature, are all considerations in the issuance of such permits. Although fish waste, including heads, viscera, and bones, is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (Council 1999). Such pollutants have the potential to adversely impact EFH. The wide differences in habitats, types of processors, and seafood processing methods define those impacts and can also prevent the effective use of technology-based effluent limits.

In Alaska, seafood processors are allowed to deposit fish parts in a zone of deposit (ZOD) (EPA 2001). This can alter benthic habitat, reduce locally associated invertebrate populations, and lower dissolved oxygen levels in overlying waters. Impacts from accumulated processing wastes are not limited to the area covered by the ZOD. Severe anoxic and reducing conditions occur adjacent to effluent piles (EPA 1979). Examples of localized damage to benthic environment include several acres of bottomdriven anoxic by piles of decomposing waste up to 26 feet (7.9 meters) deep. Juvenile and adult stages of flatfish are drawn to these areas for food sources. One effect of this attraction may lead to increased predation on juvenile fish species by other flatfishes, diving seabirds, and marine mammals drawn to the food source (Council 1999). However, due to the difficulty in monitoring these areas, impacts to species can go undetected.

Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Increased turbidity decreases light penetration into the water column, reducing primary production. Reduced primary production decreases the amount of food available for consumption by higher trophic level organisms. In addition, stickwater takes the form of a fine gel or slime that can concentrate on surface waters and move onshore to cover intertidal areas.

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
2. To the maximum extent practicable, avoid the practice of discharging untreated solid and liquid waste directly into the environment. Encourage the use of secondary or wastewater treatment systems where possible.
3. Do not allow designation of new ZODs. Explore options to eliminate or reduce ZODs at existing facilities.
4. Control stickwater by physical or chemical methods.
5. Promote sound fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
6. Encourage the alternative use of fish processing wastes (e.g., fertilizer for agriculture and animal feed).
7. Explore options for additional research. Some improvements in waste processing have occurred, but the technology-based effluent guidelines have not changed in 20 years.
8. Locate new plants outside rearing and nursery habitat. Monitor both biological and chemical changes to the site.

Water Intake Structures/Discharge Plumes

The withdrawal of water by intake structures is a common aquatic activity. Water may be withdrawn and used, for example, to cool power-generating stations and create temporary ice roads and ice ponds. In the case of power plants, the subsequent discharge of heated and/or chemically treated discharge water can also occur.

Water intake structures and effluent discharges can interfere with or disrupt EFH functions in the source or receiving waters by (1) entrainment, (2) impingement, (3) discharge, (4) operation and maintenance, and (5) construction-related impacts.

Entrainment is the withdrawal of aquatic organisms along with the cooling water into the cooling system. These organisms are usually the egg and larval stages of managed species and their prey. Entrainment can subject these life stages to adverse conditions resulting from the effects of increased heat, antifouling chemicals, physical abrasion, rapid pressure changes, and other detrimental effects. Consequently, diverting water without adequate screening prevents that portion of EFH from providing important habitat functions necessary for the early life stages of managed living marine resources and their prey. Long-term water withdrawal may adversely affect fish and shellfish populations by adding another source of mortality to the early life stage, which often determines recruitment and year-class strength (Travnichek et al. 1993).

Impingement occurs when organisms that are too large to pass through in-plant screening devices become stuck against the screening device or remain in the forebay sections of the system until they are removed by other means (Grimes 1975, Hanson et al. 1977, Helvey and Dorn 1987, Helvey 1985, Langford et al. 1978, Moazzam and Rizvi 1980). The organisms cannot escape due to the water flow that either pushes them against the screen or prevents them from exiting the intake tunnel. Similar to entrainment, the withdrawal of water can trap particular species, especially when visual acuity is reduced (Helvey 1985). This condition reduces the ability of the source waters to provide normal EFH functions necessary for subadult and adult life stages of managed living marine resources and their prey.

Thermal effluents in inshore habitat can cause severe problems by directly altering the benthic community or killing marine organisms, especially larval fish. Temperature influences biochemical processes of the environment and the behavior (e.g., migration) and physiology (e.g., metabolism) of marine organisms (Blaxter 1969). Further, the proper functioning of sensitive areas may be affected by the action of intakes as selective predators, resulting in cascading negative consequences as observed by the overexploitation of local fish populations in coral-reef fish communities (Carr et al. 2002).

Other impacts to aquatic habitats can result from construction-related activities (e.g., dewatering, dredging, etc.), as well as routine operation and maintenance activities. A broad range of impacts associated with these activities depend on the specific design and needs of the system. For example, dredging activities can cause turbidity, degraded water quality, noise, and substrate alterations. Many of these impacts can be reduced or eliminated through the use of various techniques, procedures, or technologies, but some may not be fully eliminated except by eliminating the activity itself.

Power plants may use once-through cooling biocides, such as sodium hypochlorite and sodium bisulfate, periodically to clean the intake and discharge structures. Chlorine is extremely toxic to aquatic life.

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Locate facilities that rely on surface waters for cooling in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where managed species or their prey concentrate. Locate discharge points in areas with low concentrations of living marine resources. Incorporate cooling towers at discharge points to control temperature, and use enough safeguards to ensure against release of blow-down pollutants into the aquatic environment in concentrations that reduce the quality of EFH.
2. Design intake structures to minimize entrainment or impingement. Use velocity caps that produce horizontal intake/discharge currents and ensure that intake velocities across the intake screen do not exceed 0.5 foot (0.15 meter) per second.
3. Design power plant cooling structures to meet the best technology available requirements as developed pursuant to Section 316(b) of the CWA. Use alternative cooling strategies, such as closed cooling systems (e.g., dry cooling), to completely avoid entrainment or impingement impacts in all industries that require cooling water. When alternative cooling strategies are not feasible, other BTAs may include, but are not limited to, fish diversion or avoidance systems, fish return systems that convey organisms away from the intake, mechanical screen systems that prevent organisms from entering the intake system, and habitat restoration measures.
4. Regulate discharge temperatures (both heated and cooled effluent) so they do not appreciably alter the temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters. Implement strategies to diffuse the heated effluent.
5. Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible. Implement the least damaging antifouling alternatives.
6. Mitigate for impacts related to power plants and other industries requiring cooling water. Ensure that mitigation compensates for the net loss of EFH habitat functions from placement and operation of the intake and discharge structures. Provide mitigation for the loss of habitat from placement of the intake structure and delivery pipeline, the loss of fish larvae and eggs that may be entrained by large intake systems, and the degradation or loss of habitat from placement of the outfall structure and pipeline, as well as the treated water plume.
7. Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe. Ensure that pipes extend a substantial distance offshore and are buried deep enough not to affect shoreline processes. Set buildings and associated structures far enough back from the shoreline to preclude the need for bank armoring.

Vessel Operations and Marine Transportation

The growth in Alaska coastal communities is putting demands on port districts to increase infrastructure capacity to accommodate additional vessel operations for cargo handling activities and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size (Council 1999). In addition, increasing boat sales have put more pressure on improving and building new commercial fishing and small boat harbors.

The expansion of port facilities, vessel/ferry operations, and recreational marinas can bring additional impacts to EFH, especially by filling productive shallow water habitats. There is considerable evidence that docks and piers block sunlight penetration, alter water flow, introduce chemicals, and restrict access and navigation. The increase in hard surfaces close to the marine environment increases nonpoint surface discharges, adds debris sources, and reduces buffers between land use and the aquatic ecosystem. These include direct, indirect, and cumulative impacts on shallow subtidal, deep subtidal, eelgrass beds, mudflats, sand shoals, rock reefs, and salt marsh habitats. Such impacts would be site-specific. Some activities affecting these habitats, including new channel deepening and maintenance dredging, disposal of dredged material, reduced water quality from resuspension of contaminated sediments, ballast water discharge, and shading from overwater structures, are addressed in other sections. Additional impacts include vessel groundings, modification of water circulation (breakwaters, channels, and fill), vessel wake generation, pier lighting, anchor and prop scour, discharge of contaminants and debris, and changing natural patterns of fish movement.

Potential adverse impacts to EFH can occur during both the construction and operation phases. An increase in the number and size of vessels can generate more wave and surge effects on shorelines. These vessel-wakes, or wash events, can affect shorelines depending on the wake wave energy, the water depth, and the type of shoreline. Vessel wakes can cause a significant increase in shoreline erosion, affect wetland habitat, and increase water turbidity. Vessel prop wash can also damage aquatic vegetation and disturb sediments, which may increase turbidity and suspend contaminants (Klein 1997, Warrington 1999).

Impacts can also occur from anchor scour. Mooring buoys, when anchored in shallow nearshore waters, can drag the anchor chain across the bottom, destroying submerged vegetation and creating a circular scour hole (Walker et al. 1989, *in* Shafer 2002).
Vessel discharges, engine operations, bottom paint sloughing, boat washdowns, painting, and other vessel maintenance activities can deliver debris, nutrients, and contaminants to waterways and may degrade water quality and contaminate sediments.

Inadequate flushing of harbors also results in water quality problems (USACE 1993, Klein 1997). Poor flushing in marinas can increase temperature and raise phytoplankton populations with nocturnal dissolved oxygen level declines, resulting in organism hypoxia and pollutant inputs (Cardwell et al. 1980). An exchange of at least 30 percent of the water in the marina during a tidal change should minimize temperature increases and dissolved oxygen problems (Cardwell et al. 1980).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Locate marinas in areas of low biological abundance and diversity; if possible, for example, avoid the disturbance of eelgrass or other submerged aquatic vegetation including macroalgae, mudflats, and wetlands as part of the project design. In situations where such impacts are unavoidable, consider mitigation as appropriate.
2. If practicable, excavate uplands to create marina basins rather than converting intertidal or shallow subtidal areas to deeper subtidal areas for basin creation.
3. Leave riparian buffers in place to help maintain water quality and nutrient input.
4. Should mitigation be required, include a monitoring plan to gauge the success of mitigation efforts.
5. Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process. Vessels should be operated at sufficiently low speeds to reduce wake energy, and no-wake zones should be designated near sensitive habitats.
6. Incorporate BMPs to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and nonpoint source contaminants from upland facilities related to vessel operations and navigation.
7. Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash. Use subsurface floats or other methods to prevent contact of the anchor line with the substrate.

8. Use catchment basins for collecting and storing surface runoff from upland repair facilities. Include parking lots and other impervious surfaces as components of the site development plan to remove contaminants prior to delivery to any receiving waters.
9. Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
10. Locate marinas where they do not interfere with drift sectors determining the structure and function of adjacent habitats.
11. To facilitate the movement of fish around breakwaters, provide a shallow shelf or “fish bench” on the outside of the breakwater.
12. Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.
13. Use appropriate timing windows for construction and dredging activities to avoid potential impacts on EFH.

Introduction of Exotic Species

Introductions of exotic species into estuarine, riverine, and marine habitats have been well documented (Rosecchi et al. 1993, Kohler and Courtenay 1986, Spence et al. 1996) and can be intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms). Exotic fish, shellfish, pathogens, and plants can enter the environment from industrial shipping (e.g., as ballast), recreational boating, aquaculture, biotechnology, and aquariums. The transportation of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Long-term impacts from the introduction of nonindigenous and reared species can change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce exotic lethal disease. Overall, exotic species introductions create five types of negative effects: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases. Habitat alteration includes the excessive colonization of exotic species (e.g., *Spartina* grasses), which precludes the growth of endemic organisms (e.g., eelgrass). The introduction of exotic species may alter community structure by predation on native species or by population explosions of the introduced species. For example, this has occurred in freshwater lakes on Alaska’s Kenai Peninsula, where introduced northern pike have depleted local salmonid populations through rampant juvenile predation. Spatial alteration occurs when territorial introduced species compete with and displace native species. Although hybridization is rare, it may occur between native and introduced species and can result in gene pool deterioration.

Non-native plants and algae can degrade coastal and marine habitats by changing natural habitat qualities. Introduced organisms increase competition with indigenous species, or they may forage on indigenous species, which can reduce fish and shellfish populations. Long-term impacts from the introduction of nonindigenous species can change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce exotic lethal diseases. The introduction of exotic organisms also threatens native biodiversity and could lead to changes in relative abundance of species and individuals that are of ecological and economic importance.

The introduction of bacteria, viruses, and parasites is another severe threat to EFH as it may reduce habitat quality. New pathogens or higher concentrations of disease can be spread throughout the environment, resulting in deleterious habitat conditions.

Relatively few exotic, invasive species have been documented in Alaska. It is believed that this is due to a combination of factors, including geographic isolation, harsh climate conditions and cold temperatures, fewer concentrated, highly disturbed habitat areas, and the state's stringent plant and animal transportation laws (Fay 2002).

Alaska waters are, however, vulnerable to exotic species invasion. "Potential introduction pathways include fish farms, the intentional movement of game or bait fish from one aquatic system to another, the movement of large ships and ballast water from the United States West Coast and Asia, fishing vessels docking at Alaska's busy commercial fishing ports, construction equipment, trade of live seafood, aquaculture, and contaminated sport angler gear brought to Alaska's world-renowned fishing sites" (Fay 2002). More information can also be found at http://www.uaf.edu/ces/aiswg/

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Uphold fish and game regulations of the Alaska Board of Fisheries (AS 16.05.251) and Board of Game (AS 16.05.255), which prohibit and regulate the live capture, possession, transport, or release of native or exotic fish or their eggs.
2. Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
3. Encourage vessels to perform a ballast water exchange in marine waters (in accordance with the U.S. Coast Guard's voluntary regulations) to minimize the possibility of introducing exotic estuarine species into similar habitats. Ballast water taken on in marine waters will contain fewer organisms, and these will be less likely to become invasive in estuarine conditions than species transported from other estuaries.
4. Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
5. Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (propellers, hulls, anchors, fenders, etc.). Bilges should be emptied and cleaned thoroughly by using hot water or a mild bleach solution. These activities should be performed in an upland area to prevent introduction of non-native species during the cleaning process.
6. Treat effluent from public aquaria displays and laboratories and educational institutes using exotic species before discharge to prevent the introduction of viable animals, plants, reproductive material, pathogens, or parasites into the environment.
7. Prevent introduction of non-native plant species into aquatic and riparian ecosystems by avoiding use of non-native seed mixes or invasive, non-native landscaping materials near waterways and shorelines.
8. Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals. These materials may harbor invasive species and pathogens and should be treated accordingly.

Road Construction and Maintenance

The building and maintenance of roads can affect aquatic habitats by increasing rates of natural processes such as debris slides or landslides and sedimentation, introducing exotic species, degrading water quality, and introducing chemical contamination. Paved and dirt roads introduce an impervious or semipervious surface into the landscape. This surface intercepts rain and creates runoff, carrying soil, sand and other sediments, and oil-based materials quickly downslope. If roads are built near streams, wetlands, or other sensitive areas, they may experience increased sedimentation that occurs from maintenance and use, as well as during storm and snowmelt events. Even carefully designed and constructed roads can become sources of sediment and pollutants if they are not properly maintained.

