

## Crab FMP Amendment 40 - amendment text for updating EFH description and non-fishing impacts to EFH, changing HAPC timeline, and updating EFH research objectives (EFH Omnibus Amendment)

**1. In the Executive Summary, in the text box titled “Amendments to the BSAI King and Tanner Crab FMP”, delete “(proposed)” after Amendments 12 and 16, and insert the following description of Amendment 40 in sequential order:**

40. Revisions to essential fish habitat information (revised Amendment 16).

**2. In Section 8.1.6.2, Description of Habitat Areas of Particular Concern, insert the following two new paragraphs before the paragraph beginning “In 2005...”:**

Proposed HAPCs, 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 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council. The Council will establish a process to review the proposals. The Council may periodically review existing HAPCs for efficacy and considerations based on new scientific research.

**3. In Section 8.1.6.3, Conservation and Enhancement Recommendations for EFH and HAPC, revise the section content as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined):**

Appendix F identifies fishing and non-fishing threats to EFH. Conservation and enhancement recommendations for non-fishing threats to EFH and HAPCs are described therein.

In order to protect EFH from fishing threats, the Council established the following areas (maps of these areas, as well as their coordinates, are contained in Appendix F):

- Aleutian Islands Habitat Conservation Area
- Aleutian Islands Coral Habitat Protection Areas

~~Maps of these areas, as well as their coordinates, are contained in Appendix F. In addition, the Council established restrictions for these areas as described below. In order to minimize adverse effects of fishing, the Council established restrictions for the EFH conservation areas and HAPCs. These restrictions are described below.~~

### ***Aleutian Islands Habitat Conservation Area***

The use of nonpelagic trawl gear is prohibited year-round in the Aleutian Islands Habitat Conservation Area, except in designated areas; however, the use of trawl gear is prohibited in the king and Tanner crab fisheries (see Section 8.1.1).

### ***Aleutian Islands Coral Habitat Protection Areas***

The use of bottom contact gear, as described in 50 CFR part 679, and anchoring by federally permitted

fishing vessels is prohibited in the Aleutian Islands Coral Habitat Protection Areas.

~~In order to minimize adverse effects of fishing, the Council also established restrictions for HAPCs. These restrictions are described below.~~

#### ***Alaska Seamount Habitat Protection Areas***

The use of bottom contact gear and anchoring by a federally permitted fishing vessel, as described in 50 CFR part 679, is prohibited in the Alaska Seamount Habitat Protection Area. Anchoring by a federally permitted fishing vessel, as described in 50 CFR part 679, is also prohibited.

#### ***Bowers Ridge Habitat Conservation Zone***

The use of mobile bottom contact gear, as described in 50 CFR part 679, is prohibited in the Bowers Ridge Habitat Conservation Zone.

***4. In Section 8.1.6.4, Review of EFH and HAPC, revise the second paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined):***

~~Additionally, the Council may use the FMP amendment cycle every three years to solicit proposals for HAPCs and/or conservation and enhancement measures to minimize the potential adverse effects of fishing. Any proposal endorsed by the Council would be implemented by FMP amendment. HAPC proposals may be solicited every 5 years, coinciding with the EFH 5-year review, or may be initiated at any time by the Council.~~

***5. Delete Section 8.1.7, Habitat Areas of Particular Concern, in its entirety, and renumber Section 8.1.8, AFA Sideboard Restrictions, as Section 8.1.7.***

***6. In Appendix D, excise the existing heading and content of Appendix D.3, Essential Fish Habitat and Habitat Areas of Particular Concern. Insert the complete Section D.3 after Appendix E, and rename it as Appendix F. Rename existing Appendices F, G, and H sequentially as Appendices G, H, and I.***

***7. In the new Appendix F, Section 1.0, insert the following new paragraph at the end of the section:***

In 2009 and 2010, the Council undertook a 5-year review of EFH for the Council's managed species, which was documented in the Final EFH 5-year Review for 2010 Summary Report published in April 2010 (NPFMC and NMFS 2010). The review evaluated new information on EFH, including EFH descriptions and identification, and fishing and non-fishing activities that may adversely affect EFH. The review also assessed information gaps and research needs, and identified whether any revisions to EFH are needed or suggested. The Council identified various elements of the EFH descriptions meriting revision, and approved omnibus amendments 98/90/40/15/11 to the BSAI Groundfish FMP, the GOA Groundfish FMP, the BSAI King and Tanner Crab FMP, the Scallop FMP, and the Salmon FMP, respectively, in 2011. Amendment 40 to the BSAI King and Tanner Crab FMP revised the EFH descriptions for crab species; updated the description of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities; revised the timeline associated with the HAPC process to a 5-year timeline coinciding with the EFH 5-year review; and updated EFH research objectives in the FMP.

**8. In the new Appendix F, Section 2.0, revise the table references in the first paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined), and insert new Tables 1-3 directly afterward.**

This section describes habitat requirements and life histories of the crab species managed by this FMP. Information contained in this appendix details life history information for federally managed crab species. Each species or species group is described individually; however, summary tables that denote habitat associations (Table 12), biological associations ~~reproductive traits~~ (Table 23), and predator and prey associations (Table 34) are also provided. In each section, a species-specific table summarizes habitat requirements.



Table 2. Summary of biological associations for BSAI crab species.

BSAI Crab Species	Life Stage	Reproductive Traits																										
		Age at Maturity				Fertilization/Egg Development					Spawning Behavior					Spawning Season												
		Female		Male		External	Internal	Oviparous	Ovoviviparous	Viviparous	Batch Spawner	Broadcast Spawner	Egg Case Deposition	Nest Builder	Egg/Young Guarder	Egg/Young Bearer	January	February	March	April	May	June	July	August	September	October	November	December
		50%	100%	50%	100%																							
Blue King Crab	M	6+		6+		x		x							x	x	x	x	x	x	x	x						
	LJ																											
	EJ																											
	L																											
	E																											
Golden King Crab	M	6+		6+		x		x							x	x	x	x	x	x	x	x	x	x	x	x	x	
	LJ																											
	EJ																											
	L																											
	E																											
Red King Crab	M	7 to 8		7 to 10		x		x							x	x	x	x	x	x	x	x						
	LJ																											
	EJ																											
	L																											
	E																											
Snow Crab	M	5 to 6		6 to 8		x	x	x							x	x	x	x	x	x	x							
	LJ																											
	EJ																											
	L																											
	E																											
Tanner Crab	M	6 to 8		6 to 8		x	x	x							x	x	x	x	x	x	x							
	LJ																											
	EJ																											
	L																											
	E																											



**9. In the new Appendix F, Section 2.2, delete the sentence that immediately precedes Table 1, “The following abbreviations are used in the habitat tables to specify location, position in the water column, bottom type, and other oceanographic features.”**

**10. In the new Appendix F, Section 2.1, delete existing Tables 1, 2, 3, and 4, including captions.**

**11. In the new Appendix F, delete existing Sections 2.3 through 2.10, and replace with revised Sections 2.3 through 2.7 in the attached file.**

**12. In the new Appendix F, Section 3.0, make the following edits to the existing second and third paragraphs (note, delete text indicated with ~~strikeout~~, insert text that is underlined), and insert a new fourth paragraph:**

EFH is determined to be the general distribution of a species described by life stage. General distribution is a subset of a species’ total population distribution, and is identified as the distribution of 95 percent of the species population, for a particular life stage, if life history data are available for the species. Where information is insufficient and a suitable proxy cannot be inferred, EFH is not described. General distribution is used to describe EFH for all stock conditions whether or not higher levels of information exist, because the available higher level data are not sufficiently comprehensive to account for changes in stock distribution (and thus habitat use) over time.

EFH is described for FMP-managed species by life stage as general distribution using ~~new~~ guidance from the EFH Final Rule (67 FR 2343), ~~such as~~ including the ~~updated~~ EFH Level of Information definitions. Analytical tools are used and recent scientific information is incorporated for each life history stage from updated scientific habitat assessment reports. EFH descriptions include both text (see section 3.1) and maps (see section 3.2), if information is available for a species’ particular life stage. ~~These descriptions are risk averse, supported by scientific rationale, and accounts for changing oceanographic conditions, regime shifts, and the seasonality of migrating crabs. The methodology and data sources for the EFH descriptions are described in Appendix D to the EFH EIS (NMFS 2005).~~

EFH descriptions are interpretations of the best scientific information. In support of this information, a thorough review of FMP species is contained in the Environmental Impact Statement for Essential Fish Habitat Identification and Conservation (NMFS 2005) (EFH EIS) is contained in Section 3.2.1, Biology, Habitat Usage, and Status of Magnuson-Stevens Act Managed Species and detailed by life history stage in Appendix F: EFH Habitat Assessment Reports. This EIS was supplemented in 2010 by a 5-year review, which re-evaluated EFH descriptions and fishing and non-fishing impacts on EFH in light of new information (NPFMC and NMFS 2010). The EFH descriptions are risk averse, supported by scientific rationale, and account for changing oceanographic conditions and regime shifts.

**13. In the new Appendix F, Section 3.3.5 HAPC Process, revise the existing final two paragraphs, as follows (note, deletions are indicated with ~~strikeout~~, insertions are indicated with underline):**

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~~ 5 years, to coincide with the EFH 5-year review, or may be initiated at any time by the Council. The Council will establish a process to review the proposals. 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 (NPFMC 2005).~~

**14. In the new Appendix F, Section 4.0, Effects of Fishing on Essential Fish Habitat, insert the following new paragraph at the end of the section:**

The evaluation of fishing effects on EFH for BSAI crab species was reconsidered as part of the Council's EFH 5-year Review for 2010, and is documented in the Final Summary Report for that review (NPFMC and NMFS 2010). The review evaluated new information since the development of the EFH EIS, for individual species and their habitat needs, as well as the distribution of fishing intensity, spatial habitat classifications, classification of habitat features, habitat- and feature-specific recovery rates, and gear- and habitat-specific sensitivity of habitat features. Based on the review, the Council concluded that recent research results are consistent with the habitat sensitivity and recovery parameters and distributions of habitat types used in the analysis of fishing effects documented in the EFH EIS. The review noted that fishing intensity has decreased overall, gear regulations have been designated to reduce habitat damage, and area closures have limited the expansion of effort into areas of concern.

**15. In the new Appendix F, Section 4.4.2 Blue King Crab, revise the existing paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined).**

Summary of Effects—Fishing activity effects are unknown or ~~ies~~ are considered to have overall minimal and temporary effects on the EFH for blue king crab, although ~~both~~ the Pribilof Islands stock is below MSST and the St. Matthew stock of blue king crabs has just recovered to  $B_{MSY}$  ~~are considered to be below MSST~~. It is unknown if ~~h~~Habitat loss or degradation by fishing activities had probably did not play any role in the decline of these stocks. For the Pribilof Islands blue king crab, any fishing activities thought to have adverse consequences on habitat have previously been mitigated by establishment of the Pribilof Islands trawl closure area. For St. Matthew blue king crab, there has never been a groundfish bottom trawl fishery in the area. Given the current very small overlap and fishing intensity in areas with blue king crab of all life stages, professional judgement indicates that fisheries do not currently adversely affect the EFH of blue king crab.

**16. In the new Appendix F, Section 4.4.5 Tanner Crab, revise the existing paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined).**

Summary of Effects—Fishing activities are considered to have ~~overall~~ minimal and temporary effects on the EFH for Tanner crabs. Tanner crab settle and grow on mud habitat, which was the least affected habitat in the EBS. This analysis of the spatial distribution of Tanner crabs relative to expected habitat impacts indicates that Tanner crabs have not demonstrated shifts away from regions heavily impacted by fishing. ~~The closure of the Bristol Bay region and its associated reduction in habitat impacts did not attract crabs to the region.~~ The effects of fishing activities on Tanner crab feeding activities is minimal.

**17. In the new Appendix F, delete Section 4.4.4 Scarlet King Crab and Section 4.4.7 Deepwater Tanner Crabs, and renumber all subsections in Section 4.4 accordingly.**

**18. In the new Appendix F, delete existing text in Section 5.0 Non-fishing Impacts, and replace with the revised Section 5.0 in the attached file.**

**19. In the new Appendix F, Section 7.0 Research Approach for EFH, revise the first paragraph as follows (note, delete text indicated with ~~strikeout~~, insert text that is underlined):**

The EFH EIS (NMFS 2005) identified a the following research approach for EFH regarding minimizing fishing impacts. The research approach was revised in 2010 following the Council's EFH 5-year Review for 2010, documented in a Final Summary Report (NPFMC and NMFS 2010).



**20. In the new Appendix F, Section 7.0 Research Approach for EFH, delete existing text under the heading “Objectives” and replace with the following:**

Establish a scientific research and monitoring program to understand the degree to which impacts have been reduced within habitat closure areas, and to understand how benthic habitat recovery of key species is occurring.

**21. In the new Appendix F, Section 7.0 Research Approach for EFH, delete existing text under the heading “Research Activities” and replace with the following:**

- Fishing effort data from observers and remote sensing would be used to study changes in bottom trawl and other fishing gear activity in the closed (and open) areas. Effects of displaced fishing effort would have to be considered. The basis of comparison would be changes in the structure and function of benthic communities and populations, as well as important physical features of the seabed, after comparable harvests of target species are taken with each gear type.
- Monitor the structure and function of benthic communities and populations in the newly closed areas, as well as important physical features of the seabed, for changes that may indicate recovery of benthic habitat. Whether these changes constitute recovery from fishing or just natural variability/shifts requires comparison with an area that is undisturbed by fishing and otherwise comparable.
- Validate the LEI model and improve estimates of recovery rates, particularly for the more sensitive habitats, including coral and sponge habitats in the Aleutian Islands region, possibly addressed through comparisons of benthic communities in trawled and untrawled areas.
- Obtain high resolution mapping of benthic habitats, particularly in the on-shelf regions of the Aleutian Islands.
- Time series of maturity at age should be collected to facilitate the assessment of whether habitat conditions are suitable for growth to maturity.
- In the case of red king crab spawning habitat in southern Bristol Bay, research the current impacts of trawling on habitat in spawning areas and the relationship of female crab distribution with respect to bottom temperature.

**22. In the new Appendix F, Section 8.0, insert the following reference alphabetically.**

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>

**23. Update the Table of Contents at the beginning of the new Appendix F.**

**24. In the new Appendix H, Literature Cited, insert the following reference alphabetically.**

NPFMC and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://www.alaskafisheries.noaa.gov/habitat/efh/review.htm>

**25. Update the Table of Contents for the FMP.**

## 2.3 Red king crab (*Paralithodes camtschaticus*)

### 2.3.1 Life History and General Distribution

Red king crab (*Paralithodes camtschaticus*) is widely distributed throughout the Bering Sea and Aleutian Islands, Gulf of Alaska, Sea of Okhotsk, and along the Kamchatka shelf. Red king crab are typically at depths less than 100 fathoms. King crab molt multiple times per year through age 3 after which molting is annual. At larger sizes, king crab may skip molt as growth slows. Females grow slower and do not get as large as males. In Bristol Bay, 50 percent maturity is attained by males at 12 cm carapace length (CL) and 9 cm CL by females (about 7 years). Female red king crab in the Norton Sound area reach 50 percent maturity at 6.8 cm and do not attain maximum sizes found in other areas. Size at 50 percent maturity for females in the western Aleutians is 8.9 cm CL. Natural mortality of adult red king crab is assumed to be about 16.5 percent per year ( $M=0.18$ ), due to old age, disease, and predation.

The size at 50 percent maturity is 7 and 9 cm CL for female and male red king crabs, respectively, from Norton Sound and St. Matthew and St. Lawrence Islands; it is 9 and 12 cm, respectively, for Bristol Bay and the Pribilof and Aleutian Islands.