The effects of roads on aquatic habitat can be profound. They include (1) increased deposition of fine sediments, (2) changes in water temperature, (3) elimination or introduction of migration barriers such as culverts, (4) changes in streamflow, (5) introduction of non-native plant species, and (6) changes in channel configuration.

Poorly surfaced roads can substantially increase surface erosion. The rate of erosion is primarily a function of storm intensity, surfacing material, road slope, and traffic levels. This surface erosion results in an increase in fine sediment deposition (Cederholm and Reid 1987, Bilby et al. 1989, MacDonald et al. 2001, Ziegler et al. 2001). Increased fine-sediment deposition in stream gravels has been linked to decreased fry emergence and juvenile densities, loss of winter carrying capacity, and increased predation of fishes. Increased fines can reduce benthic production or alter the composition of the benthic community. For example, embryo-to-emergent fry survival of incubating salmonids is negatively affected by increases in fine sediments in spawning gravels (Chapman 1988, Everest et al. 1987, Koski 1981, Scrivener and Brownlee 1989, Weaver and Fraley 1993, Young et al. 1991).

Roads built adjacent to streams can result in changes in water temperature and increased sunlight reaching the stream if riparian vegetation is removed and/or altered in composition. Beschta et al. (1987) and Hicks et al. (1991) document some of the negative effects of road construction on fish habitat, including elevation of stream temperatures beyond the range of preferred rearing where vegetation has been removed, inhibition of upstream migrations, increased disease susceptibility, reduced metabolic efficiency, and shifts in species assemblages.

Roads can also degrade aquatic habitat through improperly placed culverts at road-stream crossings that reduce or eliminate fish passage (Belford and Gould 1989, Clancy and Reichmuth 1990, Evans and Johnston 1980, Furniss et al. 1991). In a large river basin in Washington, 13 percent of the historical coho habitat was lost due to improper culvert design and placement (Beechie et al. 1994). Road crossings also affect benthic communities of stream invertebrates. Roads have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000). Studies indicate that populations of non-insect invertebrates tend to increase the farther away they are from a road (Luce and Crowe 2001).

Roads may be the first point of entry into a virgin landscape for non-native grass species that are seeded along road cuts or introduced from seeds transported by tires and shoes. Roads can serve as corridors for such species, allowing plants to move further into the landscape (Greenberg et al. 1997, Lonsdale and Lane 1994). Some non-native plants may be able to move away from the roadside and into aquatic sites of suitable habitat, where they may out-compete native species and have significant biological and ecological effects on the structure and function of the ecosystem.

Roads have three primary effects on hydrologic processes. First, they intercept rainfall directly on the road surface, in road cutbanks, and as subsurface water moving down the hillslope. Second, they concentrate flow, either on the road surfaces or in adjacent ditches or channels. Last, they divert or reroute water from flowpaths that would otherwise be taken if the road were not present (Furniss et al. 1991).

Road drainage and transport of water and debris, especially during heavy rains and snow melt periods, are primary reasons why roads fail, often with major structural, ecological, economic, or other social consequences. The effects of roads on peak streamflow depend on the size of the watershed and the density of roads. Two of the effects are (1) changes in flood flows (Wemple et al. 1996), mainly in smaller basins and for smaller floods (Beschta et al. 2000), and (2) increases in channel erosion and mass wasting (Montgomery 1994, Madej 2001, Wemple et al. 2001). For example, capture and rerouting of water can dewater one small stream and cause major channel adjustments in the stream receiving the additional water. In large watersheds with low road density, properly located and maintained roads may constitute a small proportion of the land surface and have relatively insignificant effects on peak flow.

Roads can lead to increased rates of natural processes such as debris or landslides and sedimentation when slopes are destabilized and surface erosion and soil mass movement increases. Erosion is most severe when poor construction practices are allowed, combined with inadequate attention to proper road drainage and maintenance practices. Mass movement risks increase when roads are constructed on high-hazard soils and overly steep slopes. In steep areas prone to landslides, rates of mass soil movements affected by roads include shallow debris slides, deep-seated slumps and earthflows, and debris flows. Accelerated erosion rates from roads because of debris slides range from 30 to 300 times the natural rate in forested areas, but vary with terrain in the Pacific Northwest (Sidle et al. 1985). The magnitude of road-related mass erosion varies by climate, geology, road age, construction practices, and storm history. Road-related mass failures can result from various causes, including improper placement and construction of road fills and stream crossings; inadequate culvert sizes to pass water, sediment, and wood during floods; poor road siting; modification of surface or subsurface drainage by the road surface or prism; and diversion of water into unstable parts of the landscape (Burroughs et al. 1976, Clayton 1983, Hammond et al. 1988, Furniss et al. 1991, Larsen and Parks 1997).

Recommended Conservation Measures

The following conservation measures for road building and maintenance should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. To the extent practicable, avoid locating roads near fish-bearing streams. Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes.
2. Incorporate appropriate erosion control and stabilization measures into road construction plans to reduce erosion potential.
3. Build bridges when possible. If culverts are to be used, they should be sized, constructed, and maintained to match the gradient and width of the stream, so as to accommodate design flood flows, and they should be large enough to provide for migratory passage of adult and juvenile fishes. If appropriate, consider using the culvert guidelines contained in the Alaska Department of Fish and Game and the Alaska Department of Transportation and Public Facilities Fish Pass Memorandum of Agreement, August, 2001 (http://www.sf.adg.state.ak.us/SARR/fishpassage/pdfs/dot_adfg_fishpass080301.pdf).
4. Locate stream crossings in stable stream reaches.
5. Design bridge abutments to minimize disturbances to streambanks and place abutments outside of the floodplain whenever possible.
6. To the extent practicable, avoid road construction across alluvial floodplains, mass wastage areas, or braided stream bottom lands unless site-specific protection can be implemented to ensure protection of soils, water, and associated resources.
7. Avoid side-casting of road construction and maintenance materials on native surfaces and into streams.
8. To the extent practicable, use native vegetation in stabilization plantings.
9. Ensure that maintenance operations avoid adverse affects to EFH.

Point-source Discharges

Point-source discharges from storm water discharges or sewage facilities are controlled through EPA's regulations under the CWA and by state water regulations. The primary concerns associated with point-source discharges in the Arctic are storm drains contaminated from communities using settling and storage ponds, street runoff, harbor activities, and honey buckets. Annually, wastewater facilities introduce large volumes of untreated excrement and chlorine through sewage outfall lines, as well as releasing treated freshwater into the nation's waters. This can significantly alter pH levels of marine waters (Council 1999).

There are many potential impacts from point-source discharge, but point-source discharges and resulting altered water quality in aquatic environments do not necessarily result in adverse impacts, either to marine resources or EFH. Because most point-source discharges are regulated by the state or EPA, effects to receiving waters are generally considered on a case-by-case basis. Point-source discharges can adversely affect EFH by (1) reducing habitat functions necessary for growth to maturity, (2) modifying community structure, (3) bioaccumulation, and (4) modifying habitat.

At certain concentrations, point-source discharges can alter the following properties of ecosystems and associated communities: diversity, nutrient and energy transfer, productivity, biomass, density, stability, connectivity, and species richness and evenness. Pollution effects may be related to changes in water flow, pH, hardness, dissolved oxygen, and other parameters that affect individuals, populations, and communities. Sewage, fertilizers, and de-icing chemicals (e.g., glycols, urea) are examples of common urban pollutants that decompose with high biological or chemical oxygen demand (Council 1999).

Point-source discharges, at certain concentrations, can alter the following characteristics of finfish, shellfish, and related organisms: growth, visual acuity, swimming speed, equilibrium, feeding rate, response time to stimuli, predation rate, photosynthetic rate, spawning seasons, migration routes, and resistance to disease and parasites. Additionally, zones of low dissolved oxygen resulting from their decomposition can retard growth of salmon eggs, larvae, and juveniles and may delay or block smolt and adult migration. Sewage and fertilizers also introduce nutrients that drive algal and bacterial blooms into urban drainages. Such blooms may smother incubating salmon or produce toxins as they grow and die. Thermal effluents from industrial sites and removal of riparian vegetation from streambanks can degrade salmon habitat by allowing solar warming of water. Heavy metals, petroleum hydrocarbons, chlorinated hydrocarbons, and other chemical wastes can be toxic to salmonids and their food, and they can inhibit salmon movement and habitat use in streams (Council 1999).

Elevated salinity levels from desalination plants also have to be considered. While studies have shown that elevated salinity levels may not produce toxic effects (Bay and Greenstein 1994), peripheral effects of pollution may include forcing rearing fish into areas of high predation. Conversely, an influx of treated freshwater from municipal wastewater plants may force rearing fish into habitat with less than optimal salinity for growth (Council 1999).

Point discharges may affect the growth, survival, and condition of managed species and prey species if high levels of contaminants (e.g., chlorinated hydrocarbons, trace metals, PAHs, pesticides, and herbicides) are discharged. If contaminants are present, they may be absorbed across the gills or concentrated through bioaccumulation as contaminated prey is consumed (Raco-Rands 1996). Many heavy metals and persistent organic compounds such as pesticides and polychlorinated biphenyls tend to adhere to solid particles discharged from outfalls. As the particles are deposited, these compounds or their degradation products (which may be equally or more toxic than the parent compounds) can enter the foodchain by bioaccumulating in benthic organisms at much higher concentrations than in the surrounding waters (Stein et al. 1995). Due to burrowing, diffusion, and other upward transport mechanisms that move buried contaminants to the surface layers and eventually to the water column, pelagic and nektonic biota may also be exposed to contaminated sediments through mobilization into the water column.

Discharge sites may also modify habitat by creating adverse impacts to sensitive areas such as freshwater shorelines and wetlands, emergent marshes, sea grasses, and kelp beds if located improperly. Extreme discharge velocities of effluent may also cause scouring at the discharge point, as well as entraining particulates and thereby creating turbidity plumes. These turbidity plumes of suspended particulates can reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area while elevated turbidity persists. The contents of the suspended material can react with the dissolved oxygen in the water and result in oxygen depletion, or smother submerged aquatic vegetation sites including eelgrass beds and kelp beds. Accumulation of outfall sediments may also alter the composition and abundance of infaunal or epibenthic invertebrate communities (Ferraro et al. 1991). Pollutants, either suspended in the water column (e.g., nitrogen, contaminants, fine sediments) or settled on the bottom, can affect habitat. Many benthic organisms are quite sensitive to grain size, and accumulation of sediments can also submerge food organisms.

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, coral reefs, and other similar fragile and productive habitats.
2. Reduce potentially high velocities by diffusing effluent to acceptable velocities.
3. Determine benthic productivity by sampling before any construction activity related to installation of new or modified facilities. Develop outfall design (e.g., modeling concentrations within the predicted plume or likely extent of deposition along a productive nearshore) with input from appropriate resource and Tribal agencies.
4. Provide for mitigation when degradation or loss of habitat occurs from placement and operation of the outfall structure and pipeline.
5. Institute source-control programs that effectively reduce noxious materials to avoid introducing these materials into the waste stream.
6. Ensure compliance with pollutant discharges regulated through discharge permits which set effluent discharge limitations and/or specify operation procedures, performance standards, or BMPs. These efforts rely on the implementation of BMPs to control polluted runoff (EPA 1993).
7. Treat discharges to the maximum extent practicable, including implementation of up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances.
8. Use land-treatment and upland disposal/storage techniques where possible. Limit the use of vegetated wetlands as natural filters and pollutant assimilators for large-scale discharges to those instances where other less damaging alternatives are not available, and the overall environmental and ecological suitability of such actions has been demonstrated.
9. Avoid siting pipelines and treatment facilities in wetlands and streams. Since pipelines and treatment facilities are not water-dependent with regard to positioning, it is not essential that they be placed in wetlands or other fragile coastal habitats. Avoiding placement of pipelines within streambeds and wetlands will also reduce inadvertent infiltration into conveyance systems and retain natural hydrology of local streams and wetlands.

Persistent Organic Pollutants (POP)

North Pacific and Alaska marine waters are perceived as pristine because most of Alaska's 6,640 miles (10,686 kilometers) of coastline are devoid of point-source pollution, unlike much of North America. Effluents from boat harbors, municipal outfalls, and other industrial activities are generally considered to be the primary sources of contamination in Alaska waters, so most efforts at monitoring and mitigation have been focused on the local level. The only major regional pollution event was the *Exxon Valdez* oil spill in 1989, a contaminant threat that has abated considerably over the last 14 years. However, there is an increasing body of evidence suggesting that the greatest contaminant threat in Alaska comes from atmospheric and marine transport of contaminants from areas quite distant from Alaska.

The geography of Alaska makes it particularly vulnerable to contaminants volatilized from Asia. During winter, the Aleutian low pressure cell steers air from Southeast Asia into the EBS and northern Gulf of Alaska (GOA), bringing precipitation along the way. When this air meets the mountains along Alaska's southern coast, more precipitation occurs, bringing entrained contaminants from the atmosphere into the marine ecosystem or coastal/interior ecosystems. Thus, pesticides applied to crops in Southeast Asia can be volatilized into the air, bound to suspended particulates, transported in the atmosphere to Alaska, and deposited in snow or rain directly into marine ecosystems or indirectly from freshwater flow to nearshore waters. Revolatilization of these compounds is inhibited by the cold temperatures associated with Alaska latitudes, resulting in a net accumulation of these compounds in northern habitats. This same distillation process also transfers volatilized contaminants from the atmosphere to the Pacific at lower latitudes, and ocean currents also deliver the contaminants to Alaska. Concentrations will be very low, but there will extensive geographical marine or land areas to act as cold deposit zones.

The effect of these transport mechanisms has been the appearance of persistent organic contaminants in northern latitudes, despite the absence of local sources. A good demonstration of global transport into northern latitudes is the presence of dichloro-diphyl-trichloroethanes (DDTs) in the blubber of ring seals in the western Canadian Arctic (Addison and Smith 1996). DDT and its congeners were first observed in these seals during the early 1970s. The persistence DDTs in these seals through the 1990s, despite North American bans on DDT use in the1970s, is evidence of continued deposition of DDT from countries still using this pesticide.

The existence of organic contaminants in biological tissues means these contaminants are being transported within the food webs in Alaska fish habitats. For example, Ewald et al. (1998) found detectable levels of polychlorinated biphenyls (PCBs), DDTs, and other pesticides in the tissues of adult sockeye salmon returning to the Copper River. These fish apparently concentrated these contaminants in their tissues during their migration in the northern GOA and delivered them to their spawning habitats in the interior of Alaska. Avian and mammalian predators of these fish would further distribute these contaminants.