### 2.3.2 Fishery

The red king crab fisheries are prosecuted using mesh covered pots (generally 7 or 8 feet square) set on single lines. Mean age at recruitment is about 8 to 9 years. Two discrete populations of red king crab are actively fished in the Bering Sea and Aleutian Islands region: Bristol Bay and Norton Sound. A third population surrounding the Aleutian Islands was managed separately as Adak and Dutch Harbor stocks until 1996 when the management areas were combined. The fishery on the Adak stock was closed in 1996, and the fishery on the Dutch Harbor stock has closed since the 1983/1984 season. These fisheries historically occurred in the winter and spring. Red king crab are allowed as bycatch during golden king crab fisheries in those areas. Other populations of red king crab are fished in the Pribilof Islands area, St. Matthew Island area, and St. Lawrence Island area, but are managed in conjunction with the predominant blue king crab fisheries. Red king crab stocks are managed separately to accommodate different life histories and fishery characteristics. Only male red king crab greater than 16.5 cm CL are allowed to be taken from Bristol Bay and the Pribilof and Aleutian Islands. The minimum size limit for harvest of male crab from the Norton Sound and the St. Matthew and St. Lawrence Islands population is 12 cm. Since the individual fishing quota fishery in 2005, the season in Bristol Bay begins on November 1 and can last for 3 months. Bycatch in red king crab fisheries consists primarily of Tanner crab and nonlegal red king crab. The commercial fishery for red king crab in Norton Sound occurs in the summer, opening in late June, and a winter through-the-ice fishery opens November 15 and closes May 15.

Bottom trawls and dredges could disrupt nursery and adult feeding areas.

### 2.3.3 Relevant Trophic Information

Pacific cod is the main predator on red king crabs. Walleye pollock, yellowfin sole, and Pacific halibut are minor consumers of pelagic larvae, settling larvae, and larger crabs, respectively. Juvenile crab may be cannibalistic during molting.

### 2.3.4 Habitat and Biological Associations

Egg: Egg hatch of larvae is synchronized with the spring phytoplankton bloom in southeast Alaska suggesting temporal sensitivity in the transition from benthic to planktonic habitat. Also see mature phase description; eggs are carried by adult female crab.

*Larvae:* Red king crab larvae spend 2 to 3 months in pelagic larval stages before settling to the benthic life stage. Reverse diel migration and feeding patterns of larvae coincide with the distribution of food sources.

*Early Juvenile:* Early juvenile stage red king crabs are solitary and need high relief habitat or coarse substrate such as boulders, cobble, shell hash, and living substrates such as bryozoans and stalked ascidians. Young-of-the-year crabs occur at depths of 50 m or less.

*Late Juvenile:* Late juvenile stage red king crabs ages 2 to 4 years exhibit decreasing reliance on habitat and a tendency for the crab to form pods consisting of thousands of crabs. Late juvenile crab associate with deeper waters and migrate to shallower water for molting and mating in the spring. Aggregation behavior continues into adulthood.

*Mature:* Mature red king crabs exhibit seasonal migration to shallow waters for reproduction. The remainder of the year, red king crabs are found in deeper waters. In Bristol Bay, red king crabs mate when they enter shallower waters (less than 50 m), generally beginning in January and continuing through June. Males grasp females just prior to female molting, after which the eggs (43,000 to 500,000 eggs) are fertilized and extruded on the female's abdomen. The female red king crab carries the eggs for 11 months before they hatch, generally in April.

**Habitat and Biological Associations: Red king crab**

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	11 mo.	N/A	May–April	N/A	N/A	N/A	fronts	
Larvae	3–5 mo.	diatoms, phytoplankton, copepod nauplii	April–August	inner and middle continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	1 to 5–6 yrs	diatoms, hydroids	all year	inner and middle continental shelf (1–100 m), nearshore bays, beach (intertidal)	demersal	subaquatic vegetation (epifauna), rock, cobble, gravel	fronts	found among biogenic assemblages (sea onions, tube worms, bryozoans, ascidians, sea stars)
Adults	5–6+ yrs	mollusks, echinoderms, polychaetes, decapod, crustaceans, algae, urchins, hydroids, sea stars	spawning Jan–June	inner and middle continental shelf (1–100 m), nearshore bays, beach (intertidal)	demersal	sand, mud, cobble, gravel	fronts	

N/A = not applicable

**2.3.5 Literature**

Foy, R.J. 2011. Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Red King Crab Fisheries of the Bering Sea and Aleutian Islands Region. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4<sup>th</sup> Ave, Suite 306, Anchorage, AK 99501.

Zheng, J. and M.S.M. Siddeek. 2011. Bristol Bay Red King Crab Stock Assessment in Spring 2011. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4<sup>th</sup> Ave, Suite 306, Anchorage, AK 99501.

## 2.4 Blue king crab (*Paralithodes platypus*)

### 2.4.1 Life History and General Distribution

Blue king crab (*Paralithodes platypus*) has a discontinuous distribution throughout its range (Hokkaido, Japan, to Southeast Alaska). In the Bering Sea, discrete populations exist in the cooler waters around the Pribilof Islands, St. Matthew Island, and St. Lawrence Island. Smaller populations have been found in Herendeen Bay and around Nunivak and King Island, as well as isolated populations in the Gulf of Alaska. Blue king crab molt multiple times as juveniles. In the Pribilof Islands area, 50 percent maturity of females is attained at 9.6 cm CL, which occurs at about 5 years of age. Blue king crab in the St. Matthew Island area mature at smaller sizes (50 percent maturity at 8.1 cm CL for females) and do not get as large overall. Skip molting occurs with increasing probability for those males larger than 10 cm CL and is more prevalent for St. Matthew Island crab. Larger female blue king crab have a biennial ovarian cycle and a 14-month embryonic period. Unlike red king crab, juvenile blue king crab do not form pods, instead they rely on cryptic coloration for protection from predators. Adult male blue king crab occur at an average depth of 70 m and an average temperature of 0.6 °C.

The size at 50 percent maturity is 9 cm and 12 cm CL for female and male crabs from the Pribilof Islands, and 8 cm and 10.5 cm CL for St. Matthew Island.

### 2.4.2 Fishery

The blue king crab fisheries are prosecuted using mesh covered pots (generally 7 or 8 feet square) set on single lines. Two discrete stocks of blue king crab are fished: the Pribilof Islands and the St. Matthew Island stocks. These blue king crab fisheries occurred in September in past years. Bycatch in the blue king crab fisheries consists almost entirely of non-legal blue king crabs. Only male crabs greater than 16.5 cm carapace width (CW) are harvested in the Pribilof Islands, while the St. Matthew Island fishery is managed with a minimum size limit of 140 mm.

Bottom trawls and dredges could disrupt nursery and adult feeding areas.

### 2.4.3 Relevant Trophic Information

Pacific cod is a predator on blue king crabs.

### 2.4.4 Habitat and Biological Associations

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Blue king crab larvae spend 3.5 to 4 months in pelagic larval stages before settling to the benthic life stage. Larvae are found in waters between 40 and 60 m deep.

Early Juvenile: Early juvenile blue king crabs require substrate characterized by gravel and cobble overlaid with shell hash and sponge, hydroid, and barnacle assemblages. These habitat areas have been found at 40 to 60 m around the Pribilof Islands.

Late Juvenile: Late juvenile blue king crabs are found in nearshore rocky habitat with shell hash.

**Mature:** Mature blue king crabs occur most often between 45 and 75 m deep on mud-sand substrate adjacent to gravel rocky bottom. Female crabs are found in a habitat with a high percentage of shell hash. Mating occurs in mid-spring. Larger older females reproduce biennially, while small females tend to reproduce annually. Fecundity of females ranges from 50,000 to 200,000 eggs per female. It has been suggested that spawning may depend on the availability of nearshore rocky-cobble substrate for protection of females. Larger older crabs disperse farther offshore and are thought to migrate inshore for molting and mating.

**Habitat and Biological Associations: Blue king crab**

Stage - EFH Level	Duration or Age	Diet/ Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	14 mo.	N/A	starting April–May	N/A	N/A	N/A	fronts	
Larvae	3.5 to 4 mo.	U	April–July	middle and inner continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	to about 5 years	U	all year	middle and inner continental shelf (1–100 m)	demersal	cobble, gravel, rock	fronts	
Adults	5+ years	U	spawning Feb–Jun	middle and inner continental shelf (1–100 m)	demersal	sand, mud, cobble, gravel, rock	fronts	

N/A = not applicable

**2.4.5 Literature**

R.J. 2011. Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Region. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4<sup>th</sup> Ave, Suite 306, Anchorage, AK 99501.

Gaeuman, W. 2011. 2011 Saint Matthew Island Blue King Crab Stock Assessment. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4<sup>th</sup> Ave, Suite 306, Anchorage, AK 99501.

**2.5 Golden king crab (*Lithodes aequispina*)**

**2.5.1 Life History and General Distribution**

Golden king crab (*Lithodes aequispina*), also called brown king crab, range from Japan to British Columbia (NMFS 2004). In the Bering Sea and Aleutian Islands, golden king crab are found primarily at depths from 200 to 1,000 m (Somerton and Otto 1986), generally in high relief habitat such as inter-island passes, and they are usually slope-dwelling (NMFS 2004). Size at sexual maturity of males has been estimated to be 13.0 cm CL in the eastern Bering Sea south of 54°14' N. latitude, 10.9 cm CL in the Bowers Ridge area, and 12.1 cm CL in the Seguam Pass area (Otto and Cummiskey 1985). Size at sexual maturity of females has been estimated to be 11.1 cm CL in the eastern Bering Sea south of 54°14' N. latitude, 10.6 cm CL in the Bowers Ridge area, and 11.3 cm CL in the Seguam Pass area (Otto and Cummiskey 1985). Females carry an average of approximately 10,000 eggs (Shirley 2006), although they may carry up to 27,000 eggs (Jewett et al. 1985), depending on their size. Females carry and incubate eggs approximately 12 months prior to hatching, but time between production of successive clutches is approximately 590 days due to a prolonged period between hatching of the clutch and molting by the female (Shirley 2006). Reproduction is asynchronous and aseasonal (Adams and Paul 1999, Somerton

and Otto 1985) as is the molting cycle (McBride et al. 1982, Otto and Cummiskey 1985, Sloan 1985, Blau and Pengilly 1994, Paul and Paul 2000).

### 2.5.2 Fishery

The golden king crab fisheries are prosecuted using mesh covered pots set on longlines to minimize gear loss. The primary fishery is in the Aleutian Islands, with minor catches coming from localized areas in the Bering Sea and Gulf of Alaska. The golden king crabs in the Aleutian Islands in the areas east and west of 174° W. longitude are managed as two separate stocks. The commercial fishing season for golden king crabs in the Aleutian Islands Area is August 15 through May 15, and male crabs greater than 15.2 cm CW are harvested. Bycatch in the commercial golden king crab fishery consists almost exclusively of non-legal golden king crab. Escape mechanisms were adopted into regulation by the Alaska Board of Fisheries in 1996 to reduce capture and handling mortality of non-target crab; a minimum of four 5.5-inch rings or at least one-third of one vertical pot surface composed of not less than 9-inch stretched webbing are required on pots used in golden king crab fisheries. Commercial fishing for golden king crabs in the Aleutian Islands Area typically occurs at depths of 183 to 549 m (Barnard and Burt 2007).

### 2.5.3 Relevant Trophic Information

Unknown

### 2.5.4 Habitat and Biological Associations

Golden king crabs occur on hard bottom, over steep rocky slopes, and on narrow ledges. Strong currents are prevalent. Golden king crabs coexist with abundant quantities of epifauna: sponges, hydroids, coral, sea stars, bryozoans, and brittle stars.

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Larvae are lecithotrophic and therefore do not require diel vertical migrations for feeding in shallow waters (Shirley and Zhou 1997). Depth distribution is unknown but is suspected to be deep and larvae are suspected to be more benthic than planktonic (Shirley and Zhou 1997). Larval period is relatively short (approximately 25 days), followed by a glaucothoe stage that lasts approximately 41 days before settlement (Shirley and Zhou 1997).

Early Juvenile: Information is not available, but apparently settle in deep water, given observations that juveniles become more abundant with increasing depth (Shirley 2006).

Late Juvenile: Late juvenile golden king crabs are found throughout the depth range of the species. Abundance of late juvenile crab increases with depth; in a 1991 pot survey in the Aleutian Islands juvenile crabs were most abundant at the deepest depths fished (548 to 913 m; Blau et al. 1996).

Mature: Large (legal) male crabs are at highest densities between 274 and 639 m whereas adult females are at highest densities between 274 and 456 m; large males and adult females are absent or at low densities greater than 730 m (Blau et al. 1996).

### Habitat and Biological Associations: Golden king crab

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs		N/A		N/A	N/A	N/A		
Larvae	2 months	U	varies	U	demersal, semi-demersal	U		
Juveniles		mollusks, echinoderms, polychaetes, diatoms, crustaceans, algae, hydroids, sea stars		lower slope and basin (1,000 to >3,000 m)	demersal, semi-demersal	sand, gravel, cobble, rock		
Adults		mollusks, echinoderms, polychaetes, diatoms, crustaceans, algae, hydroids, sea stars, brittle stars	spawning Jan–Jul	outer shelf and upper slope (100–1,000 m)	demersal, semi-demersal	sand, gravel, cobble, rock		

N/A = not applicable

#### 2.5.5 Literature

- Adams, C. F., and A. J. Paul. 1999. Phototaxis and geotaxis of light-adapted golden king crab zoeae, *Lithodes aequispinus* (Anomura: Lithodidae) in the laboratory. *J. Crust. Biol.* 19: 106–110.
- Barnard, D. R. and R. Burt. 2007. Alaska Department of Fish and Game summary of the 2005/2006 mandatory shellfish observer program database for the rationalized crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 07-02, Anchorage.
- Blau, S. F., and D. Pengilly. 1994. Findings from the 1991 Aleutian Islands golden king crab survey in the Dutch Harbor and Adak management areas including analysis of recovered tagged crabs. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K94-35, Kodiak.
- Blau, S. F., D. Pengilly, and D. Tracy. 1996. Distribution of golden king crabs by sex, size, and depth zones in the eastern Aleutian Islands, Alaska. Pages 167–185 in *High latitude crabs: Biology, management, and economics*. Alaska Sea Grant College Program Report No. 96-02, University of Alaska Fairbanks.
- Jewett, S. C., N. A. Sloan, and D. A. Somerton. 1985. Size at sexual maturity and fecundity of the fjord-dwelling golden king crab *Lithodes aequispina* Benedict from northern British Columbia. *J. Crust. Biol.* 5: 377–385.
- McBride, J., D. Fraser, and J. Reeves. 1982. Information on the distribution and biology of the golden (brown) king crab in the Bering Sea and Aleutian Islands area. NOAA, NWAFC Proc. Rpt. 92-02.
- National Marine Fisheries Service (NMFS). 2004. Bering Sea Aleutian Islands Crab Fisheries Final Environmental Impact Statement. DOC, NOAA, National Marine Fisheries Service, AK Region, P.O. Box 21668, Juneau, AK 99802-1668, August 2004.
- Otto, R. S., and P. A. Cummiskey. 1985. Observations on the reproductive biology of golden king crab (*Lithodes aequispina*) in the Bering Sea and Aleutian Islands. Pages 123–136 in *Proceedings of the International King Crab Symposium*. University of Alaska Sea Grant Report No. 85-12, Fairbanks.
- Paul, A. J., and J. M. Paul. 2000. Changes in chela heights and carapace lengths in male and female golden king crabs *Lithodes aequispinus* after molting in the laboratory. *Alaska Fishery Research Bulletin* 6(2): 70–77.
- Shirley, T. C. 2006. Cultivation potential of golden king crab, *Lithodes aequispinus*. Pages 47–54 in: Stevens, B. G., ed.. *Alaska crab stock enhancement and rehabilitation: Workshop proceedings*. Alaska Sea Grant College Program AK-SG-06-04.
- Shirley, T. C., and S. Zhou. 1997. Lecithotrophic development of the golden king crab *Lithodes aequispinus* (Anomura: Lithodidae). *J. Crust. Biol.* 17: 207–216.

- Siddeek, M.S.M., D. Pengilly, and J. Zheng. 2011. Aleutian Islands Golden King Crab Model Based Stock Assessment in Fall 2011. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4<sup>th</sup> Ave, Suite 306, Anchorage, AK 99501.
- Sloan, N.A. 1985. Life history characteristics of fjord-dwelling golden king crabs *Lithodes aequispina*. *Mar. Ecol. Prog. Ser.* 22:219-228.
- Somerton, D. A., and R. S. Otto. 1986. Distribution and reproductive biology of the golden king crab, *Lithodes aequispina*, in the eastern Bering Sea. *Fishery Bulletin* 84(3): 571–584.

## 2.6 Tanner crab (*Chionoecetes bairdi*)

### 2.6.1 Life History and General Distribution

Tanner crab (*Chionoecetes bairdi*), originally described by Rathbun (1924), is one of five species in the genus *Chionoecetes*. The common name for *C. bairdi* of “Tanner crab” has been modified to “southern Tanner crab” (McLaughlin et al. 2005). Previously, the term “Tanner crab” has also been used to refer to other members of the genus, or to the genus as a whole.

Tanner crab are distributed on the continental shelf of the North Pacific Ocean and Bering Sea from Kamchatka to Oregon. In the east, their range extends as far south as Oregon (Hosie and Gaumer 1974), and in the west as far south as Hokkaido, Japan (Kon 1996). The northern extent of their range is in the Bering Sea (Somerton 1981a) where they are found along the Kamchatka peninsula (Slizkin 1990) to the west and in Bristol Bay to the east. Off Alaska, Tanner crab are concentrated around the Pribilof Islands and immediately north of the Alaska Peninsula. They are found in lower abundance in the Gulf of Alaska. The corresponding age of maturity for male and female Tanner crab is approximately 6 to 8 years. Natural mortality of adult Tanner crab is assumed to be about 20 percent per year ( $M=0.23$ ).

In the eastern Bering Sea, the Tanner crab distribution may be limited by water temperature (Somerton 1981a). *C. bairdi* is common in the southern half of Bristol Bay, around the Pribilof Islands, and along the shelf break where water temperatures are generally warmer. The southern range of the cold water congener the snow crab, *C. opilio*, in the eastern Bering Sea is near the Pribilof Islands (Turnock and Rugolo 2009). The distributions of snow and Tanner crab overlap on the shelf from approximately 56° to 58° N., and in this area, the two species hybridize (Karinen and Hoopes 1971).

Tanner crabs in the eastern Bering Sea are considered to be a separate stock distinct stock from Tanner crabs in the eastern and western Aleutian Islands (NPFMC 1998). The unit stock is that defined across the geographic range of the eastern Bering Sea continental shelf, and managed as a single unit. Clinal differences in some biological characteristics may exist across the range of the unit stock (Somerton 1981a).

#### Reproduction

In most majid crabs, the molt to maturity is the final or terminal molt. For *C. bairdi*, it is now accepted that both males (Otto 1998, Tamone et al. 2007) and females (Donaldson and Adams 1989) undergo terminal molt at maturity. Females terminally molt from their last juvenile, or pubescent, instar usually while being grasped by a male (Donaldson and Adams 1989). Subsequent mating occurs annually in a hard shell state (Hilsinger 1976) and after extrusion of a clutch of eggs. Mating in old-shell adult females has been documented (Donaldson and Hicks 1977); fertile egg clutches can be produced in the absence of males by using stored sperm from the spermathacae (Adams and Paul 1983, Paul and Paul 1992). Two or more consecutive egg fertilization events can follow a single copulation using stored sperm to self-



fertilize (Paul 1982, Adams and Paul 1983); egg viability, however, decreases with time and age of the stored sperm (Paul 1984).

Maturity in males can be classified either physiologically or morphometrically. Physiological maturity is the presence of spermatophores in the male gonads whereas morphometric maturity is the presence of a large claw (Brown and Powell 1972). During the molt to morphometric maturity, there is a disproportionate increase in the size of the chelae in relation to the carapace (Somerton 1981a). Many earlier studies on Tanner crabs assumed that morphometrically mature male crabs continued to molt and grow throughout life, however, evidence is irrefutable supporting a terminal molt for males (Tamone et al. 2007). A consequence of the terminal molt in male Tanner crab is that a substantial portion of the population may never reach the legal harvest size of 138 mm carapace width.

While observations are lacking for the eastern Bering Sea, seasonal differences have been observed between mating periods for pubescent and multiparous Tanner crab females in the Gulf of Alaska and Prince William Sound. Pubescent molting and mating takes place over a protracted period from winter through early summer, whereas multiparous mating occurs over a relatively short period during mid-April to early June (Hilsinger 1976, Munk et al. 1996, and Stevens 2000). In the eastern Bering Sea, egg condition for multiparous Tanner crabs assessed between April and July 1976 also suggested that hatching and extrusion of new clutches for this maturity status began in April and ended sometime in mid-June (Somerton 1981a).

#### *Fecundity*

A variety of factors affect female Tanner crab fecundity including female size, maturity status, age post terminal molt, and egg loss (NMFS 2004). Among these factors, female size is the most important, with estimates of 89,000 to 424,000 eggs for eastern Bering Sea females 75 to 124 mm CW, respectively (Haynes et al. 1976). Maturity status is another significant factor affecting fecundity with primiparous females being only approximately 70 percent as fecund as equal size multiparous females (Somerton and Meyers 1983). The number of years post maturity molt and whether a female has had to use stored sperm from that first mating can also affect egg counts (Paul 1984, Paul and Paul 1992). Additionally, older senescent females often carry small clutches or no eggs (i.e., barren) suggesting that female Tanner crab reproductive output is a declining function of age (NMFS 2004).

#### *Size at Maturity*

Somerton (1981b) noted differences in the size of Tanner crab female maturity across its eastern Bering Sea range as seen in trawl survey data. Between 1975 and 1979 east of 167°15' W. longitude, the mean size of mature females in the stock ranged from 92.0 to 93.6 mm CW. West of that longitude, the size of 50 percent female maturity ranged from 78.0 to 82.0 mm CW. For Alaska Department of Fish and Game harvest strategy purposes, mature females are defined as females greater than or equal to 80 mm CW. For male Tanner crab during the same survey years, the observed mean size at maturity was 117.0 mm CW and 108.9 mm CW east and west of 167°15' W. longitude, respectively (Somerton 1981b). Size at 50 percent maturity, is 93.3 mm CW for males and 69.3 mm CW for females in the eastern Bering Sea.

#### *Natural Mortality*

Due to a lack of age information, Somerton (1981a) estimated mortality separately for individual eastern Bering Sea cohorts of juveniles and adults. Somerton postulated that because of net selectivity of the survey sampling gear, age 5 Tanner crab (mean CW=95 mm) were the first cohort to be fully recruited to the gear; he estimated an instantaneous natural mortality rate of 0.35 for this size class using catch curve analysis. Using a catch curve analysis with two different data sets, Somerton then estimated natural mortality rates of adults (fished population) from data from the eastern Bering Sea population survey of 0.20 to 0.28. When using catch per unit of effort data from the Japanese fishery, the estimated rates were 0.13 to 0.18. Somerton concluded that estimates (0.22 to 0.28) from models that used both the survey and

fishery data were the best. The natural mortality rate of eastern Bering Sea Tanner crab is set at 0.23 for the purpose of assessing stock status and setting the overfishing level based on the current expectation of longevity of at least 18 to 20 years.

## 2.6.2 Fishery

### *Management Unit*

Fisheries have historically taken place for Tanner crab throughout their range in Alaska, but currently only the fishery in the eastern Bering Sea is managed under a federal fisheries management plan (NPFMC 1998). The plan defers certain management controls for Tanner crab to the state of Alaska with federal oversight (Bowers et al. 2008). The state manages Tanner crab based on registration areas, divided into districts. Under the plan, the state can adjust or further subdivide these districts as needed to avoid overharvest in a particular area, change size limits from other stocks in the registration area, change fishing seasons, or encourage exploration (NPFMC 1998).

The Bering Sea District of Tanner crab Registration Area J includes all waters of the Bering Sea north of Cape Sarichef at 54°36' N. latitude and east of the U.S.-Russia Maritime Boundary Line of 1991. This district is divided into the Eastern and Western Subdistricts at 173° W. longitude. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168° W. longitude and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008).

The domestic Tanner crab (*C. bairdi*) pot fishery rapidly developed in the mid 1970s. For stock biomass and fishery data tabled in this document, “year” refers to the survey year, and fishery data are those subsequent to the survey, through prior to the survey in the following year. Other notation is explicit, for example, 2008/09 is the 2008 summer survey and the winter 2009 fishery. United States landings were first reported for Tanner crab in 1968 at 1.01 million pounds taken incidentally to the eastern Bering Sea red king crab fishery. Tanner crab was targeted thereafter by the domestic fleet and landings rose sharply in the early 1970s, reaching a high of 66.6 million pounds in 1977. Landings fell precipitously after the peak in 1977 through the early 1980s, and domestic fishing was closed in 1985 and 1986 as a result of depressed stock status. In 1987, the fishery reopened and landings rose again in the late 1980s to a second peak in 1990 at 40.1 million pounds, and then fell sharply through the mid 1990s. The domestic Tanner crab fishery closed between 1997 and 2004 as a result of severely depressed stock condition. The domestic Tanner crab fishery re-opened in 2005 and has averaged 1.7 million pounds retained catch between 2005 and 2007. Landings of Tanner crab in the foreign Japanese pot and tangle net fisheries were reported between 1965 and 1978, peaking at 44.0 million pounds in 1969. The Russian tangle net fishery was prosecuted between 1965 and 1971 with peak landings in 1969 at 15.6 million pounds. Both the Japanese and Russian Tanner crab fisheries were displaced by the domestic fishery by the late 1970s.

Discard and bycatch losses of Tanner crab originate from the directed pot fishery, non-directed pot fisheries (notably, for snow crab and red king crab), and the groundfish trawl fisheries. Discard/bycatch mortalities were estimated using post-release handling mortality rates of 50 percent for pot fishery discards and 80 percent for trawl fishery bycatch (Turnock and Rugolo 2009). The pattern of total discard/bycatch losses is similar to that of the retained catch. These losses were persistently high during the late 1960s through the late 1970s; male losses peaked in 1970 at 44.5 million pounds. A subsequent peak mode of discard/bycatch losses occurred in the late 1980s through the early 1990s, which, although briefer in duration, revealed higher losses for males than the earlier mode, peaking at 49.2 million pounds in 1990. From 1965 through 1975, the groundfish trawl fisheries contributed significantly to total bycatch losses, although the combined pot fisheries are the principal source of contemporaneous non-retained losses to the stock. Total Tanner crab retained catch plus non-directed losses of males and females, reflect the performance patterns in the directed and non-directed fisheries. Total male catch rose sharply with

fishery development in the early 1960s and reveals a bimodal distribution between 1965 and 1980 with peaks of 104.7 million pounds in 1969 and 115.5 million pounds in 1977. Total male catch rose sharply after the directed domestic fishery reopened in 1987 and reached a peak of 89.3 million pounds in 1990. Total male and female catch fell sharply thereafter with the collapse of the stock and the fishery closure in 1997.

Since re-opening of the domestic fishery in 2005, the relationship of total male discard/bycatch losses by all pot and trawl fisheries combined to retained catch shifted significantly relative to that between 1980 and 1996. For 2005 through 2008, the ratio of total male discard losses to retained catch was 4.3, 3.8, 4.6, and 2.4, respectively, and averaged 3.8 (statistical error = 0.5). The majority of these male losses are sub-legal sized crab, and a principal contributor to these non-retained losses is the directed Tanner crab fishery. This contrasts with the pre-closure performance of the domestic fishery between 1980 and 1996, which averaged 1.1 (statistical error = 0.1) pounds of non-retained male losses to each pound of retained catch. These ratios in terms of numbers of non-retained male losses to retained legal crab are more striking due to the contribution of sub-legal sized crab to total male discards. Discard and bycatch losses of male and female Tanner crab during the closures of the directed domestic fishery (1985 through 1986 and 1997 through 2004) reflect losses due to non-directed eastern Bering Sea pot fisheries and the domestic groundfish trawl fishery.

### 2.6.3 Relevant Trophic Information

Pacific cod is thought to be the main predator on Tanner crabs in terms of biomass (Livingston 1989, Livingston et al. 1993). Sculpins, while of lower stock biomass than the eastern Bering Sea Pacific cod, are also a significant predator of Tanner crabs of all sizes, and particularly large, mature crabs of both sexes. Predators consume primarily age 0 and 1 juvenile Tanner crab with a less than 70 mm CW. However, flathead sole, rock sole, halibut, skates, yellowfin sole, and eel pouts are important in terms of numbers of juvenile crab. Larval predators include salmon, herring, jellyfish, and chaetognaths. Cannibalism has been observed in laboratory environments among juvenile crabs during molting.

### 2.6.4 Habitat and Biological Associations

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Larvae of *C. bairdi* Tanner crabs are typically found in the Bering Sea and Aleutian Islands water column from 0 to 100 m in early summer. They are strong swimmers and perform diel migrations in the water column (down at night). They usually stay near the depth of the chlorophyll maximum during the day. The last larval stage settles onto the bottom mud.

Early Juvenile: Early juvenile *C. bairdi* Tanner crabs occur at depths of 10 to 20 m in mud habitat in summer and are known to burrow or associate with many types of cover. Early juvenile *C. bairdi* Tanner crabs are not easily found in winter.

Late Juvenile: The preferred habitat for late juvenile *C. bairdi* Tanner crabs is mud. Late juvenile Tanner crab migrate offshore of their early juvenile nursery habitat.

Mature: Mature *C. bairdi* Tanner crabs migrate inshore, and mating is known to occur from February through June. Mature female *C. bairdi* Tanner crabs have been observed in high density mating aggregations, or pods, consisting of hundreds to thousands of crabs per mound. These mounds may provide protection from predators and also attract males for mating. Mating need not occur annually as female *C. bairdi* Tanner crabs can retain viable sperm in spermathecae and mobilize stored sperm in the absence of male for self-fertilization of a newly extruded clutch of eggs. Females carry clutches of 50,000 to 400,000 eggs and nurture the embryos for 1 year after fertilization before hatching. While the congener

*C. opilio* has been shown to exhibit biennial spawning in cold water realms less than or equal to 1.5 °C (Rugolo et al. 2005), this behavior has not been observed in *C. bairdi* presumptively since Tanner crab inhabit warmer waters than the snow crab. Primiparous females may carry the fertilized eggs for as long as 1.5 years. Brooding occurs in 100 to 150 m depths.