Distribution of Contaminants in Marine Habitats
A large variety of contaminants can be found in Alaska's marine environment, including persistent organic pollutants (POPs) and heavy metals. POPs are characterized as those with half-lives over 2 months, bioaccumulation factors greater than 5,000, potential for long-range transport, and capable of toxic effects. Currently, 12 classes of compounds are considered POPs and are regulated by the Stockholm Convention on Persistent Organic Pollutants (Table 5.7-1). In addition to POPs, heavy metals present in Alaska habitats include mercury (Hg), cadmium, chromium, arsenic, lead, and silver. Contaminants found in Alaska marine mammals sampled between southeastern Alaska and the Aleutian and Pribilof Islands include PCBs, DDT, chlordanes, hexachlorocyclohexanes (HCHs), hexachlorobenzene, dieldrin, butyltins, arsenic, mercury, cadmium, and lead (Barron and Heintz in press). With over 100,000 chemicals on the market and an additional 1,000 to 2,000 new ones introduced annually, there are likely other toxic compounds in the environment whose concentrations are increasing. In addition, combustion and industrial processes result in the inadvertent production of unregulated chemicals (Arctic Monitoring and Assessment Programme [AMAP] 2002).

There have been few large-scale evaluations of the spatial or temporal patterns to contamination in Alaska's marine environment. Most effort at monitoring contaminant loads in Alaska waters has focused on Arctic habitats where there is evidence that PCBs and DDTs have declined over the last 25 years (AMAP 2002). Recently, Beckmen et al. (2001) reported on the concentrations of PCBs in sea lion scats collected from around the GOA. These data suggest that sea lion prey in the eastern Aleutian Islands have greater PCB loads than prey near Kodiak, Cook Inlet, and Prince William Sound. Prey from the latter three locations also have lower PCB loads than those from southeastern Alaska. Some of the relatively high values observed in the eastern Aleutians may reflect the addition of PCB point-source inputs at specific sites (Barron and Heintz in press), but it would seem unlikely that a few point sources could account for the general elevated state of PCB loads in the entire Aleutians.

The Twelve Persistent Organic Pollutants Regulated by the POPs Treaty

	Common Name	Effect on Organisms
Pesticides	Dieldrin	Reproductive impairment; renal and liver damage
	Aldrin	Neurological damage; reproductive impairment
	Chlordane	Altered hormone function
	DDT/DDE	Neurological damage; hormonal disruption; reproductive impairment
	Endrin	Developmental abnormalities
	Heptachlor	Liver damage; hormonal changes
	Hexachlorobenzene	Reduced embryo weights in herring gulls
	Mirex	Kidney lesions in fish
	Toxaphene	"Broken-back" syndrome in fish
Polychlorinated biphenyls	PCBs	Poor reproductive success Impaired immune function
Industrial and Incineration Byproducts	Dioxins	Immune suppression; hormonal dysfunction; developmental impairment
	Furans	Developmental impairment; increased abortions

Source: World Federation of Public Health Associations 2000. Persistent organic pollutants and human health. Washington, DC.

Temporal studies provide little information because they are quite limited as to the number of locations evaluated and the samples collected. The mechanism, however, by which contaminants are delivered to the Alaska marine environment guarantees that the contaminants will be found in Alaska waters for as long as they are released (Wania and Mackay 1999). For example, the types of PCBs found in seals from sites near the Russian coast are consistent with those used in Russian electrical equipment (Muir and Norstrom 2000). Contributions of contaminants by marine transport will continue for some time. More water-soluble organic contaminants like HCHs are slower to accumulate in Arctic and subarctic food webs and appear to be increasing (Wania and Mackay 1999). Mercury appears to be higher in more recent samples (mid 1990s) than in the 1980s and 1970s, and rates of Hg accumulation also appear to be higher than they were 10 to 20 years ago (Muir et al. 1999). Polybrominated diphenyl ethers (PBDEs) also appear to be increasing in marine mammals (Ikonomou et al. 2002) and may surpass PCBs as the most prevalent persistent organic pollutants (POPs) in arctic habitats.

Factors Leading to Higher Contaminant Loads

The trophic structure of Alaska marine food webs, coupled with the tendency of contaminants to accumulate in Alaska habitats, causes apex predators to concentrate significant amounts of POPs in their tissues. Organisms occupying the top trophic levels in a food web bioaccumulate the highest concentrations of contaminants (Ruus et al. 2002). For example, the total PCB concentration in seal-eating killer whales sampled near Kenai Fjords National Monument was one to two orders of magnitude greater than fish-eating killer whales, indicating the significance of their trophic position (Ylitalo et al. 2001a). Further, seal-eating killer whale PCB loads were greater than the loads typically associated with belugas from the St. Lawrence River, while those of resident, fish-eating killer whales were consistent with loads observed in harbor seals in Puget Sound (Ylitalo et al. 2001a). The few data available on organisms at lower trophic levels in Alaska’s marine habitats indicate these species experience relatively low contaminant loads (de Brito et al. 2002, Aono et al. 1997, Kawano et al. 1986). Thus, Alaska killer whales are likely accumulating loads of contaminants from remote sources that are consistent with those of marine mammals living near heavily contaminated urban areas as a result of their high trophic position. While this interpretation fails to account for differences in life stage, sex, or analytical method, it illustrates the need for more detailed information about this region.

This issue is particularly relevant when the contaminant loads experienced by Alaska natives subsisting on foods derived from marine habitats are considered. In one study, the total PCB concentration (not lipid adjusted) in serum collected from Aleutian males, ages 45 to 54, averaged 8.7 parts per billion (Alaska Division of Public Health 2003). By comparison, the concentrations in similarly aged males from around the Great Lakes who also consumed large amounts of fish (more than 52 meals per year) averaged 4.8 parts per billion (Hanrahan et al. 1999). Reference males in the latter study were demographically similar, ate less fish, and averaged 1.5 parts per billion. The relatively high level for the Alaska natives is likely the result of their trophic position relative to that of the Great Lakes fishers. Alaska natives with subsistence lifestyles who live in the Aleutians probably consume seals and fish, leading to a trophic position above that of Great Lakes fishers, who likely consume more grains and plant materials than Aleutian natives.

A second contributing factor to increased contaminant loads among apex predators in Alaska is their relatively long life. Contaminant loads increase with age in fish (Vuorinen et al. 2002), Steller sea lions (O’Hara 2001, Ylitalo et al. 2001b), and humans (Alaska Division of Public Health 2003). Female pinnipeds in the EBS and northern GOA typically begin reproducing at 5 years of age (Riedman 1990), allowing time for significant accumulation of contaminants, especially because pinnipeds eat relatively large (i.e., old) prey. For example, the pollock consumed by Steller sea lions average 1.3 feet (393 mm) and Atka mackerel 1.06 feet (323 mm) (Zeppelin et al. 2003). This translates to fish ages of approximately 3 to 5 years old. These sizes, however, were at the low end of the size distribution, indicating that sea lions can eat much older prey. Vuorinen et al. (2002) reported a sevenfold increase in POP loads of sprat between ages 2 and 10, demonstrating the increased potential for exposure associated with consuming older prey.

Significance of Contaminant Loads

It is not clear if the levels of contaminants in Alaska waters are causing deleterious effects to populations, because research in this area is still in its infancy. Relatively small and spotty contaminant surveys have established that POPs are present in Alaska waters, forage, and predators. No comprehensive geographical and temporal studies have been done to date to examine trends or sources of variation. The potential for the problem has been exposed; the extent and significance remain to be determined.

The potential for significant effects is most likely greatest among apex predators. Contamination is probably widespread among forage species at low levels, but apex predators are likely be the most affected as a result of their longevity, lipid storage, and the relatively high concentrations they bear. In mammals, it is most likely that lipophilic contaminants would have the greatest impacts on first-born young. The accumulation contaminants in females increase with age, but decrease after females reach reproductive age. This is the result of their transfer of contaminants to their offspring in milk. This process has been reported for sea lions, fur seals (Beckmen et al. 1999), and humans (Yang et al. 2002). This process occurs repeatedly for each offspring, consequently, the first-born offspring receives adult level contaminant loads during its most sensitive developmental stage. Beckmen et al. (1999) reported that first-born northern fur seal pups of primiparous mothers had higher PCB levels in their blood than pups of multiparous mothers. This higher load was correlated with a reduced ability to form antibodies to tentanus, along with reduced concentrations of thyroxine and vitamin A in their blood. Barron and Heintz (in press) compared reported PCB loads in juvenile Steller sea lions with loads known to cause deleterious effects in other pinnepeds and concluded that some sea lions in the mid-1980s likely experienced immunological impairment. Assessing impacts on humans is more difficult and controversial. While the acute impacts of contaminants on humans are known, the long-term impacts following neonatal exposure have not been explored.

Recent declines in apex predator populations in the EBS and northern GOA may be related to contaminant loading in the region. Over the last 25 years, the populations of Steller sea lions, harbor seals, northern fur seals, and many birds have declined. The reasons underlying these declines are likely complex and may not be the same for all species. For example, the decline in Steller sea lions is presumed to have resulted from nutritional stress, but more recent evidence suggests other factors, including contaminants, may be limiting their recovery (De Master et al. 2001). Contaminants are unlikely to be causing acutely toxic effects in the regions. Sublethal impacts of contaminants, however, could be working indirectly to impair populations through reduced immune function (Beckmen 2001) or reproduction (Reinjders 1986). Both of these characters are displayed by Steller sea lion populations from the affected region. York et al. (1996) attributed continuing declines in affected populations to a failure to recruit offspring to maturity. Zenteno-Savin et al. (1997) reported elevated levels of haptoglobin, an acute-phase reaction protein in the blood of Steller sea lions and harbor seals from affected populations relative to levels observed in stable or increasing populations. This protein is indicative of non-specific stressors that could include injury, disease, or toxicity. Thus, a recent panel was unable to reject contaminants as a factor contributing to the failed recovery of Steller sea lion populations (Barron and Heintz 2001).

Impacts may also occur at lower trophic levels, but there has been even less research in this area. Atlantic salmon in the Baltic Sea and salmonids in the Great Lakes have both experienced a common syndrome variously named M74 or early mortality syndrome. The syndrome is characterized by low thiamine content in eggs, resulting in near complete mortality of affected brood years. While the cause for the reduced thiamine content in spawning adults remains unknown, increased levels of PCB and dibenzofurans and dibenzo-dioxins were correlated with the onset of the disease in Baltic salmon (Vuorinen et al. 2002).

The impacts of persistent contaminants on populations in Alaska waters are not likely to be acute. The impacts are more likely be expressed as sublethal impacts in apparently healthy animals. These sublethal impacts ultimately lead to reduced reproductive fitness or decreased survival to maturity; therefore, they manifest themselves indirectly. Science is certain that the physical properties of these compounds couple with global climate patterns to ensure that they will be deposited in Alaska habitats, while maintaining their toxicity and perfusing through Alaska food webs, which include some of the most valuable fisheries on the planet. What is uncertain is how these compounds impact the health of organisms deriving sustenance from those food webs and how those impacts might feed back into the food web.

Recommended Conservation Measures

No specific conservation measures or mitigation strategies are proposed relative to contaminants, many unknowns exist. POP contaminants are present in Alaska waters and in forage species and in predators up through apex predators, but the significance of the present loads is not known. Also, the relative concentrations in forage species (pollock for example) from the EBS, near Russia, or the northern GOA are not known. Comprehensive studies on a geographical, temporal, or widespread species scale to determine any relationship between contaminant loads and population changes have not been conducted. POP contaminants may contribute to poor recovery in some species, but mitigation strategies, whether they would be changes in fishing regulations or international regulation to curb contaminant releases, will likely need a better research foundation to support changes.

Mining

Mining activity can lead to the direct loss of EFH for certain species. Mineral extraction, such gold and gravel source mining, from the seafloor and coastal beaches can increase water turbidity, alter seafloor and coastline features, and destroy or alter marine infauna and epifauna. The re-suspension of organic materials could affect less motile organisms (i.e., eggs and recently hatched larvae) in the area. Benthic habitats could be damaged or destroyed by these actions. Mining large quantities of beach gravel may significantly affect the removal, transport, and deposition of sand and gravel along the shore, both at the mining site and down-current (Council 1999). Neither the future extent of this activity nor the effects of such mortality on the abundance of marine species is known. Changes in bathymetry and bottom type may also alter population and migrations patterns (Hurme and Pullen 1988).

Mining practices can include physical impacts from intertidal dredging and chemical impacts from the use of additives such as flocculates (Council 1999). Impacts may include the removal of substrates that serve as habitat for fish and invertebrates; habitat creation or conversion in less productive or uninhabitable sites, such as anoxic holes or silt bottom; burial of productive habitats, such as in near-shore disposal sites (as in beach nourishment); release of harmful or toxic materials either in association with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and adverse modification of hydrologic conditions so as to cause erosion of desirable habitats.

Mining and mineral extraction activities take many forms, such as commercial dredging and recreational suction dredging, placer, area surface removal, and contour operations. Activities include gravel mining (NMFS 2004), exploration, site preparation, mining, milling, waste management, decommissioning or reclamation, and mine abandonment (American Fisheries Society [AFS] 2000). Mining and its associated activities have the potential to cause environmental impacts from exploration through post-closure. These impacts may include adverse effects to EFH. The operation of metal, coal, rock quarries, and gravel pit mining has caused varying degrees of environmental damage in urban, suburban, and rural areas. Some of the most severe damage, however, occurs in remote areas, where some of the most productive fish habitat is often located (Sengupta 1993).

In Alaska, existing regulations, promulgated and enforced by other federal and state agencies, have been designed to control and manage these changes to the landscape to avoid and minimize impacts. These regulations are regularly updated as new technologies are developed to improve mineral extraction, reclaim mined lands, and limit environmental impacts. However, while environmental regulations may avoid, limit, control, or offset many of these potential impacts, mining will, to some degree, always alter landscapes and environmental resources.

Potential impacts from mining include (1) adverse modification of hydrologic conditions so as to cause erosion of desirable habitats, (2) removal of substrates that serve as habitat for fish and invertebrates, (3) conversion of habitats,(4) release of harmful or toxic materials, and (5) creation of harmful turbidity levels.

The effects depend on the type, extent, and location of the activities. Minerals are extracted using several methods. Surface mining involves suction dredging, hydraulic mining, panning, sluicing, strip mining, and open-pit mining (including heap leach mining). Underground mining uses tunnels or shafts to extract minerals by physical or chemical means. Surface mining probably has a greater potential to affect aquatic ecosystems, though specific effects will depend on the extraction and processing methods and the degree of disturbance (Spence et al. 1996). Surface mining has the potential to eliminate vegetation, permanently alter topography, permanently and drastically alter soil and subsurface geological structure, and disrupt surface and subsurface hydrologic regimes (AFS 2000). While mining may not be as geographically pervasive as other sediment-producing activities, surface mining typically increases sediment delivery much more per unit of disturbed area than other activities because of the level of disruption of soils, topography, and vegetation. (Nelson et al. 1991).

Mining and placement of spoils in riparian areas can cause the loss of riparian vegetation and changes in heat exchange, leading to higher summer temperatures and lower winter stream temperatures (Spence et al. 1996). Bank instability can also lead to altered width-to-depth ratios, which further influence temperature (Spence et al. 1996). Mining efforts can also bury productive habitats near mine sites.

Mining operations can release harmful or toxic materials and their byproducts, either in association with actual mining, or in connection with machinery and materials used for mining. Mining can also introduce levels of heavy metals and arsenic that are naturally found within the streambed sediments. Tailings and discharge waters from settling ponds can result in loss of EFH and life stages of managed species. The impact degrades water quality, and levels can become high enough to prove lethal (North Pacific Fishery Management Council [Council] 1999). Submarine disposal of mine tailings can also alter the behavior of marine organisms. Submarine mine tailings may not provide suitable habitat for some benthic organisms. In laboratory experiments, benthic dwelling flatfishes (Johnson et al. 1998a) and crabs (Johnson et al. 1998b) strongly avoided mine tailings.

Commercial operations may also involve road building, disposal, and leaching of extraction chemicals, all of which may create serious impacts to EFH. Cyanide, sulfuric acid, arsenic, mercury, heavy metals, and reagents associated with such development are a threat to EFH. Improper handling or in-water disposal of tailings may be toxic to managed species or their prey downstream. Upland disposal of tailings in unstable or landslide prone areas can cause large quantities of toxic compounds to be released into streams or to contaminate groundwater (Council 1999). Indirectly, the sodium cyanide solution used in heap leach mining is contained in settling ponds from which groundwater and surface waters may become contaminated (Nelson et al. 1991).

Water pollution by heavy metals and acid is often associated with mineral mining operations, as ores rich in sulfides are commonly mined for gold, silver, copper, iron, zinc, and lead. When stormwater comes in contact with sulfide ores, sulfuric acid is commonly produced (West et al. 1995). Abandoned pit mines can also cause severe water pollution problems.

Recreational gold mining with such equipment as pans, motorized or nonmotorized sluice boxes, concentrators, rockerboxes, and dredges can adversely affect EFH on a local level. Commercial mining is likely to involve activities at a larger scale with much disturbance and movement of the channel involved (Oregon Water Resources Research Institute [OWRRI] 1995).

Sand and gravel source mining is extensive and occurs by several methods. These include wet-pit mining (i.e., removal of material from below the water table), dry-pit mining on beaches, exposed bars, and ephemeral streambeds, and subtidal mining. Sand and gravel mining in riverine, estuarine, and coastal environments can create EFH impacts, including (1) turbidity plumes and resuspension effects, (2) removal of spawning habitat, and (3) alteration of channel morphology.

Mechanical disturbance of EFH spawning habitat by mining equipment can also lead to high mortality rates in early life stages. One result is the creation of turbidity plumes, which can move spawning habitat several kilometers downstream. Sand and gravel mining in riverine, estuarine, and coastal environments can also suspend materials at the sites.

Sedimentation may be a delayed effect because gravel removal typically occurs at low flow when the stream has the least capacity to transport fine sediments out of the system. Another delayed sedimentation effect results when freshets inundate extraction areas that are less stable than they were before the activity occurred. In addition, for species such as salmon, gravel operations can also interfere with migration past the site if they create physical or thermal changes, either at or downstream from the work site (OWRRI 1995).

Additionally, extraction of sand and gravel in riverine ecosystems can directly eliminate the amount of gravel available for spawning if the extraction rate exceeds the deposition rate of new gravel in the system. Gravel excavation also reduces the local supply of gravel to downstream habitats. The extent of suitable spawning habitat may be reduced where degradation reduces gravel depth or exposes bedrock (Spence et al. 1996).

Mining can also alter channel morphology by making the stream channel wider and shallower. Consequently, the suitability of stream reaches as rearing EFH may be decreased, especially during summer low-flow periods when deeper waters are important for survival. Similarly, a reduction in pool frequency may adversely affect migrating adults that require holding pools (Spence et al. 1996). Changes in the frequency and extent of bedload movement and increased erosion and turbidity can also remove spawning substrates, scour redds (resulting in a direct loss of eggs and young), or reduce their quality by deposition of increased amounts of fine sediments. Other effects that may result from sand and gravel mining include increased temperatures (from reduction in summer base flows and decreases in riparian vegetation), decreased nutrients (from loss of floodplain connection and riparian vegetation), and decreased food production (loss of invertebrates) (Spence et al. 1996).

Examples of using gravel removal to improve habitat and water quality are limited and isolated (OWRRI 1995). Deep pools created by material removal in streams appear to attract migrating adult salmon for holding. These concentrations of fish may result in high losses as a result of increased predation or recreational fishing pressure.

Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), OWRRI (1995), Washington Department of Fish and Wildlife (1998), and NMFS (2004). They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat (marine vegetation), known spawning areas, and riparian areas,
2. Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present, such as seasonal timing windows.
3. Identify upland or off-channel (where the channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to EFH, if possible.
4. Design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to EFH, if operations in EFH cannot be avoided. This includes, but is not limited to, migratory corridors, foraging and spawning areas, stream/river banks, intertidal areas, etc.
5. Use an integrated environmental assessment, management, and monitoring package in accordance with state and federal law and regulations. Allow for adaptive operations to minimize adverse effects on EFH.
6. Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.
7. Treat wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams. Test wastewater before discharge for compliance with federal and state clean water standards.
8. Minimize opportunities for sediments to enter or affect EFH. Use methods such as contouring, mulching, and construction of settling ponds to control sediment transport.
9. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels. Use methods such as turbidity/sediment curtains to limit the spread of suspended sediments and minimize the area affected.
10. If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds if leachate can enter EFH through groundwater.
11. Restore natural contours and plant native vegetation to the extent practicable. Monitor the site to evaluate performance and implement corrective measures if necessary.
12. Minimize the aerial extent of ground disturbance (e.g., through phasing of operations), and stabilize disturbed lands to reduce erosion.

Dredging

Dredging navigable waters creates a continuous impact primarily affecting benthic and water-column habitats in the course of constructing and operating marinas, harbors, and ports. Routine dredging (i.e., the excavation of soft-bottom substrates) is used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. In addition, port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. Elimination or degradation of aquatic and upland habitats is commonplace because port expansion almost always affects open water, submerged bottoms, and, possibly, riparian zones.

The environmental effects of dredging on EFH can include (1) direct removal/burial of organisms; (2) turbidity/siltation effects, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances; (5) entrainment; (6) noise disturbances; and (6) alteration to hydrodynamic regimes and physical habitat.

Many EFH species forage on infaunal and bottom-dwelling organisms. Dredging may adversely affect these prey species at the site by directly removing or burying immobile invertebrates such as polychaete worms, crustacean, and other EFH prey types (Newell et al. 1998, Van der Veer et al. 1985). Similarly, the dredging activity may also force mobile animals such as fish to migrate out of the project area. Recolonization studies suggest that recovery may not be quite as straightforward. Physical factors, including particle size distribution, currents, and compaction/stabilization processes following deposition reportedly can regulate recovery after dredging events. Rates of recovery listed in the literature range from several months for estuarine muds to up to 2 to 3 years for sands and gravels. Recolonization can also take up to 1 to 3 years in areas of strong current, but up to 5 to 10 years in areas of low current. Thus, forage resources for benthic feeders may be substantially reduced.

The use of certain types of dredging equipment can result in greatly elevated levels of fine-grained mineral particles or suspended sediment concentration, usually smaller than silt, and organic particles in the water column. The associated turbidity plumes of suspended particulates may reduce light penetration and lower the rate of photosynthesis for subaquatic vegetation (Dennison 1987) and the primary productivity of an aquatic area if suspended for extended periods of times (Cloern 1987). If suspended sediments loads remain high, fish may suffer reduced feeding ability (Benfield and Minello 1996) and be prone to fish gill injury (Nightingale and Simenstad 2001a).

Sensitive habitats such as submerged aquatic vegetation beds, which provide food and shelter, may also be damaged. Eelgrass beds are critical to nearshore food web dynamics (Wyllie-Echeverria and Phillips 1994, Murphy et al. 2000). Studies have shown seagrass beds to be among the areas of highest primary productivity in the world (Herke and Rogers 1993, Hoss and Thayer 1993). This primary production, combined with other nutrients, provide high rates of secondary production in the form of fish (Herke and Rogers 1993, Good 1987, Sogard and Able 1991).

The contents of the suspended material may react with the dissolved oxygen in the water and result in short-term oxygen depletion to aquatic resources (Nightingale and Simenstad 2001a). Dredging can also disturb aquatic habitats by resuspending bottom sediments and, thereby, recirculate toxic metals (e.g., lead, zinc, mercury, cadmium, copper etc.), hydrocarbons (e.g., polyaromatics), hydrophobic organics (e.g., dioxins), pesticides, pathogens, and nutrients into the water column (EPA 2000). Toxic metals and organics, pathogens, and viruses, absorbed or adsorbed to fine-grained particulates in the material, may become biologically available to organisms either in the water column or through food chain processes.

Direct uptake of fish species by hydraulic dredging at the proposed borrow site is also an issue. Definitive information in the literature shows that elicit avoidance responses to the suction dredge entrainment occurs for both benthic and water column oriented species (Larson and Moehl 1990, McGraw and Armstrong 1990).

Dredging, as well as equipment such as pipelines used in the process, may damage or destroy spawning, nursery, and other sensitive habitats such as emergent marshes and subaquatic vegetation, including eelgrass beds and kelp beds. Dredging may also modify current patterns and water circulation of the habitat by changing the direction or velocity of water flow, water circulation, or dimensions of the waterbody traditionally used by fish for food, shelter, or reproductive purposes.

Recommended Conservation Measures

The recommended conservation measures for dredging include the following. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Avoid new dredging to the maximum extent practicable.
2. Where possible, minimize dredging by using natural and existing channels.
3. Site activities that would likely require dredging (such as placement of piers, docks, marinas, etc.) in deep-water areas or design such structures to alleviate the need for maintenance dredging.
4. Incorporate adequate control measures by using BMPs to minimize turbidity and dispersal of dredged material in areas where the dredging equipment would cause such effects.

5. For new dredging projects, undertake multi-season, pre-, and post-dredging biological surveys to assess the cumulative impacts to EFH and allow for implementation of adaptive management techniques.
6. Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.
7. Perform dredging at times when impacts to federally managed species or their prey are least likely. Avoid dredging in areas with submerged aquatic vegetation.
8. Reference all dredging latitude-longitude coordinates at the site so that information can be incorporated into a geographical information system format. Inclusion of aerial photos may be useful to identify precise locations for long-term evaluation.
9. Test sediments for contaminants as per EPA and USACE requirements.
10. Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible, to ensure that actions are taken to curtail those causes.
11. Ensure that bankward slopes of the dredged area are slanted to acceptable side slopes (e.g., 3:1) to prevent sloughing.
12. Avoid placing pipelines and accessory equipment used in conjunction with dredging operations to the maximum extent possible close to kelp beds, eelgrass beds, estuarine/salt marshes, and other high value habitat areas.

The disposal of dredged material can adversely affect EFH by (1) altering or destroying benthic communities, (2) altering adjacent habitats, and (3) creating turbidity plumes and introducing contaminants and/or nutrients.

Disposing dredged materials result in varying degrees of change in the physical, chemical, and biological characteristics of the substrate. Discharges may adversely affect infaunal and bottom-dwelling organisms at the site by smothering immobile organisms (e.g., prey invertebrate species) or forcing mobile animals (e.g., benthic-oriented fish species) to migrate from the area. Infaunal invertebrate plants and animals present prior to a discharge are unlikely to recolonize if the composition of the discharged material is drastically different.

Erosion, slumping, or lateral displacement of surrounding bottom of such deposits can also adversely affect substrate outside the perimeter of the disposal site by changing or destroying benthic habitat. The bulk and composition of the discharged material and the location, method, and timing of discharges may all influence the degree of impact on the substrate.

The discharge of material can result in greatly elevated levels of fine-grained mineral particles, usually smaller than silt, and organic particles in the water column (i.e., turbidity plumes). These suspended particulates may reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area if suspended for long intervals. Aquatic vegetation such as eelgrass beds and kelp beds may also be affected. Managed fish species may suffer reduced feeding ability, leading to limited growth and lowered resistance to disease if high levels of suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion. Toxic metals and organics, pathogens, and viruses absorbed into or adsorbed to fine-grained particulates in the material may become biologically available to organisms either in the water column or through food chain processes.

The discharge of dredged or fill material can change the chemistry and the physical characteristics of the receiving water at the disposal site by introducing chemical constituents in suspended or dissolved form. Reduced clarity and excessive contaminants can reduce, change, or eliminate the suitability of water bodies for populations of groundfish, other fish species, and their prey. The introduction of nutrients or organic material to the water column as a result of the discharge can lead to a high biochemical oxygen demand (BOD), which in turn can lead to reduced dissolved oxygen, thereby potentially affecting the survival of many aquatic organisms. Increases in nutrients can favor one group of organisms such as polychaetes or algae to the detriment of other types.

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Study all options for disposal of dredged materials, including upland disposal sites, and select disposal sites that minimize adverse effects to EFH.
2. Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.
3. Encourage beneficial uses of dredged materials. Consider using dredging material for beach replenishment and construction where appropriate. When dredging material is placed in open water, consider the possibilities for enhancing marine fishery resources.
4. State and federal agencies should identify the direct and indirect impacts open-water disposal permits for dredged material may have on EFH during proposed project reviews. Determine benthic productivity by sampling prior to any discharge of fill material. Develop the sampling design with input from state and federal natural resource agencies.
5. Minimize the areal extent of any disposal site in EFH, or avoid the site entirely. Mitigate all non-avoidable adverse impacts as appropriate.

Fill Material

Adverse impacts to EFH from the introduction of fill material include (1) loss of habitat function and (2) changes in hydrologic patterns.

Aquatic habitats sustain remarkably high levels of productivity and support various life stages of fish species and their prey. Many times, these habitats are used for multiple purposes, including habitat necessary for spawning, breeding, feeding, or growth to maturity. The introduction of fill material eliminates those functions and permanently removes the habitat from production.