#### Habitat and Biological Associations: Tanner crab

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	1 year	N/A	April–March	N/A	N/A	N/A	fronts	
Larvae	2 to 7 mo.	diatoms, algae, zooplankton	summer	inner and middle continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	1 to 6 years	crustaceans, polychaetes, mollusks, diatoms, algae, hydroids	all year	inner and middle continental shelf (1–100 m), nearshore bays, beach (intertidal)	demersal	mud	fronts	
Adults	6+ years	polychaetes, crustaceans, mollusks, hydroids, algae, diatoms	spawning Jan–June (peak April–May)	inner and middle continental shelf (1–100 m)	demersal	mud	fronts	

N/A = not applicable

#### 2.6.5 Literature

- Adams, A. E. and A. J. Paul. 1983. Male parent size, sperm storage and egg production in the Crab *Chionoecetes bairdi* (DECAPODA, MAJIDAE). International Journal of Invertebrate Reproduction. 6:181-187.
- Brown, R. B. and G. C. Powell. 1972. Size at maturity in the male Alaskan Tanner crab, *Chionoecetes bairdi*, as determined by chela allometry, reproductive tract weights, and size of precopulatory males. Journal of the Fisheries Research Board of Canada. 29:423-427.
- Donaldson, W. E. and D. M. Hicks. 1977. Technical report to industry on the Kodiak crab population surveys. Results, life history, information, and history of the fishery for Tanner crab. Alaska Dept. Fish and Game, Kodiak Tanner crab research. 46 p.
- Donaldson, W. E., and A. A. Adams. 1989. Ethogram of behavior with emphasis on mating for the Tanner crab *Chionoecetes bairdi* Rathbun. Journal of Crustacean Biology. 9:37-53.
- Donaldson, W. E., R. T. Cooney, and J. R. Hilsinger. 1981. Growth, age, and size at maturity of Tanner crab *Chionoecetes bairdi* M. J. Rathbun, in the northern Gulf of Alaska. Crustaceana. 40:286-302.
- Haynes, E., J. F. Karinen, J. Watson, and D. J. Hopson. 1976. Relation of number of eggs and egg length to carapace width in the brachyuran crabs *Chionoecetes bairdi* and *C. opilio* from the southeastern Bering Sea and *C. opilio* from the Gulf of St. Lawrence. J. Fish. Res. Board Can. 33:2592-2595.
- Hilsinger, J. R. 1976. Aspects of the reproductive biology of female snow crabs, *Chionoecetes bairdi*, from Prince William Sound and the adjacent Gulf of Alaska. Marine Science Communications. 2:201-225.
- Hosie, M. J. and T. F. Gaumer. 1974. Southern range extension of the Baird crab (*Chionoecetes bairdi* Rathbun). Calif. Fish and Game. 60:44-47.
- Karinen, J. F. and D. T. Hoopes. 1971. Occurrence of Tanner crabs (*Chionoecetes* sp.) in the eastern Bering Sea with characteristics intermediate between *C. bairdi* and *C. opilio*. Proc. Natl. Shellfish Assoc. 61:8-9.
- Kon, T. 1996. Overview of Tanner crab fisheries around the Japanese Archipelago, p. 13-24. In High

- Livingston, P. A. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the eastern Bering Sea. *Fishery Bulletin*. 87:807-827.
- Livingston, P. A., A. Ward, G. M. Lang, and M. S. Yang. 1993. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1987 to 1989. NOAA Technical Memorandum, NMFS-AFSC-11, DOC, NOAA, NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, 192 p.
- McLaughlin, P. A. and 39 coauthors. 2005. Common and scientific names of aquatic invertebrates from the United States and Canada: crustaceans. *American Fisheries Society Special Publication* 31. 545 p.
- Munk, J. E., S. A. Payne, and B. G. Stevens. 1996. Timing and duration of the mating and molting season for shallow water Tanner crab (*Chionoecetes bairdi*), p. 341 (abstract only). In *High Latitude Crabs: Biology, Management and Economics*. Alaska Sea Grant Report, AK-SG-96-02, University of Alaska Fairbanks.
- NMFS. 2004. Final Environmental Impact Statement for Bering Sea and Aleutian Islands Crab Fisheries. National Marine Fisheries Service, P.O. Box 21668, Juneau, AK 99802-1668.
- NPFMC. 1998. Fishery Management Plan for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite, 306, Anchorage, AK 99501.
- NPFMC. 2007. Initial Review Draft Environmental Assessment, Amendment 24 to the Fishery Management Plan for Bering Sea and Aleutian Islands King and Tanner crabs to Revise Overfishing Definitions. North Pacific Fishery Management Council, 605 W. 4th Avenue, 306, Anchorage, AK 99501.
- Otto, R. S. 1998. Assessment of the eastern Bering Sea snow crab, *Chionoecetes opilio*, stock under the terminal molting hypothesis, p. 109-124. In G. S. Jamieson and A. Campbell, (editors), *Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management*. Canadian Special Publication of Fisheries and Aquatic Sciences.
- Paul, A. J. 1982. Mating frequency and sperm storage as factors affecting egg production in multiparous *Chionoecetes bairdi*, p. 273-281. In B. Melteff (editor), *Proceedings of the International Symposium on the Genus Chionoecetes: Lowell Wakefield Symposium Series*, Alaska Sea Grant Report, 82-10. University of Alaska Fairbanks.
- Paul, A. J. 1984. Mating frequency and viability of stored sperm in the Tanner crab *Chionoecetes bairdi* (DECAPODA, MAJIDAE). *Journal of Crustacean Biology*. 4:375-381.
- Paul, A. J. and J. M. Paul. 1992. Second clutch viability of *Chionoecetes bairdi* Rathbun (DECAPODA: MAJIDAE) inseminated only at the maturity molt. *Journal of Crustacean Biology*. 12:438-441.
- Rugolo, L.J. and B.J. Turnock. 2011. 2011 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. In *2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands*. NPFMC, 605 W 4<sup>th</sup> Ave, Suite 306, Anchorage, AK 99501.
- Rugolo, L, D. Pengilly, R. MacIntosh and K. Gravel. 2005. Reproductive dynamics and life-history of snow crab (*Chionoecetes opilio*) in the eastern Bering Sea. Final Completion Report to the NOAA, Award NA17FW1274, Bering Sea Snow Crab Fishery Restoration Research.
- Rathbun, M. J. 1924. New species and subspecies of spider crabs. *Proceedings of U.S. Nat. Museum*. 64:1-5.
- Slizkin, A. G. 1990. Tanner crabs (*Chionoecetes opilio*, *C. bairdi*) of the northwest Pacific: distribution, biological peculiarities, and population structure, p. 27-33. In *Proceedings of the International Symposium on King and Tanner Crabs*. Lowell Wakefield Fisheries Symposium Series, Alaska Sea Grant College Program Report 90-04. University of Alaska Fairbanks.
- Somerton, D. A. 1981a. Life history and population dynamics of two species of Tanner crab, *Chionoecetes bairdi* and *C. opilio*, in the eastern Bering Sea with implications for the management of the commercial harvest, PhD Thesis, University of Washington, 220 p.

- Somerton, D. A. 1981b. Regional variation in the size at maturity of two species of Tanner Crab (*Chionoecetes bairdi* and *C. opilio*) in the eastern Bering Sea, and its use in defining management subareas. Canadian Journal of Fisheries and Aquatic Science. 38:163-174.
- Somerton, D. A. and W. S. Meyers. 1983. Fecundity differences between primiparous and multiparous female Alaskan Tanner crab (*Chionoecetes bairdi*). Journal of Crustacean Biology. 3:183-186.
- Sparks, A.K. 1982. Observations on the histopathology and probable progression of the disease caused by *Trichomaris invadens* in the Tanner crab, *Chionoecetes bairdi*. J. Invertebr. Pathol. 34:184-191.
- Stevens, B. G. 2000. Moonlight madness and larval launch pads: tidal synchronization of Mound Formation and hatching by Tanner crab, *Chionoecetes bairdi*. Journal of Shellfish Research. 19:640-641.
- Tamone, S. L., S. J. Taggart, A. G. Andrews, J. Mondragon, and J. K. Nielsen. 2007. The relationship between circulating ecdysteroids and chela allometry in male Tanner crabs: Evidence for a terminal molt in the genus *Chionoecetes*. J. Crust. Biol. 27:635-642.
- Turnock, B. and L. Rugolo. 2009. Stock assessment of eastern Bering Sea snow crab (*Chionoecetes opilio*). Report to the North Pacific Fishery Management Council, Crab Plan Team. 102 p.
- Zheng, J. 2008. Temporal Changes in Size at Maturity and Their Implications for Fisheries Management for Eastern Bering Sea Tanner Crab. J. Northw. Alt. Fish. Sci., 41: 137–149. doi:10.2960/J.v41.m623

## 2.7 Snow crab (*Chionoecetes opilio*)

### 2.7.1 Life History and General Distribution

Snow crab (*Chionoecetes opilio*) are distributed on the continental shelf of the Bering Sea, Chukchi Sea, and as far south as the Sea of Japan in the western Pacific Ocean. Snow crab occur in the western Atlantic Ocean as far south as Maine. Snow crab are not present in the Gulf of Alaska. In the Bering Sea, snow crab are common at depths less than 200 m. The eastern Bering Sea population within U.S. waters is managed as a single stock; however, the distribution of the population extends into Russian waters to an unknown degree. While 50 percent of the females are mature at 5 cm CW, the mean size of mature females varies from year to year over a range of 6.3 to 7.2 cm CW. Females cease growing with a terminal molt upon reaching maturity and rarely exceed 8 cm CW. The median size of maturity for males is about 8.5 cm CW (approximately 6 to 8 years old). Males larger than 6 cm grow at about 2 cm per molt, up to an estimated maximum size of 14.5 cm CW, but individual growth rates vary widely. Male snow crab have a terminal molt on reaching maturity. Natural mortality of adult snow crab is estimated at 0.23 using maximum observed age from tagging of about 18 years.

#### Maturity

Maturity for females is determined by visual examination during the survey and used to determine the fraction of females mature by size for each year. Female maturity is determined by the shape of the abdomen, by the presence of brooded eggs or egg remnants.

Morphometric maturity for males is determined by chela height measurements, which are available starting from the 1989 survey. The number of males with chela height measurements has varied between about 3,000 and 7,000 per year. A mature male refers to a morphometrically mature male. Morphometric maturity for males refers to a marked change in chelae size (thereafter termed “large claw”), after which males are assumed to be effective at mating. Males are functionally mature at smaller sizes than when they become morphometrically mature, although the contribution of these “small-clawed” males to annual reproductive output is negligible. The minimum legal size limit for the snow crab fishery is 78 mm; however, the size for males that are generally accepted by the fishery is greater than 101 mm. Historical quotas were based on the survey abundance of large males (greater than 101 mm).

One maturity curve for males was estimated using the average fraction mature based on chela height data and applied to all years of survey data to estimate mature survey numbers. The separation of mature and immature males by chela height at small widths may not be adequately refined given the current measurement to the nearest millimeter. Chela height measured to the nearest tenth of a millimeter (by Canadian researchers on North Atlantic snow crab) shows a clear break in chela height at small and large widths and shows fewer mature animals at small widths than the Bering Sea data measured to the nearest millimeter. Measurements taken in 2004 and 2005 on Bering Sea snow crab chela to the nearest tenth of a millimeter show a similar break in chela height to the Canadian data (Rugolo et al. 2005).

The probability of a new shell crab maturing was estimated in the model at a smooth function to move crab from immature to mature. The probability of maturing was estimated to match the observed fraction mature for all mature males and females observed in the survey data. The probability of maturing was fixed in the September 2009 assessment. The probability of maturing by size for female crab was about 50 percent at about 48 mm and increased to 100 percent at 60 mm. The probability of maturing for male crab was about 15 percent to 20 percent at 60 mm to 90 mm, increased sharply to 50 percent at about 98 mm, and was 100 percent at 108 mm.

#### Natural Mortality

Natural mortality (M) is an essential control variable in population dynamic modeling, and may have a large influence on derived optimal harvest rates. Natural mortality rates estimated in a population dynamics model may have high uncertainty and may be correlated with other parameters, and therefore are usually fixed. The ability to estimate natural mortality in a population dynamics model depends on how the true value varies over time as well as other factors (Fu and Quinn 2000, Schnute and Richards 1995).

Nevissi et al. (1995) used radiometric techniques to estimate shell age from last molt. The total sample size was 21 male crabs (a combination of Tanner and snow crab) from a collection of 105 male crabs from various hauls in the 1992 and 1993 NMFS Bering Sea survey. Fishing mortality rates before and during the time period when these crab were collected were relatively high, and therefore maximum age would represent Z (total mortality) rather than M. Representative samples for the five shell condition categories were collected that made up the 105 samples. The oldest looking crab within shell conditions 4 and 5 were selected from the total sample of SC4 and SC5 crabs to radiometrically age (Orensanz, School of Fisheries, University of Washington, personal communication). Shell condition 5 crab (SC5 = very, very old shell) had a maximum age of 6.85 years (standard deviation 0.58, 95 percent confidence interval approximately 5.69 to 8.01 years). The average age of six crabs with SC4 (very old shell) and SC5, was 4.95 years. The range of ages was 2.70 to 6.85 years for those same crabs. Given the small sample size, this maximum age may not represent the 1.5 percent percentile of the population that is approximately equivalent to Hoenig's (1983) method. Maximum life span defined for a virgin stock is reasonably expected to be longer than these observed maximum ages from exploited populations. Radiometric ages estimated by Nevissi et al. (1995) may be underestimated by several years, due to the continued exchange of material in crab shells even after shells have hardened (Craig Kestelle, Alaska Fisheries Science Center, Seattle, WA, personal communication).

Tag recovery evidence from eastern Canada reveals observed maximum ages in exploited populations of 17 to 19 years (Nevissi et al. 1995, Sainte-Marie 2002). A maximum time at large of 11 years for tag returns of terminally molted mature male snow crab in the North Atlantic has been recorded since tagging started about 1993 (Fonseca et al. 2008). Fonseca et al. (2008) estimated a maximum age of 7.8 years post terminal molt using data on dactyl wear.

In a virgin population of snow crab, longevity would be at least 20 years. Hence 20 years is used as a proxy for longevity, and it is assumed that this age would represent the upper 99<sup>th</sup> percentile of the

distribution of ages in an unexploited population if observable. Under negative exponential depletion, the 99<sup>th</sup> percentile corresponding to age 20 of an unexploited population corresponds to a natural mortality rate of 0.23. Using Hoenig's (1983) method an  $M=0.23$  corresponds to a maximum age of 18 years.  $M=0.23$  was used for all crab in Model 1.

Model scenarios that estimated male natural mortality use mean  $M=0.23$ , with a statistical error equal to 0.054 estimated from using the 95 percent confidence interval of  $\pm 1.7$  years, on maximum age estimates from dactal wear and tag return analysis, in Fonseca et al. (2008).

## 2.7.2 Fishery

Snow crab were harvested in the Bering Sea by the Japanese from the 1960s until 1980 when the Magnuson Act prohibited foreign fishing. Retained catch in the domestic fishery increased in the late 1980s to a high of about 328 million pounds in 1991. During 2000/01 to 2006/07, however, fisheries retained low catches due to low abundance and a reduced harvest rate.

Several modifications to pot gear have been introduced to reduce bycatch mortality. In the 1978/79 season, pots used in the snow crab fishery first contained escape panels to prevent ghost fishing. Escape panels consisted of an opening with one-half the perimeter of the tunnel eye laced with untreated cotton twine. The size of the cotton laced panel to prevent ghost fishing was increased in 1991 to at least 18 inches in length. No escape mechanisms for undersized crab were required until the 1997 season when at least one-third of one vertical surface had to contain not less than 5 inches stretched mesh webbing or have no less than four circular rings of no less than 3 3/4 inches inside diameter. In the 2001 season the escapement for undersize crab was increased to at least eight escape rings of no less than 4 inches placed within one mesh measurement from the bottom of the pot, with four escape rings on each side of the two sides of a four-sided pot, or one-half of one side of the pot must have a side panel composed of not less than 5 1/4 inch stretched mesh webbing.

The snow crab fishery is prosecuted using mesh covered pots (generally 7 or 8 feet square) set on single lines. Male only crab greater than 7.8 cm CW may be harvested; however, a market minimum size of about 10.2 cm CW is generally observed. Most male snow crab probably enter the fishery at around age 8 to 10 years. Discard from the directed pot fishery was estimated from observer data since 1992 and ranged from 11 percent to 64 percent (average 33 percent) of the retained catch of male crab biomass. Female discard catch is very low and not a significant source of mortality. Size frequency data and catch per pot have been collected by observers on snow crab fishery vessels since 1992. Observer coverage was 10 percent on catcher vessels larger than 125 feet (since 2001), and 100 percent coverage on catcher/processors (since 1992).

Snow crab are probably one stock in the Bering Sea. The season opening date since the 2008 season is October 15, however, fishing usually occurs after January 15, which was the fishery opening date pre-2008. A 3-inch maximum tunnel height opening for snow crab pots is required to inhibit the bycatch of red king crab. A minimum of eight 4-inch escape rings are required on snow crab pots to reduce capture and handling mortality of smaller non-target crab. Bycatch in the snow crab fishery consists primarily of *C. bairdi* and *C. opilio* less than 10.2 cm CW.

Bottom trawls and dredges could disrupt nursery and adult feeding areas. In 1992 trawl discard mortality was about 4 million pounds, increased to about 7.8 million pounds in 1995, then declined to about 2 to 3 million pounds until 1999. Trawl bycatch in 2007 and 2008 was 0.97 and 0.66 million pounds, respectively. Discard in groundfish fisheries from highest to lowest snow crab bycatch is the yellow fin sole trawl fishery, flathead sole trawl fishery, Pacific cod bottom trawl fishery, rock sole trawl fishery, and the Pacific cod hook and line and pot fisheries.