The discharge of dredged or fill material can modify current patterns and water circulation by obstructing flow, changing the direction or velocity of water flow and circulation, or otherwise changing the dimensions of a water body. As a result, adverse changes can occur in the location, structure, and dynamics of aquatic communities; shoreline and substrate erosion and deposition rates; the deposition of suspended particulates; the rate and extent of mixing of dissolved and suspended components of the water body; and water stratification (NMFS 1998, b).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH:

1. Federal, state, and local resource management and permitting agencies should address the cumulative impacts of past and current fill operations on EFH and consider them in the permitting process for individual projects.
2. Minimize the areal extent of any fill in EFH, or avoid it entirely. Mitigate all non-avoidable adverse impacts as appropriate.

3. Consider alternatives to the placement of fill into areas that support EFH. Identify and characterize EFH habitat functions/services in the project areas, so that appropriate mitigation can be determined if necessary.

Dock Construction and Pile Driving

Pilings are an integral component of many overwater and in-water structures. They provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and help in the construction of breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic, or a combination thereof. Piles are usually driven into the substrate by using either impact hammers or vibratory hammers. Impact hammers consist of a heavy weight that is repeatedly dropped onto the top of the pile, driving it into the substrate. Vibratory hammers use a combination of a stationary, heavy weight and vibration, in the plane perpendicular to the long axis of the pile, to force the pile into the substrate. The type of hammer used depends on a variety of factors, including pile material and substrate type. Impact hammers can be used to drive all types of piles, while vibratory hammers are generally most efficient at driving piles with a cutting edge (e.g., hollow steel pipe) and are less efficient at driving displacement piles (those without a cutting edge that must displace the substrate). Displacement piles include solid concrete, wood, and closed-end steel pipe.

While impact hammers are able to drive piles into most substrates (including hardpan, glacial till, etc.), vibratory hammers are limited to softer, unconsolidated substrates (e.g., sand, mud, and gravel). Because vibratory hammers do not use force to drive the piles, the bearing capacity is not known, and the piles must often be proofed with an impact hammer. This involves striking the pile a number of times with the impact hammer to ensure that it meets the designed bearing capacity. Under certain circumstances, piles may be driven using a combination of vibratory and impact hammers. The vibratory hammer makes positioning and plumbing of the pile easier; therefore, it is often used to drive the pile through the soft, overlying material. Once the pile stops penetrating the sediment, the impact hammer is used to finish driving the pile to final depth. An additional advantage of this method is that the vibratory hammer can be used to extract and reposition the pile, while the impact hammer cannot.

Overwater structures usually must meet seismic stability criteria, requiring that the supporting piles are attached to, or driven into, the underlying hard material. This requirement often means that at least some impact driving is necessary. Piles that do not have to be seismically stable, including temporary piles, fender piles, and some dolphin piles, may be driven with a vibratory hammer, providing the type of pile and sediments are appropriate.

Piles can be removed using a variety of methods, including vibratory hammer, direct pull, clam shell grab, or cutting/breaking the pile below the mudline. Vibratory hammers can be used to remove all types of pile, including wood, concrete, and steel. Old brittle piles may, however, break under the vibrations; this may necessitate using another method. The direct pull method involves placing a choker around the pile and pulling upward with a crane or other equipment. Broken stubs in soft substrates can be removed with a clam shell and crane, although suitable conditions rarely exist in Alaska. In this method, the clam shell grips the pile near the mudline and pulls it out. More commonly, piles may be cut or broken below the mudline, leaving the buried section in place.

Pile driving can generate intense underwater sound pressure waves that may adversely affect EFH. These pressure waves have been shown to injure and kill fish (CalTrans 2001, Longmuir and Lively 2001, Stotz and Colby 2001, Stadler, pers. obs. 2002). Injuries associated directly with pile driving are poorly studied, but include rupture of the swimbladder and internal hemorrhaging (CalTrans 2001; Abbott and Bing-Sawyer 2002; Stadler, pers. obs. 2002). Sound pressure levels (SPLs) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes (Hastings 2002).

The type and intensity of the sounds produced during pile driving depend on a variety of factors, including, but not limited to, the type and size of the pile, the firmness of the substrate into which the pile is being driven, the depth of water, and the type and size of the pile-driving hammer. SPLs are positively correlated with the size of the pile, as more energy is required to drive larger piles. Wood and concrete piles appear to produce lower sound pressures than hollow-steel piles of a similar size, although it is unclear if the sounds produced by wood or concrete piles are harmful to fishes. Hollow-steel piles as small as 14 inches (35.5 centimeters) in diameter have been shown to produce SPLs that can injure fish (Reyff 2003). Firmer substrates require more energy to drive piles and produce more intense sound pressures. Sound attenuates more rapidly with distance from the source in shallow water than it does in deep water (Rogers and Cox 1988).

Driving large hollow-steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. When exposed to sounds that are similar to those of a vibratory hammer, fish consistently displayed an avoidance response (Enger et al. 1993, Dolat 1997, Knudsen et al. 1997, Sand et al. 2000), and they did not habituate to the sound, even after repeated exposure (Dolat 1997, Knudsen et al. 1997). Fishes may respond to the first few strikes of an impact hammer with a startle response. After these initial strikes, the startle response wanes, and the fishes may remain within the field of a potentially harmful sound (Dolat 1997, NMFS 2001). The differential responses to these sounds are due to the differences in the duration and frequency of the sounds. When compared to impact hammers, the sounds produced by vibratory hammers are of longer duration (minutes versus milliseconds) and have more energy in the lower frequencies (15 to 26 hertz [hz] versus 100 to 800 hz) (Würsig, et al. 2000, Carlson et al. 2001). Studies have shown that fish respond to particle acceleration of 0.01 meter per second squared (m/s^2) at infrasound frequencies, that the response to infrasound is limited to the nearfield (less than 1 wavelength), and that the fish must be exposed to the sound for several seconds (Enger et al. 1993, Knudsen et al. 1994, Sand et al. 2000). Impact hammers, however, produce such short spikes of sound with little energy in the infrasound range, that fish fail to respond to the particle motion (Carlson et al. 2001). Thus, impact hammers may be more harmful than vibratory hammers because they produce more intense pressure waves and because the sounds produced do not elicit an avoidance response in fishes, which exposes them to those harmful pressures for longer periods.

The degree to which an individual fish exposed to sound will be affected depends on a number of variables, including (1) species of fish, (2) fish size, (3) presence of a swimbladder, (4) physical condition of the fish, (5) peak sound pressure and frequency, (6) shape of the sound wave (rise time), (7) depth of the water around the pile, (8) depth of the fish in the water column, (9) amount of air in the water, (10) size and number of waves on the water surface, (11) bottom substrate composition and texture, (12) effectiveness of bubble curtain sound/pressure attenuation technology, (13) tidal currents, and (14) presence of predators.

Depending on these factors, effects on fish can range from changes in behavior to immediate mortality.

There are little data on the SPL required to injure fish. Short-term exposure to peak SPLs above 190 dB (re:1 Pa) is thought to impose physical harm on fish (Hastings 2002). However, 155 dB (re:1 Pa) may be sufficient to stun small fish temporarily (personal communication, J. Miner, Gunderboom, Inc., Anchorage, Alaska, 2002). Stunned fish, while perhaps not physically injured, are more susceptible to predation. Small fish are more prone to injury by intense sound than are larger fish of the same species (Yelverton et al. 1975). For example, a number of surfperches (*Cymatogaster aggregata* and *Embiotoca lateralis*) were killed during impact pile driving (Stadler, pers. obs. 2002). Most of the dead fish were the smaller *C. aggregata* and similar sized specimens of *E. lateralis*, even though many larger *E. lateralis* were in the same area. Dissections revealed that the swimbladder of the smallest fish (80 millimeter [mm] forklength [FL]) was completely destroyed, while that of the largest individual (170 mm FL) was nearly intact, indicating a size-dependent effect. The SPLs that killed these fish are unknown. Of the reported fish kills associated with pile driving, all have occurred during use of an impact hammer on hollow-steel piles (Longmuir and Lively 2001, NMFS 2001, Stotz and Colby 2001, NMFS 2003).

Systems successfully designed to reduce the adverse effects of underwater SPLs on fish have included the use of air bubbles. Both confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures up to 28 dB (Würsig et al. 2000, Longmuir and Lively 2001, Christopherson and Wilson 2002, Reyff and Donovan 2003). When using an unconfined air bubble system in areas of strong currents, it is critical that the pile be fully contained within the bubble curtain. To accomplish this when designing the system, adequate air flow and ring spacing, both vertically and in terms of distance from the pile, are factors that should be considered.

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Install hollow-steel piles with an impact hammer at a time of year when larval and juvenile stages of fish species with designated EFH are not present. If the first measure is not possible, then the following measures regarding pile driving should be incorporated when practicable to minimize adverse effects:
2. Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
3. Use a vibratory hammer when driving hollow-steel piles. When impact hammers are required due to seismic stability or substrate type, drive the pile as deep as possible with a vibratory hammer before using the impact hammer.
4. Implement measures to attenuate the sound should SPLs exceed the 180 dB (re:1 Pa) threshold. If sound pressure levels are anticipated to exceed acceptable limits, implement appropriate mitigation measures when practicable. Methods to reduce the sound pressure levels include, but are not limited to, the following:
    a) Surround the pile with an air bubble curtain system or air-filled coffer dam.
    b) Because the sound produced has a direct relationship to the force used to drive the pile, use a smaller hammer to reduce the sound pressures.
    c) Use a hydraulic hammer if impact driving cannot be avoided. The force of the hammer blow can be controlled with hydraulic hammers; reducing the impact force will reduce the intensity of the resulting sound.
5. Drive piles when the current is reduced (i.e., centered around slack current) in areas of strong current to minimize the number of fish exposed to adverse levels of underwater sound.

Overwater Structures

Overwater structures include commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys. These structures typically are located in intertidal areas out to about 49 feet (15 meters) below the area exposed by the mean lower low tide (i.e., the shallow subtidal zone). Light, wave energy, substrate type, depth, and water quality are the primary factors controlling the plant and animal assemblages found at a particular site. Overwater structures and associated activities can alter these factors and interfere with key ecological functions such as spawning, rearing, and refugia. Site-specific factors (e.g., water clarity, current, depth, etc.) and the type and use of a given overwater structure determine the occurrence and magnitude of these impacts.

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by changes in ambient light conditions, alteration of the wave and current energy regime, and activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

Overwater structures can create shade, which reduces the light levels below the structure. The size, shape, and intensity of the shadow cast by a particular structure depends upon its height, width, construction materials, and orientation. High and narrow piers and docks produce narrower, more diffuse shadows than do low and wide structures. Increasing the numbers of pilings used to support a given pier enhances the shade pilings cast on the under-pier environment. In addition, less light is reflected underneath structures built with light-absorbing materials (e.g., wood) than under structures built with light-reflecting materials (e.g., concrete or steel). Structures that are oriented north-south produce a shadow that moves across the bottom throughout the day, resulting in a smaller area of permanent shade than those that are oriented east-west.

The shadow cast by an overwater structure affects both the plant and animal communities below the structure. Distributions of plants, invertebrates, and fishes appear severely limited in under-dock environments when compared to adjacent, unshaded, vegetated habitats. Light is the most important factor affecting aquatic plants. Under-pier light levels can fall below threshold amounts for the photosynthesis of diatoms, benthic algae, eelgrass, and associated epiphytes and other autotrophs. These photosynthesizers are an essential part of nearshore habitat and the estuarine and nearshore foodwebs that support many species of marine and estuarine fishes. Eelgrass and other macrophytes can be reduced or eliminated, even through partial shading of the substrate, and have little chance to recover.

Fishes rely on visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. The reduced-light conditions found under an overwater structure may limit the ability of fishes, especially juveniles and larvae, to perform these essential activities. Shading from overwater structures may also reduce prey organism abundance and the complexity of the habitat by reducing aquatic vegetation and phytoplankton abundance (Kahler et al. 2000, Haas et al. 2002). Glasby (1999) found that epibiotic assemblages on pier pilings at marinas subject to shading were markedly different than in surrounding areas. Other studies have shown shaded epibenthos to be reduced relative to that in open areas. These factors are thought to be responsible for the observed reductions in juvenile fish populations found under piers and the reduced growth and survival of fishes held in cages under piers, when compared to open habitats (Able et al. 1998, Duffy-Anderson and Able 1999).

The shadow cast by an overwater structure may increase predation on managed species of fish by creating a light/dark interface that allows ambush predators to remain in a darkened area (barely visible to prey) and watch for prey to swim by against a bright background (high visibility) (Helfman 1981). Prey species moving around the structure are unable to see predators in the dark area under the structure and are more susceptible to predation. Furthermore, the reduced vegetation (i.e., eelgrass) densities associated with overwater structures decrease the available refugia from predators.

Wave energy and water transport alterations from overwater structures can impact the nearshore detrital foodweb by altering the size, distribution, and abundance of substrate and detrital materials. Disruption of longshore transport can alter substrate composition and present potential barriers to the natural processes that build spits and beaches and provide substrates required for plant propagation, fish and shellfish settlement and rearing, and forage fish spawning.

Pilings can alter adjacent substrates with increased shell deposition from piling communities and changes to substrate bathymetry. Changes in substrate type can alter the nature of the flora and fauna native to a given site. In the case of pilings, native dominant communities typically associated with sand, gravel, mud, and eelgrass substrates are replaced by communities associated with shell hash substrates.

Treated wood used for pilings and docks releases contaminants into saltwater environs. PAHs are commonly released from creosote-treated wood. PAHs can cause a variety of deleterious effects (cancer, reproductive anomalies, immune dysfunction, and growth and development impairment) to exposed fish (Johnson et al. 1999, Johnson 2000, Stehr et al. 2000). Wood also is commonly treated with other chemicals such as ammoniacal copper zinc arsenate and chromated copper arsenate (Poston 2001). These preservatives are known to leach into marine waters for a relatively short time after installation, but the rate of leaching varies considerably, depending on many factors. Concrete and steel, on the other hand, are relatively inert and do not leach contaminants into the water.

Construction and maintenance of overwater structures often involve driving pilings and dredging navigation channels. Both activities may also adversely affect EFH.

While the effect of some individual overwater structures on EFH may be minimal, the overall impact may be substantial when considered cumulatively. The additive effects of these structures increase the overall magnitude of impact and reduce the ability of EFH to support native plant and animal communities.

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Use upland boat storage whenever possible to minimize need for overwater structures.
2. Locate overwater structures in deep enough waters to avoid intertidal and shade impacts, minimize or preclude dredging, minimize groundings, and avoid displacement of submerged aquatic vegetation, as determined by a preconstruction survey.
3. Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
4. Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, the following:
   a) Maximize the height of the structure, and minimize the width of the structure to decrease the shade footprint and using grated decking material.
   b) Use reflective materials (e.g., concrete or steel instead of materials that absorb light such as wood) on the underside of the dock to reflect ambient light.
   c) Use the fewest number of pilings necessary to support the structures to allow light into under-pier areas and minimize impacts to the substrate.
   d) Align piers, docks, and floats in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure and to reduce the duration of light limitation.
5. Use floating rather than fixed breakwaters whenever possible, and remove them during periods of low dock use. Encourage seasonal use of docks and off-season haul-out.

6. Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
7. Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
8. Conduct in-water work when managed species and prey species are least likely to be impacted.
9. To the extent practicable, avoid the use of treated wood timbers or pilings. If practicable, use alternative materials such as untreated wood, concrete, or steel.
10. Mitigate for unavoidable impacts to benthic habitats. Mitigation should be adequate, monitored, and adaptively managed.

Flood Control and Shoreline Protection

Protecting riverine and estuarine communities from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of existing shoreline and riparian habitat. The use of dikes and berms can also have long-term adverse effects on tidal marsh and estuarine habitats. Tidal marshes are highly variable, but typically have freshwater vegetation at the landward side, saltwater vegetation at the seaward side, and gradients of species inbetween that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through highly dendritic tidal creeks that empty into the bay or estuary. Freshwater entering along the upper edges of the marsh drains across the surface and enters the tidal creeks. Structures placed for coastal shoreline protection include, but are not limited to, concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), vegetative plantings, and sandbags.

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing freshwater flushing and annual flushing, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh proper intercept and carry away freshwater drainage, block freshwater from flowing across seaward portions of the marsh, increase the speed of runoff of freshwater to the bay or estuary, lower the water table, permit saltwater intrusion into the marsh proper, and create migration barriers for aquatic species. In deeper channels where reducing conditions prevail, large quantities of hydrogen sulfide are produced. These quantities are toxic to marsh grasses and other aquatic life. Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects on the tidal marsh include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, reduced invertebrate populations, and general loss of productive wetland characteristics. Loss of these low-salinity environments reduces estuarine fertility, restricts suitable habitat for aquatic species, and creates abnormally high salinity during drought years. Low-salinity environments form a barrier that prevents the entrance of many marine species, including competitors, predators, parasites, and pathogens.

Armoring of shorelines to prevent erosion and to maintain or create shoreline real estate simplifies habitats, reduces the amount of intertidal habitat, and affects nearshore processes and the ecology of numerous species (Williams and Thom 2001). Hydraulic effects on the shoreline include increased energy seaward of the armoring, reflected wave energy, dry beach narrowing, substrate coarsening, beach steepening, sediment storage capacity changes, organic debris loss, and down-drift sediment starvation (Williams and Thom 2001). Installation of breakwaters and jetties can result in community changes from burial or removal of resident biota, changes in cover and preferred prey species, and predator attraction (Williams and Thom 2001). As with armoring, breakwaters and jetties modify hydrology and nearshore sediment transport, as well as movement of larval forms of many species (Williams and Thom 2001).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Minimize the loss of riparian habitats as much as possible.
2 Do not undertake diking and draining of tidal marshlands and estuaries.
3. Wherever possible, use soft approaches (such as beach nourishment, vegetative plantings, and placement of LWD) to shoreline modifications.
4. Include efforts to preserve and enhance EFH by providing new gravel for spawning areas, removing barriers to natural fish passage, and using weirs, grade control structures, and low-flow channels to provide the proper depth and velocity for fish.
5. Construct a low-flow channel to facilitate fish passage and help maintain water temperature in reaches where water velocities require armoring of the riverbed.
6. Offset unavoidable impacts to in-stream fish habitat by providing rootwads, deflector logs, boulders, and rock weirs and by planting shaded riverine aquatic cover vegetation.
7. Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

Utility Lines, Cables, and Pipelines

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for water, sewage, etc. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. Many of the primary and direct impacts occur during the construction phase of installation, such as ground disturbance in the clearing of the right-of-way, access roads, and equipment staging areas. Indirect impacts can include increased turbidity, saltwater intrusion, accelerated erosion, and introduction of urban and industrial pollutants.

Adverse effects on EFH from the installation of pipelines, utility lines, and cables can occur through (1) destruction of organisms and habitat, (2) turbidity impacts, (3) resuspension of contaminants, and (4) changes in hydrology.

Destruction of organisms and habitats can occur in pipeline or cable right of way. This destruction can lead to long-term or permanent damage depending on the degree and type of habitat disturbance and the mitigation measures employed. Shallow-water environments, rocky reefs, nearshore and offshore rises, salt and freshwater marshes (wetlands), and estuaries are more likely to be adversely impacted than open-water habitats. This is due to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978).

Because vegetated coastal wetlands provide forage for and protection of commercially important invertebrates and fish, marsh degradation due to plant mortality, soil erosion, or submergence will eventually decrease productivity. Vegetation loss and reduced soil elevation within pipeline construction corridors should be expected with the continued use of current double-ditching techniques (Polasek 1997).

Increased water turbidity from higher than normal sediment loading can result in decreased primary production. Depending on the time of year of the construction, adverse impacts can occur, such as during highly productive spring phytoplankton blooms or times when organisms are already under stressed conditions. Changes in turbidity can temporarily alter phytoplankton communities. Depending upon the severity of the turbidity, these changes in water clarity can affect the EFH habitat functions of species higher in the food chain.

Another impact is resuspension of contaminants such as heavy metals and pesticides from the sediment, which can have lethal effects (Gowen 1978). Spills of petroleum products, solvents, and other construction-related material can also adversely affect habitat.

Pipeline canals have the potential to change the hydrology of coastal areas by (1) facilitating rapid drainage of interior marshes during low tides or low precipitation, (2) reducing or interrupting freshwater inflow and associated littoral sediments, and (3) allowing saltwater to move farther inland during periods of high tides (Chabreck 1972). Saltwater intrusion into freshwater marshes often causes loss of salt-intolerant emergent and submerged aquatic plants (Chabreck 1972, Pezeshki 1987), erosion, and net loss of soil organic matter (Craig et al. 1979).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Align crossings along the least environmentally damaging route. Avoid sensitive habitats such as hard-bottom (e.g., rocky reefs), cold-water corals, submerged aquatic vegetation, oyster reefs, emergent marsh, and mud flats. If impacts remain after all appropriate and practicable avoidance and minimization has been achieved, consider compensatory mitigation.
2. Use horizontal directional drilling where cables or pipelines would cross anadromous fish streams, salt marsh, vegetated inter-tidal zones, or steep erodible bluff areas adjacent to the inter-tidal zone to avoid surface disturbances.
3. Avoid construction of permanent access channels since they disrupt natural drainage patterns and destroy wetlands through excavation, filling, and bank erosion.
4. Store and contain excavated material on uplands. If storage in wetlands or waters cannot be avoided, use alternate stockpiles to allow continuation of sheet flow. Store stockpiled materials on construction cloth rather than bare marsh surfaces, sea grasses, or reefs.
5. Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation. Restore original marsh elevations. Stockpile topsoil and organic surface material such as root mats separately, and return it to the surface of the restored site. Use adequate material so that the proper preproject elevation is attained following settling and compaction of the material. If excavated materials are insufficient to accomplish this, use similar particle-size material to restore the trench to the required elevation. After backfilling, implement erosion protection measures where needed.
6. Use existing rights-of-way whenever possible to lessen overall encroachment and disturbance of wetlands.
7. Bury pipelines and submerged cables where possible. Unburied pipelines, or pipelines buried in areas where scouring or wave activity eventually exposes them, run a much greater risk of damage leading to leaks or spills.
8. Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass, etc.) or in areas that present no safety hazard. If allowed to remain in place, ensure that pipelines are properly pigged, purged, filled with seawater, and capped before abandonment in place.
9. Use silt curtains or other type barriers to reduce turbidity and sedimentation whenever possible near the project site.
10. Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles. Consider using mats and boards to avoid sensitive areas. Caution equipment

operators to avoid sensitive areas. Clearly mark sensitive areas to ensure that equipment operators do not traverse them.

11. Limit construction equipment to the minimum size necessary to complete the work. Use shallow-draft equipment to minimize effects and to eliminate the necessity for temporary access channels. Minimize the size of the pipeline trench proper. Use the push-ditch method, in which the trench is immediately backfilled. This reduces the impact duration, and it should, therefore, be used when possible.
12. Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
13. Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact. If transmission lines span streams, site towers at least 200 feet from streams.
14. For activities on the Continental Shelf, shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
15. For activities on the Continental Shelf, to the extent practicable, locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
16. For activities on the Continental Shelf, to avoid and minimize adverse impacts to managed species, implement the following to the extent practicable:
    a) Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor, whenever possible. Particular considerations (i.e., currents, ice scour) may require deeper burial or weighting to maintain adequate cover. Buried pipeline and cables should be examined periodically for maintenance of adequate earthen cover.
    b) Where burial is not possible, such as in hard-bottomed areas, attach pipelines and cables to substrate to minimize conflicts with fishing gear. Wherever possible, mark the route by using lighted buoys and/or lighted ranges on platforms to reduce the risk of damage to fishing gear and the pipelines.
    c) Locate alignments along routes that will minimize damage to marine and estuarine habitat. Avoid laying cable over high-relief bottom habitat and across live bottom habitats such as coral and sponge. If coral or sponge habitats are encountered, NMFS is interested in position and description information.
    d) Where user conflicts are likely, consult and coordinate with fishing stakeholder groups during the route-planning process to minimize conflict.

Urban/Suburban Development

Development activities within watersheds and in coastal marine areas often impact the EFH of managed species on both long- and short-term scales. The primary impacts include (1) the loss of riparian and shoreline habitat and vegetation and (2) runoff.

Shoreline stabilization projects can impede or accelerate natural movements of shoreline substrates, thereby affecting intertidal and sub-tidal habitats. Channelization of rivers causes loss of floodplain connectivity and simplification of habitat. The resulting sediment runoff can also restrict tidal flows and elevations.

Runoff from urban areas, such as construction sediments, oil from autos, bacteria from failing septic systems, road salts, and heavy metals. Urban areas have an insidious pollution potential that one-time events such as oil spills do not. Pollutant increases result in gradual declines in habitat quality.

Among contaminants that can enter watersheds, polycyclic aromatic hydrocarbons (PAHs) are among the most toxic to aquatic life and can persist for decades (Short et al. 2003). Waterborne PAH levels are often significantly higher in urbanized than non-urbanized watersheds (Fulton et al. 1993). Petroleum-based contaminants contain PAHs, which when released into the environment through spill, combustion and atmospheric deposition can cause acute toxicity to managed species and their prey, as some PAHs are known carcinogens and mutagens (Neff 1985).

Failing septic systems are an outgrowth of urban development. EPA estimates that 10 to 25 percent of all individual septic systems are failing at any one time, introducing excrement, detergents, chlorine and other chemicals into the environment. Even treated wastewater from urban areas can alter the physiology of intertidal organisms (Moles, A. and N. Hale 2003). Sewage discharge is a major source of coastal pollution, contributing 41, 16, 41, and 6 percent of the total pollutant load for nutrients, bacteria, oils, and toxic metals, respectively (Kennish 1998). Nutrients such as phosphorus concentrations, in particular, are indicative of urban stormwater runoff (Holler 1990). Sewage wastes may also contain significant amounts of organic matter that exert a biochemical oxygen demand (Kennish 1998). Organic contamination contained within urban runoff can also cause immuno suppression (Arkoosh et al. 2001, NMFS Draft 1998).

Recommended Conservation Measures

The recommended conservation measures for urban/suburban development are provided below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Implement Best Management Practices (BMPs) for sediment control during construction and maintenance operations (EPA 1993). These can include avoiding ground-disturbing activities during the wet season; minimizing exposure time of disturbed lands; using erosion prevention and sediment control methods; minimizing the spatial extent of vegetation disturbance; maintaining buffers of vegetation around wetlands, streams, and drainage ways; and avoiding building activities in areas with steep slopes and areas prone to mass wasting events with highly erodible soils. Use methods such as sediment ponds, sediment traps, bioswales, or other facilities designed to slow water runoff and trap sediment and nutrients.
2. Avoid using hard engineering structures for shoreline stabilization and channelization when possible. Use bioengineering approaches (i.e., applying vegetation approaches with principles of geomorphology, ecology, and hydrology) to protect shorelines and riverbanks. Naturally stable shorelines and river banks should not be altered.
3. Encourage comprehensive planning for watershed protection to avoid filling and building in floodplain areas affecting EFH. Development sites should be planned to minimize clearing and grading, cut-and-fill, and new impervious surfaces.
4. Where feasible, remove impervious surfaces such as abandoned parking lots and buildings from riparian and shoreline areas, and reestablish wetlands and native vegetation.
5. Protect and restore vegetated buffer zones of appropriate width along all streams, lakes, and wetlands that include or influence EFH.
6. Manage stormwater to duplicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
7. Where in-stream flows are insufficient to maintain water quality and quantity needed for EFH, establish conservation guidelines for water use permits and encourage the purchase or lease of water rights and the use of water to conserve or augment instream flows in accordance with state and federal water laws.
8. Encourage municipalities to use the best available technologies in upgrading their wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
9. Design and install proper on-site disposal systems. Locate them away from open waters, wetlands, and floodplains.

Fish Habitat Restoration and Enhancement

Habitat loss and degradation are major, long-term threats to the sustainability of fishery resources (NMFS 2002). Viable coastal and estuarine habitats are important to maintaining healthy fish stocks. Healthy habitats function to provide good water quality and quantity, appropriate substrate, ample food sources, erosion control, coastal infrastructure, and substantial hiding places needed to sustain fisheries. Restoration and/or enhancement of coastal and riverine habitat that supports managed fisheries and their prey will assist in sustaining and rebuilding fisheries stocks and recovering certain threatened or endangered species by increasing or improving ecological structure and functions. Habitat restoration/enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of historic hydrology, dam or berm removal, fish passage barrier removal/ modification, road-related sediment source reduction, natural or artificial reef/substrate/habitat creation, establishment or repair of riparian buffer zones, improvement of freshwater habitats that support anadromous fishes, planting of native coastal wetland and submerged aquatic vegetation, creation of oyster reefs, removal of marine debris, and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries. Additionally, restoration activities planned for the Arctic should also consider effects of climate change on the restoration activity, such as species composition.

The implementation of restoration/enhancement activities may have localized and temporary adverse impacts on EFH. Possible impacts can include (1) localized nonpoint source pollution such as influx of sediment or nutrients, (2) interference with spawning and migration periods, (3) temporary or permanent removal feeding opportunities, and (4) indirect effects from actual construction portions of the activity.