### 2.7.3 Relevant Trophic Information

Pacific cod, sculpins, skates, eel pouts, and halibut are the main predators on snow crabs in terms of biomass. Snow crabs less than 7 cm CW are most commonly consumed. Other predators include yellowfin sole, flathead sole, Alaska plaice, walleye pollock, rock sole, bearded seals, and walrus. Juvenile snow crabs have been observed to be cannibalistic during molting in laboratory environments.

### 2.7.4 Habitat and Biological Associations

Egg: See mature phase description; eggs are carried by adult female crab.

Larvae: Larvae of *C. opilio* snow crab are found in early summer and exhibit diel migration. The last of three larval stages settles onto bottom in nursery areas.

Early Juvenile: Shallow water areas of the eastern Bering Sea are considered nursery areas for *C. opilio* snow crabs and are confined to the middle shelf area due to the thermal limits of early and late juvenile life stages.

Late Juvenile: A geographic cline in size of *C. opilio* snow crabs indicates that a large number of morphometrically immature crabs occur in shallow waters less than 80 m.

Mature: Female and male *C. opilio* snow crabs are acknowledged to attain terminal molt status at maturity. Primiparous female snow crabs mate January through June and may exhibit longer egg development period and lower fecundity than multiparous female crabs. Multiparous females release eggs and mate mainly in March and April (Rugolo et al. 2005). Multiparous female snow crabs can store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two clutches can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known. Females carry clutches of approximately 36,000 eggs and nurture the embryos for approximately 1 year after fertilization. However, fecundity may decrease between the time of egg extrusion and hatching, presumably due to predation, parasitism, abrasion, or decay of unfertilized eggs. Brooding probably occurs in depths greater than 50 m.

#### Habitat and Biological Associations: Snow crab

Stage - EFH Level	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs	1 year	N/A		N/A	N/A	N/A	fronts	
Larvae	2 to 7 mo.	diatoms, algae, zooplankton	spring, summer	inner and middle continental shelf (1–100 m)	pelagic	N/A	fronts	
Juveniles	1 to 4 years	crustaceans, polychaetes, mollusks, diatoms, algae, hydroids	all year	inner, middle, and outer continental shelf (1–200 m)	demersal	mud	fronts	
Adults	4+ years	polychaetes, brittle stars, mollusks, crustaceans, hydroids, algae, diatoms	spawning Jan–June (peak April–May)	inner, middle, and outer continental shelf (1–200 m)	demersal	mud	fronts	

N/A = not applicable

### 2.7.5 Literature

- Fonseca, D. B., B. Sainte-Marie, and F. Hazel. 2008. Longevity and change in shell condition of adult male snow crab *Chionoecetes opilio* inferred from dactyl wear and mark-recapture data. *Transactions of the American Fisheries Society* 137:1029–1043.
- Fu, C. H., and T. J. Quinn II, 2000. Estimability of natural mortality and other population parameters in a length-based model: *Pandalus borealis* in Kachemak Bay, Alaska. *Can. J. Fish. Aquat. Sci.* 57: 2420–2432.
- Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. *Fish. Bull.* 82: 898-903.
- Nevisi, A.E., J.M. Orensanz, A.J.Paul, and D.A. Armstrong. 1995. Radiometric Estimation of shell age in Tanner Crab, *Chionoecetes opilio* and *C. bairdi*, from the eastern Bering Sea, and its use to interpret indices of shell age/condition. Presented at the International symposium on biology, management and economics of crabs from high latitude habitats October 11-13, 1995, Anchorage, Alaska.
- Rugolo, L.J., D. Pengilly, R. MacIntosh and K. Gravel. 2005. Reproductive dynamics and life-history of snow crab (*Chionoecetes opilio*) in the eastern Bering Sea. Final Completion Report to the NOAA, Award NA17FW1274, Bering Sea Snow Crab Fishery Restoration Research.
- Sainte-Marie, B., J. Sevigny and M. Carpentier. 2002. Interannual variability of sperm reserves and fecundity of primiparous females of the snow crab (*Chionoecetes opilio*) in relation to sex ratio. *Can.J.Fish.Aquat.Sci.* 59:1932-1940.
- Schnute, J. and L. Richards. 1995. The influence of error on population estimates from catchage models. *Can. J. Fish. Aquat. Sci.* 52: 2063-2077.
- Turnock, B.J. and L.J. Rugolo. 2011. Stock Assessment of eastern Bering Sea snow crab. *In* 2011 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. NPFMC, 605 W 4<sup>th</sup> Ave, Suite 306, Anchorage, AK 99501.

## 5.0 Non-fishing Activities that may Adversely Affect Essential Fish Habitat

The waters and substrates that comprise essential fish habitat (EFH) are susceptible to a wide array of human activities unrelated to fishing. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharges, water diversions, thermal additions, actions that contribute to nonpoint source pollution and sedimentation, introduction of potentially hazardous materials, introduction of exotic species, and the conversion of aquatic habitat that may eliminate, diminish, or disrupt the functions of EFH. Non-fishing activities discussed in this document are subject to a variety of regulations and restrictions designed to limit environmental impacts under federal, state, and local laws. Listing all applicable environmental laws and management practices is beyond the scope of the document. Moreover, the coordination and consultation required by section 305(b) of the Magnuson-Stevens Conservation and Management Act (MSA) does not supersede the regulations, rights, interests, or jurisdictions of other federal or state agencies. NMFS may use the information in this document as a source when developing conservation recommendations for specific actions under section 305(b)(4)(A) of the MSA. NMFS will not recommend that state or federal agencies take actions beyond their statutory authority, and NMFS' EFH conservation recommendations are not binding.

Ideally, actions that are not water-dependent should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse effects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. If avoidance or minimization is not practicable, or will not adequately protect EFH, compensatory mitigation as defined for section 404 of the Clean Water Act (CWA) should be considered to conserve and enhance EFH.

The potential for effects from larger, less readily managed processes associated with human activity also exists, such as climate change and ocean acidification. Climate change may lead to habitat changes that prompt shifts in the distribution of managed species. Likewise, should ocean conditions warm to allow for new shipping routes, new vectors may emerge for introducing invasive species in cargo and ballast waters. Ocean acidification could also alter species distributions and complicated food web dynamics. These larger ecosystem-level effects are discussed in this document where applicable, within each activity type.

This section of the fishery management plan (FMP) synthesizes a comprehensive review of the "Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska" (NMFS 2011), which is incorporated in the FMP by reference. The general purpose of that document is to identify non-fishing activities that may adversely impact EFH and provide conservation recommendations that can be implemented for specific types of activities to avoid or minimize adverse impacts to EFH. This information must be included in FMPs under section 303(a)(7) of the MSA. It is also useful to NMFS biologists reviewing proposed actions that may adversely

affect EFH, and the comprehensive document (NMFS 2011) will be utilized by federal action agencies undertaking EFH consultations with NMFS, especially in preparing EFH assessments.

The conservation recommendations for each activity category are suggestions the action agency or others can undertake to avoid, offset, or mitigate impacts to EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances; therefore, the recommendations in this document may or may not apply to any particular project. Because many non-fishing activities have similar adverse effects on living marine resources, some redundancy in the descriptions of impacts and the accompanying conservation recommendations between sections in this report is unavoidable.

The comprehensive non-fishing activities document (NMFS 2011) updates and builds upon a collaborative evaluation of non-fishing effects to EFH completed in 2004 by the NMFS Alaska Region, Northwest Region, and Southwest Region and the respective Fisheries Science Centers. In April 2005, NMFS completed the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS; NMFS 2005) and the North Pacific Fishery Management Council amended its FMPs to address the EFH requirements of the MSA. The EFH EIS contained an Appendix (Appendix G) that addressed non-fishing impacts to EFH. A 5-year review of the Council's EFH provisions, including those addressing non-fishing impacts to EFH, was completed by the Council in April 2010 (NPFMC and NMFS 2010), on the basis of which this section has been updated.

The remainder of this section addresses non-fishing activities that may adversely affect EFH. These activities are grouped into the four different systems in which they usually occur: upland, river or riverine, estuary or estuarine, and coastal or marine.

## 5.1 Upland Activities

Upland activities can impact EFH through both point source and nonpoint source pollution. Nonpoint source impacts are discussed here. Technically, the term "nonpoint source" means anything that does not meet the legal definition of point source in section 502(14) of the CWA, which refers to discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification, generally driven by anthropogenic development, are the major contributors to nonpoint source pollution.

Nonpoint source pollution is usually lower in intensity than an acute point source event, but may be more damaging to fish habitat in the long term. It may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are detected, they may not be tied to any one event or source, and may be difficult to correct, clean up, or mitigate.

The impacts of nonpoint source pollution on EFH may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat of any specific pollutant to aquatic organisms depends upon the type and concentration of the pollutant and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed

bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

### 5.1.1 Silviculture/Timber Harvest

Recent revisions to federal and state timber harvest regulations in Alaska and best management practices (BMPs) have resulted in increased protection of EFH on federal, state, and private timber lands (USDA 2008; <http://www.fs.fed.us/r10/tongass/projects/tlmp/>).

These revised regulations include forest management practices, which when fully implemented and effective, could avoid or minimize adverse effects to EFH. However, if these management practices are ineffective or not fully implemented, timber harvest could have both short and long term impacts on EFH throughout many coastal watersheds and estuaries. Historically, timber harvest in Alaska was not conducted under the current protective standards, and these past practices may have degraded EFH in some watersheds.

#### *Potential Adverse Impacts*

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). Five major categories of silvicultural activities can adversely affect EFH if appropriate forestry practices are not followed: (1) construction of logging roads, (2) creation of fish migration barriers, (3) removal of streamside vegetation, (4) hydrologic changes and sedimentation, and (5) disturbance associated with log transfer facilities (LTFs). Possible effects to EFH include the following (Northcote and Hartman 2004):

- Removal of the dominant vegetation and conversion of mature and old-growth upland and riparian forests to tree stands or forests of early seral stage;
- Reduction of soil permeability and increase in the area of impervious surfaces;
- Increase in erosion and sedimentation due to surface runoff and mass wasting processes, also potentially affecting riparian areas;
- Impaired fish passage because of inadequate design, construction, and/or maintenance of stream crossings;
- Altered hydrologic regimes resulting in inadequate or excessive surface and stream flows, increased streambank and streambed erosion, loss of complex instream habitats;
- Changes in benthic macroinvertebrate populations,
- Loss of instream and riparian cover;
- Increased surface runoff with associated contaminants (e.g., herbicides, fertilizers, and fine sediments) and higher temperatures;
- Alterations in the supply of large woody debris (LWD) and sediment, which can have negative effects on the formation and persistence of instream habitat features; and
- Excess debris in the form of small pieces of wood and silt, which can cover benthic habitat and reduce dissolved oxygen levels.

## *Recommended Conservation Measures*

The following recommended conservation measures for silviculture/timber harvest should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH. Additionally, management standards, guidelines, and BMPs are available from the Forest Service Region 10, the State of Alaska Division of Forestry, and forest plans for the Tongass and Chugach National Forests.

- **Stream Buffers:** For timber operations in watersheds with EFH, adhere to modern forest management practices and BMPs, including the maintenance of vegetated buffers along all streams to the extent practicable in order to reduce sedimentation and supply large wood.
- **Estuary and Beach Fringe:** For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH.
- **Watershed Analysis:** A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.
- **Forest Roads:** Forest roads can be a major cause of sediment into streams and road culverts can block or inhibit upstream fish passage. Roads need to be designed to minimize sediment transport problems and to avoid fish passage problems.

### **5.1.2 Pesticides**

Pesticides are substances intended to prevent, destroy, control, repel, kill, or regulate the growth of undesirable biological organisms. Pesticides include the following: insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators. More than 900 different active pesticide ingredients are currently registered for use in the United States and are formulated with a variety of other inert ingredients that may also be toxic to aquatic life. Legal mandates covering pesticides are the CWA and the Federal Insecticide, Fungicide, and Rodenticide Act. Water quality criteria for the protection of aquatic life have only been developed for a few of the currently used ingredients (EPA, Office of Pesticide Programs). While agricultural run-off is a major source of pesticide pollution in the lower 48 states, in Alaska, other human activities, such as fire suppression on forested lands, forest site preparation, noxious weed control, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, riparian habitat restoration, and urban and residential pest control, are the most common sources of these substances.

Pesticides are frequently detected in freshwater and estuarine systems that provide EFH. Pesticides can enter the aquatic environment as single chemicals or as complex mixtures. Direct applications, surface runoff, spray drift, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems. Habitat alteration from pesticides is different from more conventional water quality parameters because, unlike temperature or dissolved oxygen, the presence of pesticides can be difficult to detect due to limitations in proven methodologies. This monitoring may also be expensive. As analytical methodologies have improved in recent years, the number of pesticides documented in fish and their habitats has increased. In addition, pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus, which are then ingested by macroinvertebrates, and which, in

turn, are eaten by larger invertebrates and fish (Atlantic States Marine Fisheries Commission 1992).

### ***Potential Adverse Impacts***

There are three basic ways that pesticides can adversely affect EFH. These are (1) a direct, lethal or sublethal, toxicological impact on the health or performance of exposed fish; (2) an indirect impairment of aquatic ecosystem structure and function; and (3) a loss of aquatic macroinvertebrates that are prey for fish and aquatic vegetation that provides physical shelter for fish.

### ***Recommended Conservation Measures***

The following recommended conservation measures regarding pesticides (including insecticides, herbicides, fungicides, rodenticides, repellents, bactericides, sanitizers, disinfectants, and growth regulators) should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Incorporate integrated pest management and BMPs as part of the authorization or permitting process (Scott et al. 1999). If pesticides must be applied, consider area, terrain, weather, droplet size, pesticide characteristics, and other conditions to avoid or reduce effects to EFH.
- Carefully review labels and ensure that application is consistent with the product's directions.
- Avoid the use of pesticides within 500 linear feet and/or 1,000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, establish a 35-foot pesticide-free buffer area from any surface or marine water body and require that pesticides not be applied within 200 feet of a public water source (Alaska Department of Environmental Conservation guidelines).
- Consider current and recent meteorological conditions. Rain events may increase pesticide runoff into adjacent water bodies. Saturated soils may inhibit pesticide penetration.
- Do not apply pesticides when wind speeds exceed 10 mph.
- Begin application of pesticide products nearest to the aquatic habitat boundary and proceed away from the aquatic habitat; do not apply towards a water body.

### **5.1.3 Urban and Suburban Development**

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998 a, 1998b). Urban and suburban development and the corresponding infrastructure result in four broad categories of impacts to aquatic ecosystems: hydrological, physical, water quality, and biological (CWP 2003).

### ***Potential Adverse Impacts***

Potential impacts to EFH most directly related to general urban and suburban development discussed below are the watershed effects of land development, including stormwater runoff.

Other development-related impacts are discussed in later sections of this document, including dredging, wetland fill, and shoreline construction.

Development activities within watersheds and in coastal marine areas can impact EFH on both long and short timeframes. The Center for Watershed Protection (CWP) made a comprehensive review of the impacts associated with impervious cover and urban development and found a negative relationship between watershed development and 26 stream quality indicators (CWP 2003). The primary impacts include (1) the loss of hyporheic zones (the region beneath and next to streams where surface and groundwater mix), and riparian and shoreline habitat and vegetation; and (2) runoff. Removal of riparian and upland vegetation has been shown to increase stream water temperatures, reduce supplies of LWD, and reduce sources of prey and nutrients to the water system. An increase in impervious surfaces in a watershed, such as the addition of new roads, buildings, bridges, and parking facilities, results in a decreased infiltration to groundwater and increased runoff volumes. This also has the potential to adversely affect water quality and the shape of the hydrograph in downstream water bodies (i.e., estuaries and coastal waters).

### *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 where threats of impacts from urban and suburban development exist.

- Implement BMPs for sediment control during construction and maintenance operations (USEPA 1993).
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH.
- Where feasible, remove obsolete impervious surfaces from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
- Where instream 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.
- Use the best available technologies in upgrading wastewater systems to avoid combined sewer overflow problems and chlorinated sewage discharges into rivers, estuaries, and the ocean.
- Design and install proper wastewater treatment systems.
- Where vegetated swales are not feasible, install and maintain oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters.



#### 5.1.4 Road Building and Maintenance

Roads and trails have always been part of man's impact on his environment (Luce and Crowe 2001). Federal, state, and local transportation departments devote huge budgets to construction and upgrading of roads. As in other places, roads play an important part in access and thus are vital to the economy of Alaska (Connor 2007).

##### *Potential Adverse Impacts*

Today's road design construction and management practices have improved from the past. Roads however, still have a negative effect on the biotic integrity of both terrestrial and aquatic ecosystems (Trombulak and Frissell 2000), and the effects of roads on aquatic habitat can be profound. Potential adverse impacts to aquatic habitats resulting from existence of roads in watersheds include (1) increased surface erosion, including mass wasting events, and 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 invasive species; and (6) changes in channel configuration, and (7) the concentration and introduction of polycyclic aromatic hydrocarbons, heavy metals and other pollutants.

##### *Recommended Conservation Measures*

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

- Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes to the extent practicable.
- Build bridges rather than culverts for stream crossings 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; they should be large enough to provide for migratory passage of adult and juvenile fishes.
- Design bridge abutments to minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible.
- Specify erosion control measures in road construction plans.
- Avoid side casting of road materials on native surfaces and into streams.
- Use only native vegetation in stabilization plantings.
- Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods).
- Properly maintain roadway and associated stormwater collection systems.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats.

## 5.2 Riverine Activities

### 5.2.1 Mining

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of operations. On site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning or reclamation, and abandonment (NMFS 2004, American Fisheries Society 2000). Mining and its associated activities have the potential to cause adverse effects to EFH from exploration through post-closure. The operation of metal, coal, rock quarries, and gravel pit mines in upland and riverine areas 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, are designed to control and manage these changes to the landscape to avoid and minimize impacts. However, while environmental regulations may avoid, limit, control, or offset many potential impacts, mining will, to some degree, always alter landscapes and environmental resources (National Research Council 1999). (Additional information on mining impacts in the marine environment is covered later in this synthesis.)

#### 5.2.1.1 Mineral Mining

Mining and mineral extraction activities take many forms, such as commercial and recreational suction dredging, placer, open pit and surface mining, and contour operations. The process for mineral extraction involves exploration, mine development, mining (extraction), processing and reclamation.

#### *Potential Adverse Impacts*

The potential adverse effects of mineral mining on fish populations and EFH are well documented (Farag et al. 2003, Hansen et al. 2002, Brix et al. 2001, Goldstein et al. 1999) and depend on the type, extent, and location of the activities. Impacts associated with the extraction of material from within or near a stream or river bed may include (1) alteration in channel morphology, hydraulics, lateral migration and natural channel meander; (2) increases in channel incision and bed degradation; (3) disruption in pre-existing balance of suspended sediment transport and turbidity; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) simplification of in-channel fluvial processes and LWD deposition; (6) altered surface and ground water regimes and hydro-geomorphic and hyporheic processes; and (7) destruction of the riparian zone during extraction operations. Additional impacts may include mining-related pollution, acid mine drainage, habitat fragmentation and conversion, altered temperature regimes, reduction in oxygen concentration, the release of toxic materials (NMFS 2008), and additional impacts to wetland and riverine habitats. Many of these types of impacts have been previously introduced in the document. The additional discussion that follows is intended to round out the discussion of impacts that have not been previously introduced.

#### *Recommended Conservation Measures*

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (2009). These conservation

recommendations for mineral mining should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid mineral mining in waters, water sources and watersheds, riparian areas, hyporheic zones, and floodplains providing habitat for federally managed species.
- Schedule necessary in-water activities when the fewest species/least vulnerable life stages of federally managed species will be present.
- Minimize spillage of dirt, fuel, oil, toxic materials, and other contaminants into EFH. Prepare a spill prevention plan if appropriate.
- Treat and test wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams.
- Minimize the effects of sedimentation on fish habitat, using methods such as contouring, mulching, construction of settling ponds, and sediment curtains. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- If possible, reclaim, rather than bury, mine waste that contains heavy metals, acid materials, or other toxic compounds to limit the possibility of leachate entering groundwater.
- Restore natural contours and use native vegetation to stabilize and restore habitat function to the extent practicable. Monitor the site to evaluate performance.
- Minimize the aerial extent of ground disturbance and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments.

#### ***5.2.1.2 Sand and Gravel Mining***

In Alaska, riverine sand and gravel mining is extensive and can involve several methods: 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.

#### ***Potential Adverse Impacts***

Primary impacts associated with riverine sand and gravel mining activities include (1) turbidity plumes and re-suspension of sediment and nutrients, (2) removal of spawning habitat, and (3) alteration of channel morphology. These often lead to secondary impacts including alteration of migration patterns, physical and thermal barriers to upstream and downstream migration, increased fluctuation in water temperature, decrease in dissolved oxygen, high mortality of early life stages, increased susceptibility to predation, loss of suitable habitat (Packer et al. 2005), decreased nutrients (from loss of floodplain connection and riparian vegetation), and decreased food production (loss of invertebrates) (Spence et al. 1996).

### *Recommended Conservation Measures*

The following recommended conservation measures for sand and gravel mining are adapted from NMFS (2004) and OWRRI (1995). They should be viewed as options to avoid and minimize adverse impacts to EFH due to sand and gravel mining and promote the conservation, enhancement, and proper functioning of EFH.

- To the extent practicable, avoid sand/gravel mining in waters, water sources and watersheds, riparian areas, hyporheic zones and floodplains providing habitat for federally managed species.
- 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.
- If operations in EFH cannot be avoided, design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to living marine resources and habitat. For example, minimize the areal extent and depth of extraction.
- Include restoration, mitigation, and monitoring plans, as appropriate, in sand/gravel extraction plans.
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages.

#### 5.2.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. To reduce duplication, impacts to other systems are also addressed here.

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), plays an important role in aquatic ecosystems, including EFH. LWD and wrack promote habitat complexity and provide structure to various aquatic and shoreline habitats.

The natural deposition of LWD creates habitat complexity by altering local hydrologic conditions, nutrient availability, sediment deposition, turbidity, and other structural habitat conditions. In riverine systems, the physical structure of LWD provides cover for managed species, creates habitats and microhabitats (e.g., pools, riffles, undercut banks, and side channels), retains gravels, and helps maintain underlying channel structure (Abbe and Montgomery 1996, Montgomery et al. 1995, Ralph et al. 1994, Spence et al. 1996). LWD also plays similar role in salt marsh habitats (Maser and Sedell 1994). In benthic ocean habitats, LWD enriches local nutrient availability as deep-sea wood borers convert the wood to fecal matter, providing terrestrially-based carbon to the ocean food chain (Maser and Sedell 1994). When deposited on coastal shorelines, macrophyte wrack creates microhabitats and provides a food source for aquatic and terrestrial organisms such as isopods and amphipods, which play an important role in marine food webs.

Conversely, inorganic flotsam and jetsam debris can negatively impact EFH. Inorganic marine debris is a problem along much of the coastal United States, where it litters shorelines, fouls estuaries, entangles fish and wildlife, and creates hazards in the open ocean. Marine debris consists of a wide variety of man-made materials, including general litter, plastics, hazardous

wastes, and discarded or lost fishing gear. The debris enters waterbodies indirectly through rivers and storm water outfalls, as well as directly via ocean dumping and accidental release. Although laws and regulatory programs exist to prevent or control the problem, marine debris continues to affect aquatic resources.

### ***5.2.2.1 Organic Debris Removal***

Natural occurring flotsam, such as LWD and macrophyte wrack (i.e., kelp), is sometimes intentionally removed from streams, estuaries, and coastal shores. This debris is removed for a variety of reasons, including dam operations, aesthetic concerns, and commercial and recreational purposes (e.g., active beach log harvests, garden mulch, and fertilizer). However, the presence of organic debris is important for maintaining aquatic habitat structure and function.

### ***Potential Adverse Impacts***

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. Reductions in LWD inputs to estuaries may also affect the ecological balance of estuarine systems by altering rates and patterns of nutrient transport, sediment deposition, and availability of in-water cover for larval and juvenile fish. In rivers and streams of the Pacific Northwest, the historic practice of removing LWD to improve navigability and facilitate log transport has altered channel morphology and reduced habitat complexity, thereby negatively affecting habitat quality for spawning and rearing salmonids (Koski 1992, Sedell and Luchessa 1982).

Beach grooming and wrack removal can substantially alter the macrofaunal community structure of exposed sand beaches (Dugan et al. 2000). Species richness, abundance, and biomass of macrofauna associated with beach wrack (e.g., sand crabs, isopods, amphipods, and polychaetes) are higher on ungroomed beaches than on those that are groomed (Dugan et al. 2000). The input and maintenance of wrack can strongly influence the structure of macrofauna communities, including the abundance of sand crabs (*Emerita analoga*) (Dugan et al. 2000), an important prey species for some managed species of fish.

### ***Recommended Conservation Measures***

The recommended conservation measures for organic debris removal are listed below. They should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage the preservation of LWD whenever possible, removing it only when it presents a threat to life or property.
- Encourage appropriate federal, state, and local agencies to aid in the downstream movement of LWD around dams, culverts, and bridges wherever possible, rather than removing it from the system.
- Educate landowners and recreationalists about the benefits of maintaining LWD.
- Localize beach grooming practices, and minimize them whenever possible.
- Advise gardeners to only harvest dislodged, dead kelp and leave live, growing kelp (whether dislodged or not).

### ***5.2.2.2 Inorganic Debris***

Inorganic debris in the marine environment is a chronic problem along much of the U.S. coast, resulting in littered shorelines and estuaries with varying degrees of negative effects to coastal ecosystems. Nationally, land-based sources of marine debris account for about 80 percent of the marine debris on beaches and in U.S. waters. Debris can originate from combined sewer overflows and storm drains, stormwater runoff, landfills, solid waste disposal, poorly maintained garbage bins, floating structures, and general littering of beaches, rivers, and open waters. It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Ocean-based sources of debris also create problems for managed species. These include discarded or lost fishing gear (NMFS 2008), and galley waste and trash from commercial merchant, fishing, military, and other vessels.

#### ***Potential Adverse Impacts***

Land and ocean sourced inorganic marine debris is a very diverse problem, and adverse effects to EFH are likewise varied. Floating or suspended trash can directly affect managed species that consume or are entangled in it. Toxic substances in plastics can kill or impair fish and invertebrates that use habitat polluted by these materials. The chemicals that leach from plastics can persist in the environment and can bioaccumulate through the food web.

Once floatable debris settles to the bottom of estuaries, coastal and open ocean areas, it can continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate immobile animals and plants, creating large spaces devoid of life. Currents can carry suspended debris to underwater reef habitats where the debris can become snagged, damaging these sensitive habitats. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. Pathogens can also contaminate shellfish beds and reefs.

#### ***Recommended Conservation Measures***

Pollution prevention and improved waste management can occur through regulatory controls and best management practices. The recommended conservation measures for minimizing inorganic debris listed in the section below should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Encourage proper trash disposal, particularly in coastal and ocean settings, and participate in coastal cleanup activities.
- Advocate for local, state and national legislation that rewards proper disposal of debris.
- Encourage enforcement of regulations addressing marine debris pollution and proper disposal.
- Provide resources and technical guidance for development of studies and solutions addressing the problem of marine debris.
- Educate the public on the impact of marine debris and provide guidance on how to reduce or eliminate the problem.
- Implement structural controls that collect and remove trash before it enters nearby waterways.

- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.
- Require all existing and new commercial construction projects near the coast to develop and implement refuse disposal plans.

### 5.2.3 Dam Operation

Dams provide sources of hydropower, water storage, and flood control. Construction and operation of dams can affect basic hydrologic and geomorphic function including the alteration of physical, biological, and chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

#### *Potential Adverse Impacts (adapted from NMFS 2008)*

The effects of dam construction and operation on fish and aquatic habitat include (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow pattern alteration; (3) alteration to distribution and function of ice, sediment and nutrient budgets; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; and (5) thermal impacts. Dam construction and operations can impede or block anadromous fish passage and other aquatic species migration in streams and rivers. Unless proper fish passage structures or devices are operational, dams can either prevent access to productive upstream spawning and rearing habitat or can alter downstream juvenile migration. Turbines, spillways, bypass systems, and fish ladders also affect the quality and quantity of EFH available for salmon passage in streams and rivers (Pacific Fishery Management Council 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

#### *Recommended Conservation Measures (adapted from NMFS 2008)*

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

- Avoid construction of new dam facilities, where possible.
- Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
- Operate dams within the natural flow fluctuations rates and timing and, when possible, mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Monitor water flow and reservoir flow fluctuation.
- Understand longer term climatic and hydrologic patterns and how they affect habitat; plan project design and operation to minimize or mitigate for these changes.
- Use seasonal restrictions for construction, maintenance, and operation of dams to avoid impacts to habitat during species' critical life history stages.
- Develop and implement monitoring protocols for fish passage.
- Retrofit existing dams with efficient and functional upstream and downstream fish

passage structures.

- Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
- Downstream passage should prevent adults and juveniles from passing through the turbines and provide sufficient water downstream for safe passage.
- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
- Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
- Encourage the preservation of LWD, whenever possible.
- Develop a sediment transport and geomorphic maintenance plan to allow for peak flow mimicking that will result in sediment pulses through the reservoir/dam system and allow high flow geomorphic processes.

#### 5.2.4 Commercial and Domestic Water Use

An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide (Deegan and Buchsbaum 2005). Because human populations are expected to continue increasing in Alaska, it is reasonable to assume that water uses, including water impoundments and diversion, will similarly increase (Gregory and Bisson 1997). Groundwater supplies 87 percent of Alaska's 3,500 public drinking water systems. Ninety percent of the private drinking water supplies are groundwater. Each day, roughly 275 million gallons of water derived from aquifers, which directly support riverine systems, are used for domestic, commercial, industrial, and agricultural purposes in Alaska (Groundwater Protection Council 2010). Surface water sources serve a large number of people from a small number of public water systems (e.g., Anchorage and several southeastern communities).

##### *Potential Adverse Impacts*

The diversion of freshwater for domestic and commercial uses can affect EFH by (1) altering natural flows and the process associated with flow rates, (2) altering riparian habitats by removing water or by submersion of riparian areas, (3) removing the amount and altering the distribution of prey bases, (4) affecting water quality, and (5) entrapping fishes. Water diversions can involve either withdrawals (reduced flow) or discharges (increased flow).

##### *Recommended Conservation Measures*

These conservation measures for commercial and domestic water use should be viewed as options to avoid and minimize adverse impacts from commercial and domestic water use and promote the conservation, enhancement, and proper functioning of EFH.

- Design water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life history stages. Avoid low water levels that strand juveniles and dewater redds. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems). Install screens at water diversions on fish-bearing streams, as needed.



- Maintain water quality necessary to support fish populations by monitoring and adjusting water temperature, sediment loads, and pollution levels.
- Maintain appropriate flow velocity and water levels to support continued stream functions. Maintain and restore channel, floodplain, riparian, and estuarine conditions.
- Where practicable, ensure that mitigation is provided for unavoidable impacts to fish and their habitat.

### 5.3 Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Physical changes from shoreline construction can result in secondary impacts such as increased suspended sediment loading, shading from piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Even development projects that appear to have minimal individual impacts can have significant cumulative effects on the aquatic ecosystem (NMFS 2008).

#### 5.3.1 Dredging

The construction of ports, marinas, and harbors typically involves dredging sediments from intertidal and subtidal habitats to create navigational channels, turning basins, anchorages, and berthing docks. Additionally, periodic dredging is used to maintain the required depths after sediment is deposited into these facilities. Dredging is also used to create deepwater navigable channels or to maintain existing channels that periodically fill with sediments. (Impacts from dredging from marine mining are also addressed later.)