Unless proper precautions are taken, upland-related restoration projects can contribute to nonpoint source pollution. Such concerns should be addressed as part of the planning process. Particular in-water projects may interfere with spawning periods or impede migratory corridors and should be addressed accordingly. Projects may also have an affect on the feeding behavior of managed species. For instance, if dredging is involved, benthic food resources may be affected. Impacts can occur from individuals conducting the restoration, especially at staging areas; as part of accessing the restoration site; or due to the actual restoration techniques employed. Particular water quality impacts can derive from individuals conducting the restoration, excessive foot traffic, diving techniques, equipment handling, boat anchoring, and planting techniques.

Habitat restoration activities that include the removal of invasive species may cause minor disturbances of native species. For example, netting and trapping of invasive fish species may result in unwanted bycatch of native fish and other aquatic species. Fish passage restoration and other hydrologic restoration activities, such as the removal of culverts or other in-stream structures, installation of fishways, or other in-water activities will require temporary rerouting of flows around the project area. This could temporarily disturb on-site or adjacent habitats by altering hydrologic conditions and flows during project implementation.

Artificial reefs are sometimes used for habitat enhancement, but can have negative effects. Impacts of artificial reefs on EFH may include loss of habitat upon which the reef material is placed or the use of inappropriate, damaging materials for construction. Usually, reef materials are set upon flat sand bottoms or “biological deserts,” which end up burying or smothering bottom-dwelling organisms at the site or even preventing mobile forms (e.g., benthic-oriented fish species) from using the area as habitat. Some materials may be inappropriate for the marine environment (e.g., automobile tires or compressed incinerator ash) and can serve as sources of toxic releases or physical damage to existing habitat when breaking free of their anchoring systems (Collins et al. 1994).

Recommended Conservation Measures

The following recommended conservation measures should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

1. Minimize and avoid potential impacts to EFH during restoration activities to include, but are not limited to, the following:
    a. Use turbidity curtains, haybales, and erosion mats to protect the water column.
    b. Plan staging areas in advance, and keep them to a minimum size.
    c. Establish buffer areas around sensitive resources; flag and avoid rare plants, archeological sites, etc.
    d. Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species. Identify and implement measures to ensure native vegetation or revegetation success.
    e. Establish temporary access pathways before restoration activities to minimize adverse impacts from project implementation.
2. Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration. Determine these periods before project implementation to reduce or avoid any potential impacts.
3. Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site. Train volunteers in the use of low-impact techniques for planting, equipment handling, and any other activities associated with the restoration.
4. Monitoring address the restoration objective either directly or via a reasonable proxy (i.e re-vegetation performed as restoration for eroding stream banks may rely on the growth and survival of the planted species as a proxy for the function of water quality improvements)
5. Conduct monitoring before, during, and after project implementation to ensure compliance with project design and restoration criteria. If immediate post-construction monitoring reveals that unavoidable impacts to EFH have occurred, ensure that appropriate coordination with NMFS occurs to determine appropriate response measures, possibly including mitigation.
6. To the extent practicable, mitigate any unavoidable damage to EFH within a reasonable time after the impacts occur.
7. Remove and, if necessary, restore any temporary access pathways and staging areas used in the restoration effort.
8. Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible. Develop a sampling design with input from state and federal resource agencies. Before construction, evaluate of the impact resulting from the change in habitat (sand bottom to rocky reef, etc.). During post-construction monitoring, examine the effectiveness of the structures for increasing habitat productivity.

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APPENDIX E Supplemental Fish Habitat Descriptions.

This appendix contains additional information on habitat use of Arctic EEZ waters by other species of fish. Where information was available, maps of habitat for these species are attached to the following descriptions. This additional habitat information is provided to inform the Council and other entities that may consider actions that may affect Arctic marine habitat for fish species and to facilitate the ecosystems management approach for Arctic Management Area resources.

Habitat Description for Yellowfin Sole

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

Late Juveniles

Habitat 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

Habitat 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.

Habitat Description for Alaska Plaice

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

Late Juveniles

Habitat 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

Habitat 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).

Habitat 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 habitat for Eggs, Larvae, and Early Juveniles.

Late Juveniles

Habitat 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

Habitat 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.

Habitat Description for Starry Flounder

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

Late Juveniles

Habitat 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

Habitat 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.

Habitat Description for Capelin

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

Adults

Habitat 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.

Habitat Description for Rainbow Smelt

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

Adults

Habitat 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.

Habitat Description for Blue King Crab

Eggs

Habitat of the blue king crab eggs is inferred from the general distribution of egg-bearing female crab (see also Adults).

Larvae—No Habitat Description Determined
Insufficient information is available.

Early Juveniles—No Habitat Description Determined
Insufficient information is available.

Late Juveniles
Habitat 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
Habitat 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.

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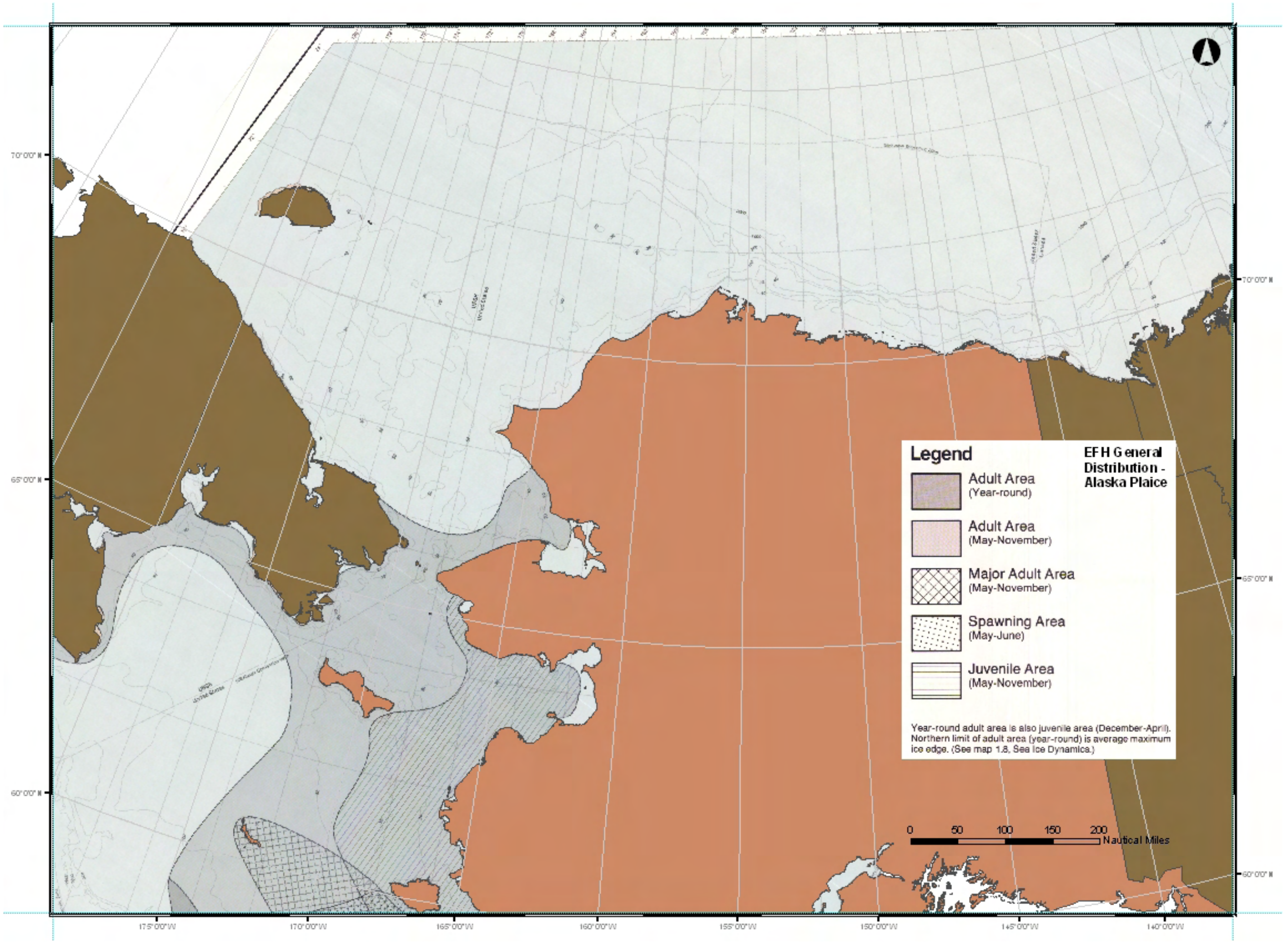
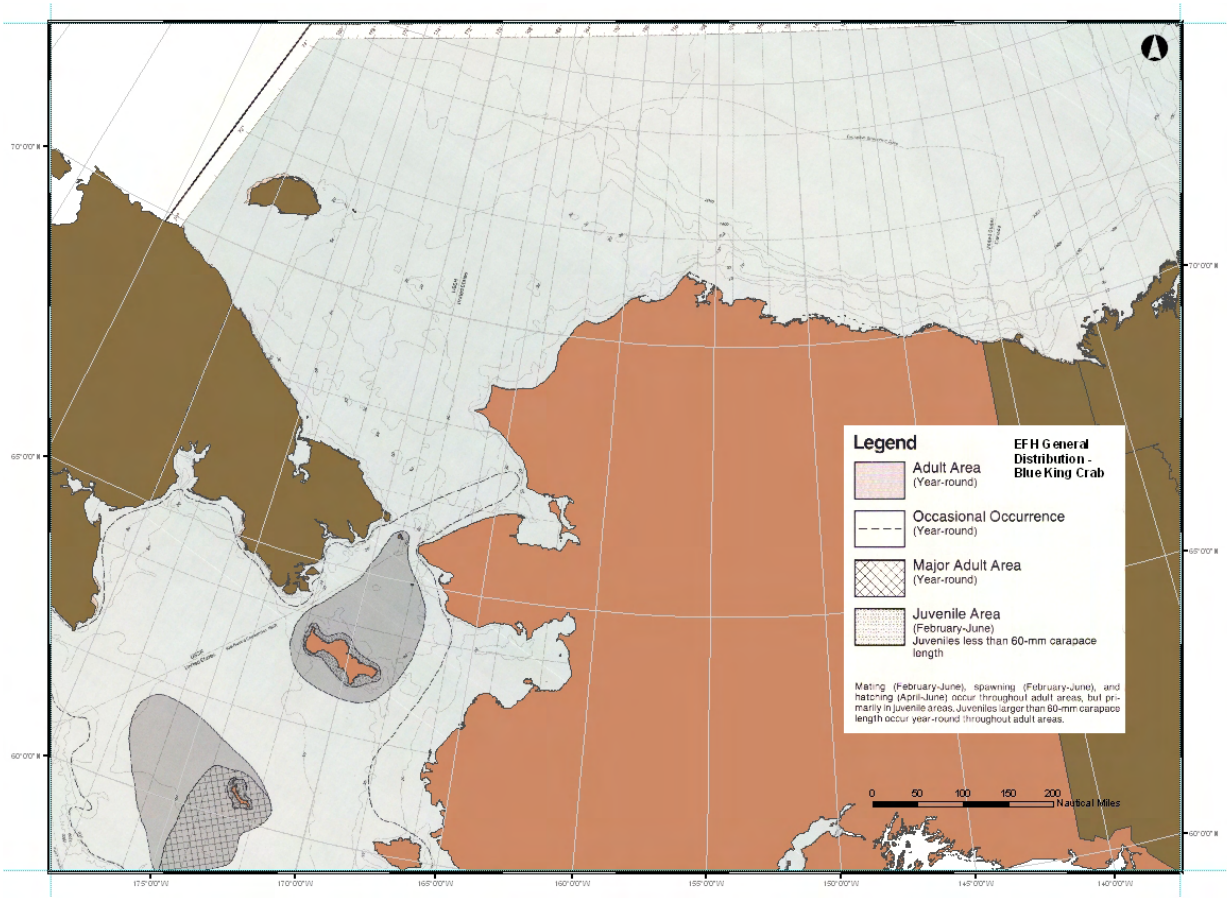
Supplemental Fish Habitat Maps

Map legend needs to have the term EFH removed.