#### *Potential Adverse Impacts*

Dredging activities can adversely affect benthic and water-column habitat. The environmental effects of dredging on managed species and their habitat can include (1) direct removal/burial of organisms; (2) turbidity and siltation, including light attenuation from turbidity; (3) contaminant release and uptake, including nutrients, metals, and organics; (4) release of oxygen consuming substances (e.g., chemicals and bacteria); (5) entrainment; (6) noise disturbances; and (7) alteration to hydrodynamic regimes and physical habitat.

#### *Recommended Conservation Measures*

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

- Avoid new dredging in sensitive habitat areas to the maximum extent practicable.
- Reduce the area and volume of material to be dredged to the maximum extent practicable.
- Avoid dredging and placement of equipment used in conjunction with dredging operations in special aquatic sites and other high value habitat areas.

- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period).
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation.
- 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.
- Prior to dredging, test sediments for contaminants as per U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) requirements.
- Provide appropriate compensation for significant impacts (short-term, long-term, and cumulative) to benthic environments resulting from dredging.
- Identify excess sedimentation in the watershed that prompts excessive maintenance dredging activities, and implement appropriate management actions, if possible.

### 5.3.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. The discharge of dredged materials or the use of fill material in aquatic habitats can result in covering or smothering existing submerged substrates, loss of habitat function, and adverse effects on benthic communities.

#### 5.3.2.1 *Disposal of Dredged Material*

##### *Potential Adverse Impacts (adapted from NMFS 2008)*

The disposal of dredged material can reduce the suitability of water bodies for managed species and their prey by (1) reducing floodwater retention in wetlands; (2) reducing nutrients uptake and release; (3) decreasing the amount of detrital input, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) habitat conversion through alteration of water depth or substrate type; (5) removing aquatic vegetation and preventing natural revegetation; (6) impeding physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983, Cloern 1987, Dennison 1987, Barr 1993, Benfield and Minello 1996, Nightingale and Simenstad 2001a); (7) directly eliminating sessile or semi-mobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990, McGraw and Armstrong 1990, Barr 1993, Newell et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); and (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000a).

##### *Recommended Conservation Measures*

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

- Avoid disposing dredged material in wetlands, submerged aquatic vegetation (SAV) and other special aquatic sites whenever possible.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements.

- Ensure that disposal sites are properly managed and monitored to minimize impacts associated with dredge material.
- Where long-term maintenance dredging is anticipated, acquire and maintain disposal sites for the entire project life.
- Encourage beneficial uses of dredged materials.

### **5.3.2.2 Fill Material**

Like the discharge of dredged material, the discharge of fill material to create upland areas can remove productive habitat and eliminate important habitat functions.

#### ***Potential Adverse Impacts***

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

#### ***Recommended Conservation Measures***

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

- Federal, state, and local resource management and permitting agencies should address the cumulative impacts of fill operations on EFH.
- Minimize the areal extent of any fill in EFH, or avoid it entirely.
- Consider alternatives to the placement of fill into areas that support managed species.
- Fill should be sloped to maintain shallow water, photic zone productivity; allow for unrestricted fish migration; and provide refugia for juvenile fish.
- In marine areas of kelp and other aquatic vegetation, fill (including artificial structure fill reefs) should be designed to maximize kelp colonization and provide areas for juvenile fish to find shelter from higher currents and exposure to predators.
- Fill materials should be tested and be within the neutral range of 7.5 to 8.4 pH.

### **5.3.3 Vessel Operations, Transportation, and Navigation**

In Alaska, the growth in coastal communities is putting demands on port districts to increase infrastructure to accommodate additional vessel operations for cargo handling and marine transportation. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size. In addition, increasing boat sales have put more pressure on improving and building new harbors, an important factor in Alaska because of the limited number of roads.

#### ***Potential Adverse Impacts***

Activities associated with the expansion of port facilities, vessel/ferry operations, and recreational marinas can directly and indirectly impact EFH. Impacts include (1) loss and conversion of habitat; (2) altered light regimes and loss of submerged aquatic vegetation; (3)

altered temperature regimes; (4) siltation, sedimentation, and turbidity; (5) contaminant releases; and; and (6) altered tidal, current, and hydrologic regimes.

### ***Recommended Conservation Measures***

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

- Locate marinas in areas of low biological abundance and diversity.
- Leave riparian buffers in place to help maintain water quality and nutrient input.
- Include low-wake vessel technology, appropriate routes, and BMPs for wave attenuation structures as part of the design and permit process.
- 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.
- Locate mooring buoys in water deep enough to avoid grounding and to minimize the effects of prop wash.
- Use catchment basins for collecting and storing surface runoff to remove contaminants prior to delivery to any receiving waters.
- Locate facilities in areas with enough water velocity to maintain water quality levels within acceptable ranges.
- Locate marinas where they do not interfere with natural processes so as to affect adjacent habitats.
- To facilitate movement of fish around breakwaters, breach gaps and construct shallow shelves to serve as “fish benches,” as appropriate.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

#### **5.3.4 Invasive Species**

Introductions of invasive 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 be spread via shipping, recreational boating, aquaculture, biotechnology, and aquariums. The introduction of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori et al. 1994).

Invasive aquatic species that are considered high priority threats to Alaska’s marine waters include Atlantic salmon (*Salmo salar*), green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), signal crayfish (*Pacifastacus leniaculus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass

(*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).<sup>1</sup>

### **Potential Adverse Impacts**

Invasive species can create five types of negative effects on EFH: (1) habitat alteration, (2) trophic alteration, (3) gene pool alteration, (4) spatial alteration, and (5) introduction of diseases.

### **Recommended Conservation Measures**

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

- 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.
- Adhere to regulations and use best management practices outlined in the State of Alaska Aquatic Nuisance Species Management Plan (Fay 2002).
- Encourage vessels to perform a ballast water exchange in marine waters to minimize the possibility of introducing invasive estuarine species into similar habitats.
- Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
- Require vessels brought from other areas over land via trailer to clean any surfaces that may harbor non-native plant or animal species (e.g., propellers, hulls, anchors, fenders).
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

#### **5.3.5 Pile Installation and Removal (From NMFS 2005)**

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 or vibratory hammers.

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<sup>1</sup> <http://www.adfg.state.ak.us/special/invasive/invasive.ph>

### 5.3.5.1 Pile Driving

#### *Potential Adverse Impacts*

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). Fish injuries associated directly with pile driving are poorly studied, but include rupture of the swim bladder 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 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. 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. The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Confined (i.e., metal or fabric sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures (Longmuir and Lively 2001, Christopherson and Wilson 2002, Reyff and Donovan 2003).

#### 5.3.5.2 Recommended Conservation Measures

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

- 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:

- Drive piles during low tide when they are located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles.
- Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1  $\mu$ Pa) threshold.
- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided.

- Drive piles when the current is reduced in areas of strong current, to minimize the number of fish exposed to adverse levels of underwater sound.

### 5.3.5.3 Pile Removal

#### *Potential Adverse Impacts*

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments (see earlier). Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing that the stub is left in place, and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles may, however, suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate using these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling.

While there is a potential to adversely affect EFH during the removal of piles, many of the piles removed in Alaska are old creosote-treated timber piles. In some cases, the long-term benefits to EFH obtained by removing a chronic source of contamination may outweigh the temporary adverse effects of turbidity.

#### *Recommended Conservation Measures*

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

- Remove piles completely rather than cutting or breaking them off, if they are structurally sound.
- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
  - When practicable, remove piles with a vibratory hammer.
  - Remove the pile slowly to allow sediment to slough off at, or near, the mudline.
  - The operator should first hit or vibrate the pile to break the bond between the sediment and the pile.
  - Encircle the pile, or piles, with a silt curtain that extends from the surface of the water to the substrate.
- Complete each pass of the clamshell to minimize suspension of sediment if pile stubs are removed with a clamshell.
- Place piles on a barge equipped with a basin to contain attached sediment and runoff water after removal.

- Using a pile driver, drive broken/cut stubs far enough below the mudline to prevent release of contaminants into the water column as an alternative to their removal.

### 5.3.6 Overwater Structures (from NMFS 2005)

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).

#### *Potential Adverse Impacts*

Overwater structures and associated developments may adversely affect EFH in a variety of ways, primarily by (1) changes in ambient light conditions, (2) alteration of the wave and current energy regime, (3) introduction of contaminants into the marine environment, and (4) activities associated with the use and operation of the facilities (Nightingale and Simenstad 2001b).

#### *Recommended Conservation Measures*

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

- Use upland boat storage whenever possible to minimize need for overwater structures.
- 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.
- Design piers, docks, and floats to be multiuse facilities to reduce the overall number of such structures and to limit impacted nearshore habitat.
- Incorporate measures that increase the ambient light transmission under piers and docks.
  - Maximize the height and minimize the width to decrease the shade footprint.
  - Use reflective materials on the underside of the dock to reflect ambient light.
  - Use the fewest number of pilings necessary to support the structures.
  - 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.
- 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.
- Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal or shallow subtidal zone.
- Maintain at least 1 foot (0.30 meter) of water between the substrate and the bottom of the float at extreme low tide.
- Conduct in-water work when managed species and prey species are least likely to be impacted.



- To the extent practicable, avoid the use of treated wood timbers or pilings.
- Mitigate for unavoidable impacts to benthic habitats.

### 5.3.7 Flood Control/Shoreline Protection (from NMFS 2005)

Structures designed to protect humans from flooding events can result in varying degrees of change in the physical, chemical, and biological characteristics of shoreline and riparian habitat. These structures also can 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 in between that are in equilibrium with the prevailing climatic, hydrographic, geological, and biological features of the coast. These systems normally drain through 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 may include 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.

#### *Potential Adverse Impacts*

Dikes, levees, ditches, or other water controls at the upper end of a tidal marsh can cut off all tributaries feeding the marsh, preventing the flow of freshwater, annual renewal of sediments and nutrients, and the formation of new marshes. Water controls within the marsh can intercept and carry away freshwater drainage, thus blocking freshwater from flowing across seaward portions of the marsh, or conversely increase the speed of runoff of freshwater to the bay or estuary. This can result in lowering the water table, which may permit saltwater intrusion into the marsh, and create migration barriers for aquatic species. In deeper channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life (NMFS 2008). Acid conditions of these channels can also result in release of heavy metals from the sediments.

Long-term effects of shoreline protection structures on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, greatly reduced invertebrate populations, and general loss of productive wetland characteristics (NMFS 2005). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods (NMFS 2008). Armoring shorelines to prevent erosion and to maintain or create shoreline real estate can reduce 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, changes in sediment storage capacity, loss of organic debris, and downdrift 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 for flood and shoreline protection should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- Avoid or minimize the loss of coastal wetlands as much as possible.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft in lieu of “hard” shoreline stabilization and modifications.
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when “hard” shoreline stabilization is deemed necessary.
- Include efforts to preserve and enhance fishery habitat to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams.
- Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
- Use seasonal restrictions to avoid impacts to habitat during critical life history stages.
- Address the cumulative impacts of development activities in the review process for flood control and shoreline protection projects.
- Use an adaptive management plan with ecological indicators to oversee monitoring and to ensure that mitigation objectives are met. Take corrective action as needed.

#### **5.3.8 Log Transfer Facilities/In-Water Log Storage (from NMFS 2005)**

Rivers, estuaries, and bays were historically the primary ways to transport and store logs in the Pacific Northwest, and log storage continues in some tidal areas today. Using estuaries and bays and nearby uplands for storage of logs is common in Alaska, with most log transfer facilities (LTFs) found in Southeast Alaska and a few located in Prince William Sound. LTFs are facilities that are constructed wholly or in part in waterways and used to transfer commercially harvested logs to or from a vessel or log raft, or for consolidating logs for incorporation into log rafts (USEPA 2000b). LTFs may use a crane, A-frame structure, conveyor, slide, or ramp to move logs from land into the water. Logs can also be placed in the water at the site by helicopters.

#### ***Potential Adverse Impacts***

Log handling and storage in the estuaries and intertidal zones can result in modification of benthic habitat and water quality degradation within the area of bark deposition (Levings and Northcote 2004). EFH may be physically impacted by activities associated with LTFs. LTFs may cause shading and other indirect effects similar in many ways to those of floating docks and other over-water structures (see earlier).

### ***Recommended Conservation Measures***

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

The physical, chemical, and biological impacts of LTF operations can be substantially reduced by adherence to appropriate siting and operational constraints. Adherence to the Alaska Timber Task Force (ATTF) operational and siting guidelines and BMPs in the National Pollutant Discharge Elimination System (NPDES) General Permit will reduce (1) the amount of bark and wood debris that enters the marine and coastal environment, (2) the potential for displacement or harm to aquatic species, and (3) the accumulation of bark and wood debris on the ocean floor. The following conservation measures reflect those guidelines.<sup>2</sup>

- Restrict or eliminate storage and handling of logs from waters where state and federal water quality standards cannot be met at all times outside of the authorized zone of deposition.
- Minimize potential impacts of log storage by employing effective bark and wood debris control, collection, and disposal methods at log dumps, raft building areas, and mill-side handling zones; avoiding free-fall dumping of logs; using easy let-down devices for placing logs in the water; and bundling logs before water storage (bundles should not be broken except on land and at millside).
- Do not store logs in the water if they will ground at any time or shade sensitive aquatic vegetation such as eelgrass.
- Avoid siting log-storage areas and LTFs in sensitive habitat and areas important for specified species, as required by the ATTF guidelines.
- Site log storage areas and LTFs in areas with good currents and tidal exchanges.
- Use land-based storage sites where possible.

### **5.3.9 Utility Line, Cables, and Pipeline Installation**

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, and other utilities. 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 direct impacts occur during construction, 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 due to ground clearing and construction.

### ***Potential Adverse Impacts***

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 and

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<sup>2</sup> See also [http://www.fs.fed.us/r10/TLMP/F\\_PLAN/APPEND\\_G.PDF](http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF).

release of contaminants, (4) changes in hydrology, and (5) destruction of vertically complex hard bottom habitat (e.g., hard corals and vegetated rocky reef).

### *Recommended Conservation Measures*

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

- Align crossings along the least environmentally damaging route.
- 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 intertidal zone.
- Store and contain excavated material on uplands.
- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation, and at original marsh elevations.
- Use existing rights-of-way whenever possible.
- Bury pipelines and submerged cables where possible.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass).
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles.
- Limit construction equipment to the minimum size necessary to complete the work.
- Conduct construction during the time of year when it will have the least impact on sensitive habitats and species.
- Suspend transmission lines beneath existing bridges or conduct directional boring under streams to reduce the environmental impact.
- For activities on the Continental Shelf, implement the following to the extent practicable:
  - Shunt drill cuttings through a conduit and either discharge the cuttings near the sea floor, or transport them ashore.
  - Locate drilling and production structures, including pipelines, at least 1 mile (1.6 kilometers) from the base of a hard-bottom habitat.
  - Bury pipelines at least 3 feet (0.9 meter) beneath the sea floor whenever possible.
  - Locate alignments along routes that will minimize damage to marine and estuarine habitat.

### 5.3.10 Mariculture

Productive embayments are often used for commercial culturing and harvesting operations. These locations provide protected waters for geoduck, oyster, and mussel culturing. In 1988, Alaska passed the Alaska Aquatic Farming Act (AAF Act) which is designed to encourage establishment and growth of an aquatic farming industry in the state. The AAF Act establishes four criteria for issuance of an aquatic farm permit, including the requirement that the farm may not significantly affect fisheries, wildlife, or other habitats in an adverse manner. Aquatic farm permits are issued by the Alaska Department of Natural Resources (ADNR).

#### *Potential Adverse Impacts*

Shellfish aquaculture tends to have less impact on EFH than finfish aquaculture because the shellfish generally are not fed or treated with chemicals (OSPAR Commission 2009). Adverse impacts to EFH by mariculture operations include (1) risk of introducing undesirable species and disease; (2) physical disturbance of intertidal and subtidal areas; and (3) impacts on estuarine food webs, including disruption of eelgrass habitat (e.g., dumping of shell on eelgrass beds, repeated mechanical raking or trampling, and impacts from predator exclusion netting, though few studies have documented impacts). Hydraulic dredges used to harvest oysters in coastal bays can cause long-term adverse impacts to eelgrass beds by reducing or eliminating the beds (Phillips 1984).