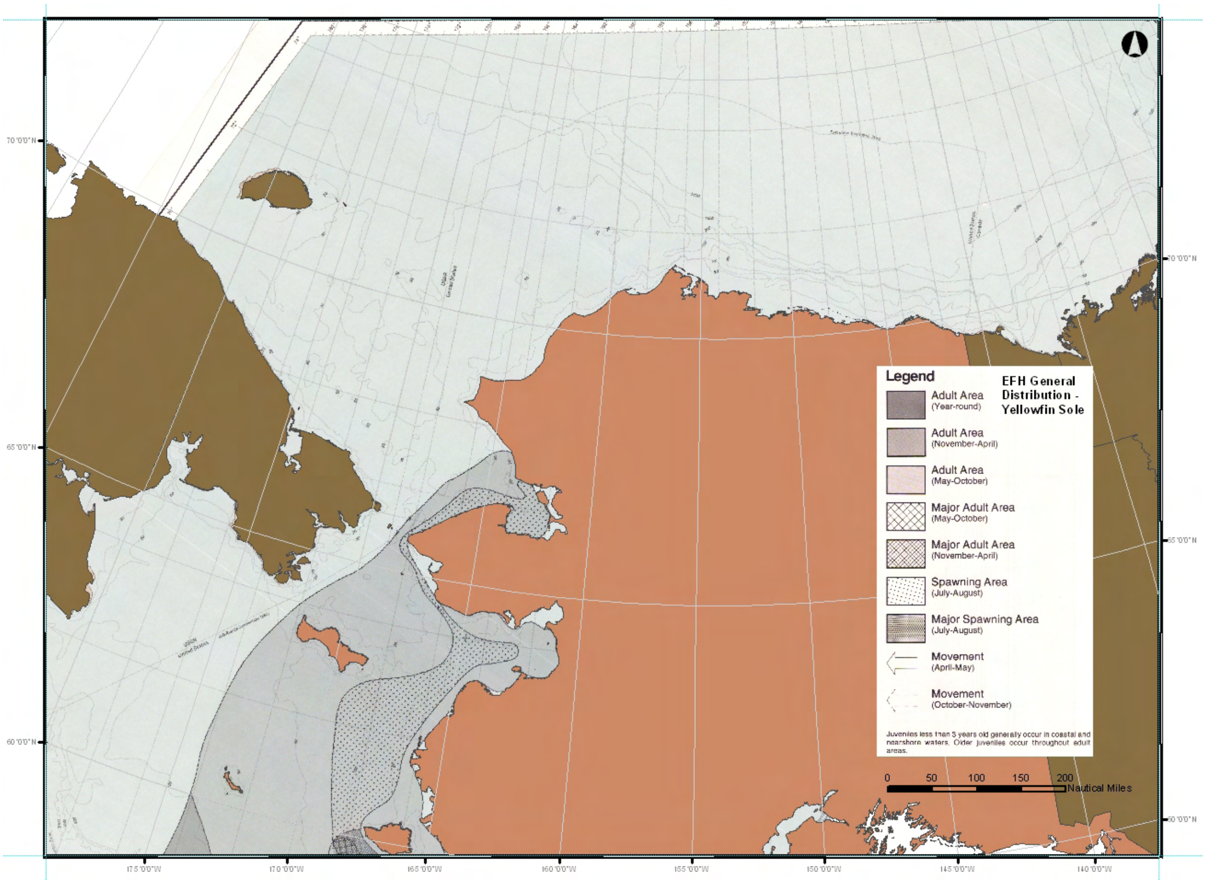
Alaska plaice habitat



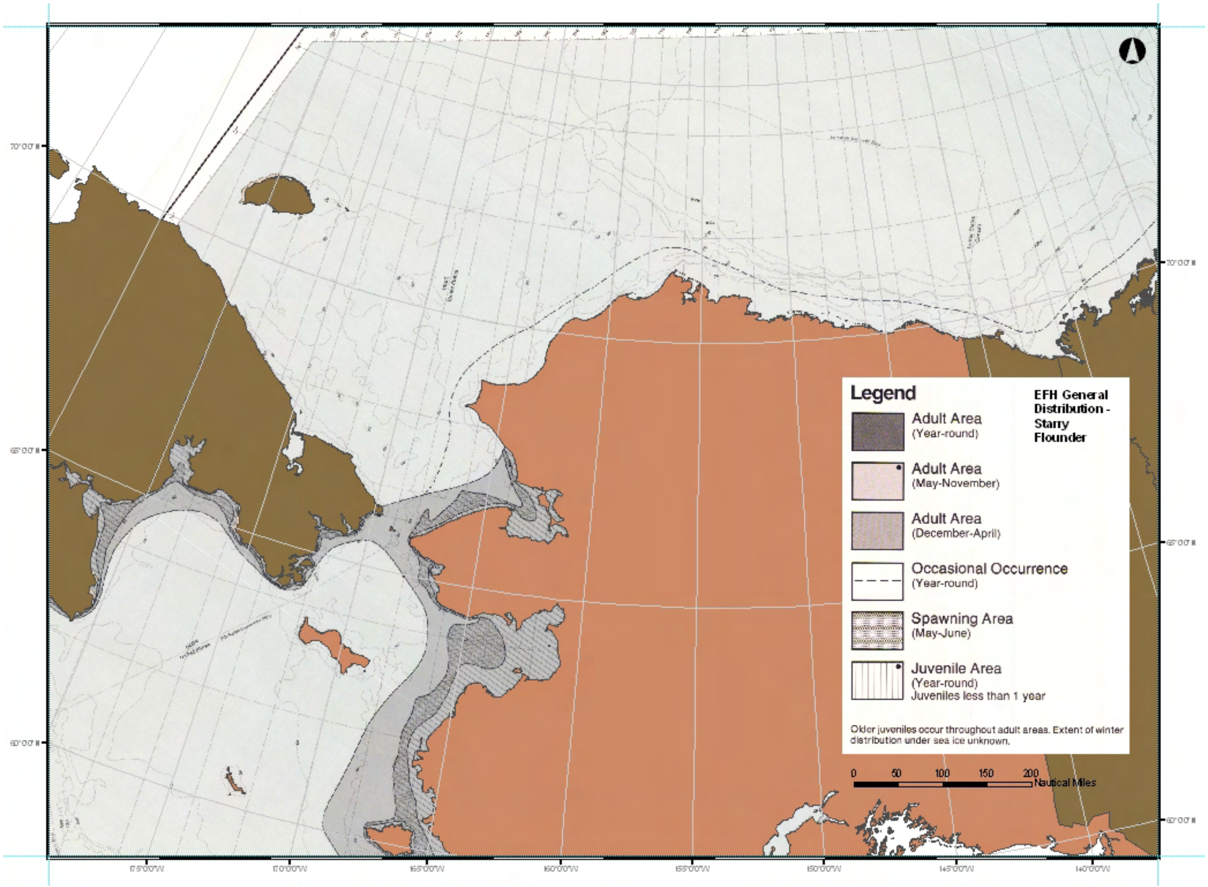
Blue king crab habitat



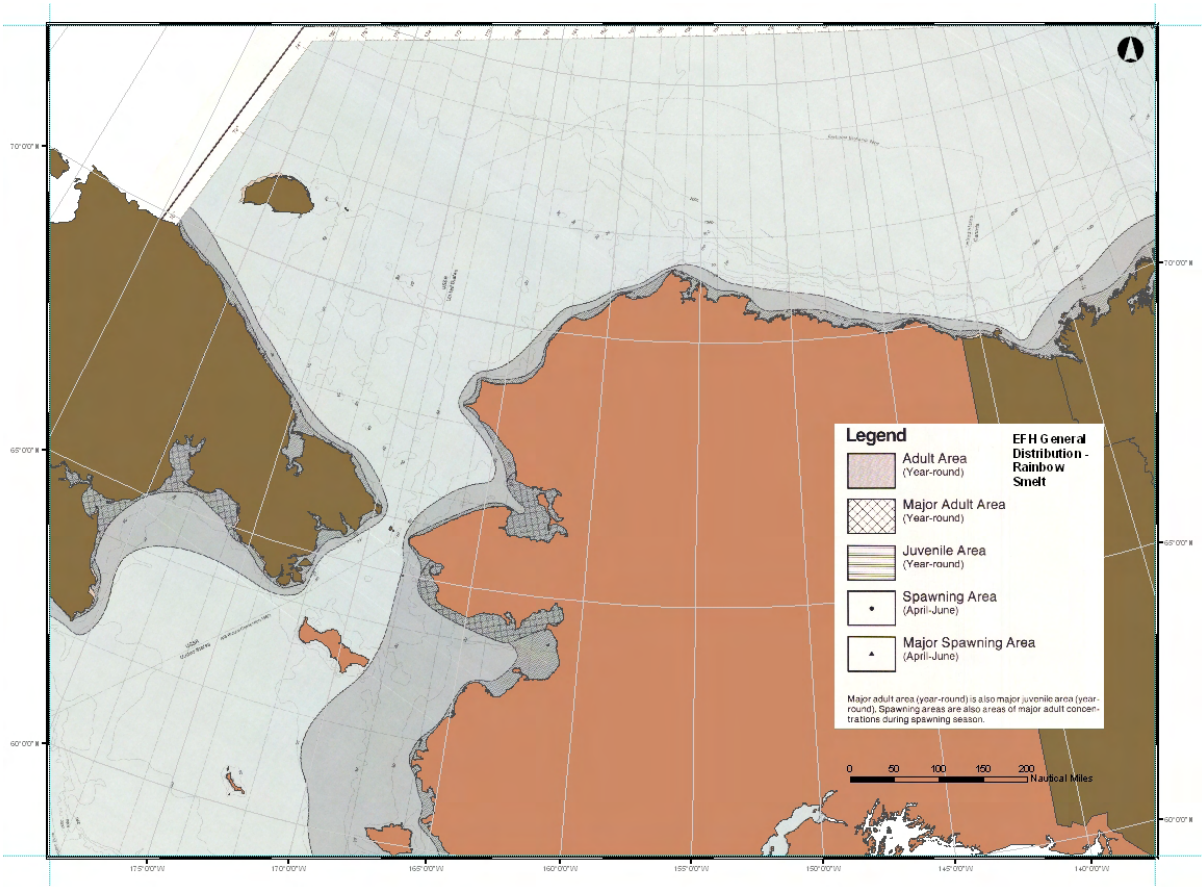
Yellowfin sole habitat



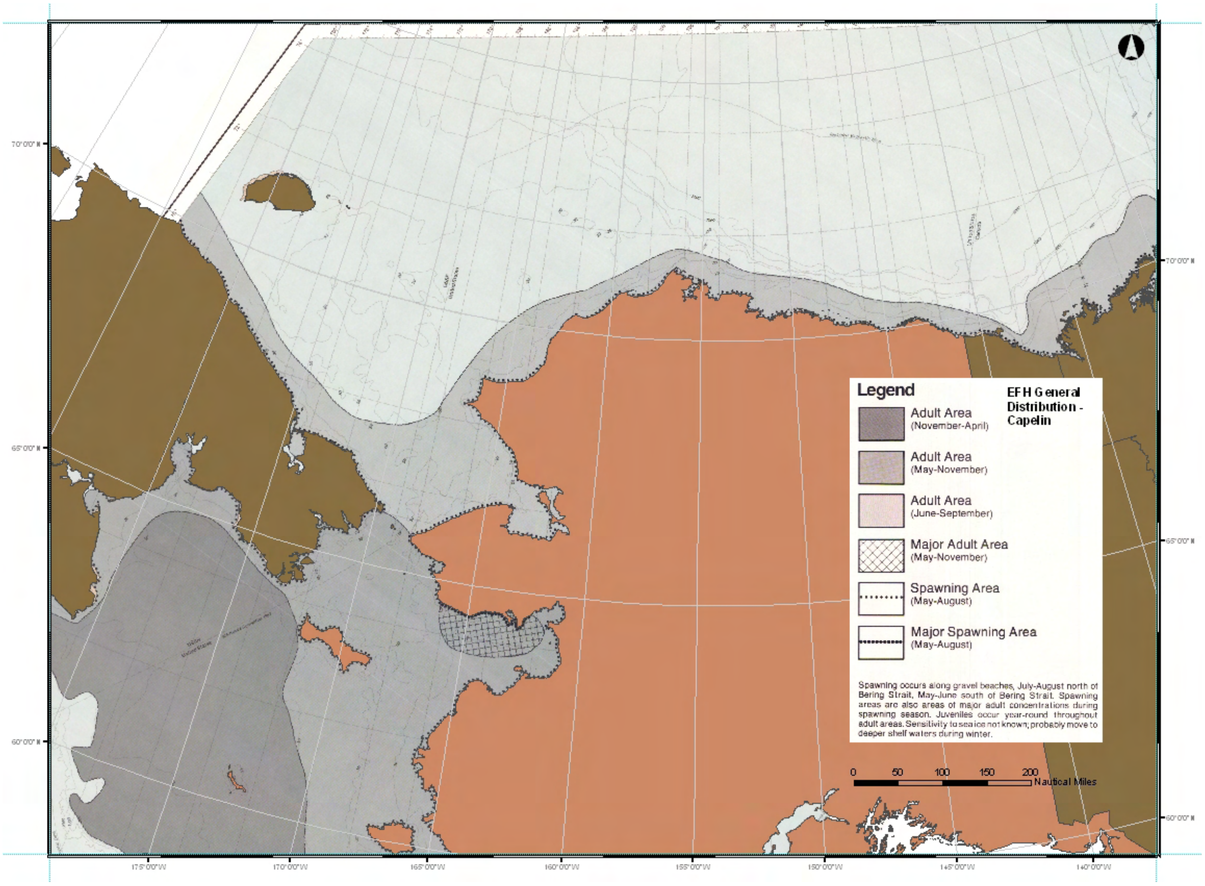
Starry flounder habitat



Rainbow smelt habitat

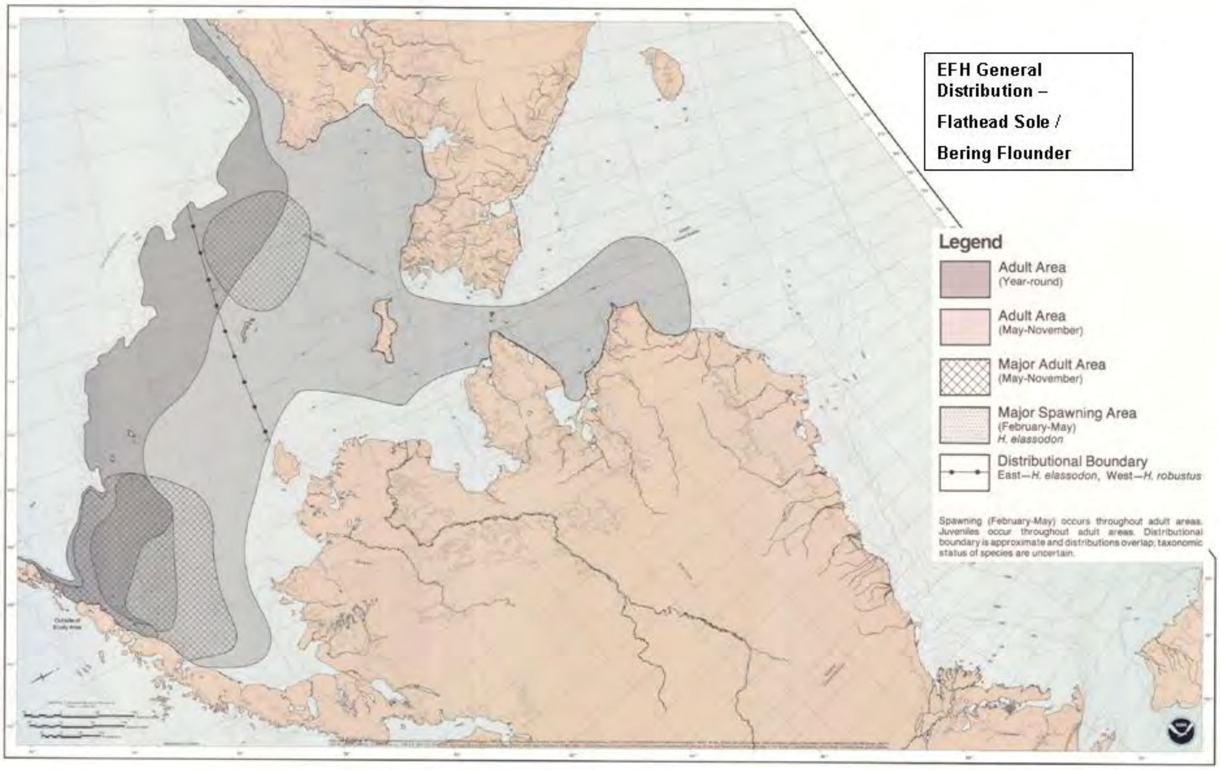


Capelin habitat



Spawning occurs along gravel beaches, July-August north of Bering Strait, May-June south of Bering Strait. Spawning areas are also areas of major adult concentrations during spawning season. Juveniles occur year-round throughout adult areas. Sensitivity to sea ice not known; probably move to deeper shelf waters during winter.

Flathead sole/Bering flounder habitat



Spawning (February-May) occurs throughout adult areas. Juveniles occur throughout adult areas. Distributional boundary is approximate and distributions overlap; taxonomic status of species are uncertain.