#### *Recommended Conservation Measures*

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

- Site mariculture operations away from kelp or eelgrass beds.
- Do not enclose or impound tidally influenced wetlands for mariculture.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.
- Encourage development of harvesting methods to minimize impacts on plant communities and the loss of food and/or habitat to fish populations during harvesting operations.
- Provide appropriate mitigation for the unavoidable, extensive, or permanent loss of plant communities.
- Ensure that mariculture facilities, spat, and related items transported from other areas are free of nonindigenous species.

## 5.4 Coastal/Marine Activities

### 5.4.1 Point-Source Discharges

Point source pollutants are generally introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of

the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff may be combined in a single discharge. Point source discharges introduce inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

### ***Potential Adverse Impacts (adopted from NMFS 2008)***

The Clean Water Act (CWA) includes important provisions to address acute or chronic water pollution emanating from point source discharges. Under the NPDES program, most point-source discharges are regulated by the state or EPA. While the NPDES program has led to ecological improvements in U.S. waters, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels.

Determining the fate and effect of natural and synthetic contaminants in the environment requires an interdisciplinary approach to identify and evaluate all processes sensitive to pollutants. This is critical as adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Exposure to pollutants can inhibit (1) basic detoxification mechanisms, e.g., production of metallothioneins or antioxidant enzymes; (2) disease resistance; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

### ***Recommended Conservation Measures***

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

- Locate discharge points in coastal waters well away from shellfish beds, sea grass beds, corals, and other similar fragile and productive habitats.
- Reduce potentially high velocities by diffusing effluent to acceptable velocities.
- Determine baseline benthic productivity by sampling before any construction activity.
- Provide for mitigation when degradation or loss of habitat occurs.
- Institute source-control programs that effectively reduce noxious materials.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs.
- Treat discharges to the maximum extent practicable.
- Use land-treatment and upland disposal/storage techniques where possible.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

## 5.4.2 Seafood Processing Waste—Shoreside and Vessel Operation

Seafood processing is conducted throughout much of coastal Alaska. Processing facilities may be vessel-based or located onshore (ADEC 2010a). 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, recreational fish cleaning at marinas and small harbors can produce a large quantity of fish waste.

Pollutants of concern from seafood processing wastewater are primarily components of the biological wastes generated by processing raw seafood into a marketable form, chemicals used to maintain sanitary conditions for processing equipment and fish containment structures, and refrigerants (ammonia and freon) that may leak from refrigeration systems used to preserve seafood (ADEC 2010b). Biological wastes include fish parts (e.g., heads, fins, bones, and entrails) and chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

### *Potential Adverse Impacts*

Seafood processing operations have the potential to adversely affect EFH through the discharge of nutrients, chemicals, fish byproducts, and “stickwater” (water and entrained organics originating from the draining or pressing of steam-cooked fish products). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Therriault et al. 2006, Roy Consultants 2003, Lotze et al. 2003). Although fish waste is biodegradable, fish parts that are ground to fine particles may remain suspended for some time, thereby overburdening habitats from particle suspension (NMFS 2005). Scum and foam from seafood waste deposits can also occur on the water surface and/or increase turbidity. Turbidity decreases light penetration into the water column, reducing primary production. 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 for fish processing waste should be viewed as options to avoid and minimize adverse impacts and promote the conservation, enhancement, and proper functioning of EFH.

- To the maximum extent practicable, base effluent limitations on site-specific water quality concerns.
- Encourage the use of secondary or wastewater treatment systems where possible.
- Do not allow designation of new zones of deposit for fish processing waste and instead seek disposal options that avoid an accumulation of waste.
- Promote sound recreational fish waste management through a combination of fish-cleaning restrictions, public education, and proper disposal of fish waste.
- Encourage alternative uses of fish processing wastes.

- Explore options for additional research.
- Monitor biological and chemical changes to the site of processing waste discharges.

#### 5.4.3 Water Intake Structures/Discharge Plumes

Withdrawals of riverine, estuarine, and marine waters are common for a variety of uses such as 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.

##### *Potential Adverse Impacts*

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) degrading water quality, (4) operation and maintenance, and (5) construction-related impacts.

##### *Recommended Conservation Measures*

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

- 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.
- Design intake structures to minimize entrainment or impingement.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA.
- Regulate discharge temperatures so they do not appreciably alter the ambient temperature to an extent that could cause a change in species assemblages and ecosystem function in the receiving waters.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible.
- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe.

#### 5.4.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). The ADNOR Division of Oil and Gas exercises similar authority over State waters (ADNR1999). Offshore petroleum exploration, development, and production activities have been conducted in Alaska waters or on the Alaska OCS in since the 1960s (Kenai Peninsula Borough 2004). 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.



### ***Potential Adverse Impacts***

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, and can cause an assortment of physical, chemical, and biological disturbances (NMFS 2005, Helvey 2002). (Some of these disturbances are listed below; however, not all of the potential disturbances in this list apply to every type of activity.)

Noise from seismic surveys, vessel traffic, and construction of drilling platforms or islands

Physical alterations to habitat from the 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

Waste discharges, including well drilling fluids, produced waters, surface runoff and deck drainage, domestic waste waters generated from the offshore facility, solid waste from wells (drilling muds and cuttings), and other trash and debris from human activities associated with the facility

Oil spills

Platform storage and pipeline decommissioning

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. New technological advances in operating procedures also reduce the potential for impacts.

### ***Recommended Conservation Measures***

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

- Avoid the discharge of produced waters into marine waters and estuaries.
- Avoid discharge of muds and cuttings into the marine and estuarine environment.
- To the extent practicable, avoid the placement of fill to support construction of causeways or structures in the nearshore marine environment.
- As required by federal and state regulatory agencies, encourage the use of geographic response strategies that identify EFH and environmentally sensitive areas.
- Evaluate potential impacts to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies which detail environmentally sensitive areas of Alaska's coastline.

#### 5.4.5 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. Good water quality and quantity, appropriate substrate, ample food sources, and adequate shelter from predators are 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 fish stocks by increasing or improving ecological structure and functions. Habitat restoration and enhancement may include, but is not limited to, improvement of coastal wetland tidal exchange or reestablishment of natural hydrology; dam or berm removal; fish passage barrier removal or modification; road-related sediment source reduction; natural or artificial reef, substrate, or 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; and improvements to feeding, shade or refuge, spawning, and rearing areas that are essential to fisheries.

##### *Potential Adverse Impacts*

The implementation of restoration and 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 removal feeding opportunities, (4) indirect effects from construction phase of the activity, (5) direct disturbance or removal of native species, and (6) temporary or permanent habitat disturbance.

##### *Recommended Conservation Measures*

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

- Use BMPs to minimize and avoid potential impacts to EFH during restoration activities.
  - Use turbidity curtains, hay bales, and erosion mats.
  - Plan staging areas in advance, and keep them to a minimum size.
  - Establish buffer areas around sensitive resources.
  - Remove invasive plant and animal species from the proposed action area before starting work. Plant only native plant species.
  - Establish temporary access pathways before restoration activities.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site.
- Conduct monitoring before, during, and after project implementation.
- To the extent practicable, mitigate any unavoidable damage to EFH.

- Remove and, if necessary, restore any temporary access pathways and staging areas used.
- 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.

#### 5.4.6 Marine Mining

Mining activities, which are also described in Sections 3.1.1 and 3.1.2 of the EFH EIS (NMFS 2005), can lead to the direct loss or degradation of EFH for certain species. Offshore mining, such as the extraction of gravel and gold in the Bering Sea, can increase turbidity, and resuspension of organic materials could impact eggs and recently hatched larvae in the area. Mining large quantities of beach gravel can also impact turbidity, and may significantly affect the transport and deposition of sand and gravel along the shore, both at the mining site and down-current (NMFS 2005).

##### *Potential Adverse Impacts*

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculants) (NMFS 2005). Physical 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. Submarine disposal of mine tailings can also alter the behavior of marine organisms.

##### *Recommended Conservation Measures*

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

- To the extent practicable, avoid mining in waters containing sensitive marine benthic habitat, including EFH (e.g., spawning, migrating, and feeding sites).
- Minimize the areal extent and depth of extraction to reduce recolonization times.
- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels.
- Monitor individual mining operations to avoid and minimize cumulative impacts.
- Use seasonal restrictions as appropriate; to avoid and minimize impacts to EFH during critical life history stages of managed species (e.g., migration and spawning).
- Deposit tailings within as small an area as possible.

## 5.5 References

- Abbe, T.B. and D.R. Montgomery. 1996. "Large woody debris jams, channel hydraulics, and habitat formation in large rivers." *Regulated Rivers: Research and Management*. 12:201-221.  
<http://www.cems.uvm.edu/ce361/papers/abbe1996.pdf>
- Abbott, R. and E. Bing-Sawyer. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Othodon microlepidotus*). Draft report prepared for Caltrans District 4. October 10, 2002.
- Alaska Department of Environmental Conservation (ADEC). 2010a. Ocean Discharge Criteria Evaluation Alaska Offshore Seafood Processors APDES General Permit AKG523000. Prepared by Tetra Tech, 10306 Eaton Place Suite 340, Fairfax, VA 22030. 152 pp.
- ADEC. 2010b. Wastewater Discharge Authorization Program, 555 Cordova Street, Anchorage, AK 99501. Fact Sheet Alaska Offshore Seafood Processors General Permit AKG523000. 43 pp.
- Alaska Department of Natural Resources (ADNR). 1999. Cook Inlet Areawide 1999 Oil and Gas Lease Sale, Final Finding of the Director. Volume II. Appendix B: "Laws and Regulations Pertaining to Oil and Gas Exploration, Development, Production, and Transportation."
- American Fisheries Society (AFS). 2000. AFS Policy Statement #13: Effects of Surface Mining on Aquatic Resources in North America (Revised). (Abbreviated) [http://www.fisheries.org/afs/docs/policy\\_13f.pdf](http://www.fisheries.org/afs/docs/policy_13f.pdf)
- Arruda, J.A., G.R. Marzolf, R.T. Faulk. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64(5):1225-35.
- Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.
- Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.
- Benfield, M.C. and T. J. Minello. 1996. "Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish." *Environmental Biology of Fishes*. 46:211-216.
- Brix, K.V., D.K. DeForest, and W.J. Adams 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. *Environmental Toxicology and Chemistry*. 20(8): 1846-1856.
- Caltrans. 2001. Fisheries Impact Assessment, Pile Installation Demonstration Project for the San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project, August 2001. 59 pp.
- Capuzzo J.M., and J.J. Sassner Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis L.* and *Mya arenaria L.* In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.
- Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, [www.cwp.org](http://www.cwp.org). 141 pp.
- Christopherson, A. and J. Wilson. 2002. Technical Letter Report Regarding the San Francisco-Oakland Bay Bridge East Span Project Noise Energy Attenuation Mitigation. Peratrovich, Nottingham & Drage, Inc. Anchorage, Alaska. 27 pp.

- Cloern, J.E. 1987. "Turbidity as a control on phytoplankton biomass and productivity in estuaries." *Continental Shelf Research*. 7:1367-1381.
- Conner, Billy, Director Alaska University Transportation Center. University of Alaska, Fairbanks PO Box 755900. 2007 Interview in Building Alaska. [http://www.buildingalaskamovie.com/interviews\\_billy.html](http://www.buildingalaskamovie.com/interviews_billy.html)
- Deegan, L.A. and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.
- Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." *Aquatic Botany*. 27:15-26.
- Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. pp 339-346. In Brown, D.R., K.L. Mitchell, and H.W. Chang, eds. Proceedings of the Fifth California Islands Symposium. Minerals Management Service Publication # 99-0038.
- Farang, A.M., D.A. Skaar, E. Nimick, C. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonids mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. *Transaction of the American Fisheries Society* 132(3): 450-457.
- Fay, V. 2002. Alaska Aquatic Nuisance Species Management Plan. Alaska Department of Fish and Game Publication. Juneau, AK. [http://www.adfg.state.ak.us/special/invasive/ak\\_ansmp.pdf](http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf).
- Goldstein, J.N., D.F. Woodward, and A.M. Farang. 1999. Movement of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. *Transactions of the American Fisheries Society* 128:121-129.
- Gregory, S.V. and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In Stouder, J.D., P.A. Bisson, and R.J. Naiman, eds. *Pacific Salmon and Their Ecosystems: Status and Future Options*, pp. 277-314. Chapman and Hall, New York.
- Groundwater Protection Council. 2010. State Groundwater Fact Sheets. [http://www.gwpc.org/e-library/documents/state\\_fact\\_sheets/alaska.pdf](http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf). Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.
- Hansen, J.A., Lipton J., and Welsh P.G. 2002. *Environmental toxicology and chemistry*. 21 (3): 633-639
- Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. August 26, 2002. Revised August 27, 2002. 8 pp.
- Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" *ICES Journal of Marine Science*. 59:S266-S271.
- Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Peninsula Borough Oil and Gas History. <http://www.cookinletoilandgas.org/kpb/history.htm>
- Kohler, C.C. and W.R. Courtenay, Jr. 1986. "Introduction of aquatic species." *Fisheries*. 11(2):39-42. Proceedings of the Seventh International Zebra Mussel and Aquatic Nuisance Species Conference. 1997.

- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. Pages 343-404 in G. W. Thayer (editor) Restoring the nation's marine environment. Publication UM-SG-TS-92-06. Maryland Sea Grant College, College Park, MD.
- Larson, K. and C. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington Sea Grant. pp. 102-112.
- Levings, C.D. and T. G. Northcote. 2004. Effects of forestry on estuarine ecosystems supporting fishes. In T.G. Northcote and G.F. Hartman, editors, Fishes and Forestry Worldwide Watershed Interactions and Management, Blackwell Publishing, pp 320 -335.
- Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Report by Fraser River Pile & Dredge Ltd., New Westminster, British Columbia. 9 pp.
- Lotze, H., I. Milewski, B. Worm, and Z. Koller. 2003 Nutrient Pollution: A Eutrophication Survey of Eelgrass Beds in Estuaries and Coastal Bays in Northern and Eastern New Brunswick. Conservation Council of New Brunswick Inc.
- Luce, A. and M. Crowe. 2001. "Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada." *Great Lakes Entomologist*. 34(1):55-60 SPR-SUM.
- Luoma, S.N. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. *Journal of Experimental Marine Biology and Ecology* 200:29-55.
- Maser, C. and J.R. Sedell. 1994. From the Forest to the Sea: the Ecology of Wood in Streams, Estuaries and Oceans. St. Lucie Press, Delray Beach, FL. 200 pp.
- McGraw, K. and D. Armstrong. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington Sea Grant. pp. 113-131.
- Mitsch WJ, Gosselink JG. 1993. Wetlands. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.
- Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. "Pool Spacing in Forest Channels." *Water Resources Research*. 31:1097-1105.
- NMFS. 2011. Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska. National Marine Fisheries Service, Alaska Region. Juneau, Alaska. November, 2011.
- NMFS. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. Northeast Regional Office Gloucester, Massachusetts NOAA Technical Memorandum NMFS-NE-209.
- NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska, Appendix G Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures.
- NMFS. 2004. Draft National Gravel Extraction Policy. 1335 East-West Highway, Silver Spring, MD 20910. <http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/gravelguidance.pdf>
- NMFS. 2002. Environmental Assessment, NMFS' Restoration Plan for the Community-Based Restoration Program. Prepared by the NOAA Restoration Center, Office of Habitat Conservation. Silver Spring, MD.
- NMFS. 1998a. Draft document - Non-fishing threats and water quality: A reference for EFH consultation

- NMFS. 1998b. Final recommendations: Essential Fish Habitat for Pacific Coast Groundfish. Prepared by: The Core Team for EFH for Pacific Coast Groundfish June 3, 1998. 2725 Montlake Blvd. E. Seattle, WA 98112. [http://www.psmfc.org/efh/groundfish\\_desc.pdf](http://www.psmfc.org/efh/groundfish_desc.pdf).
- National Oceanic and Atmospheric Agency (NOAA). 2010. Office of Ocean and Coastal Resource Management. Ocean and Coastal Management in Alaska. <http://coastalmanagement.noaa.gov/mystate/ak.html>.
- National Research Council. 1999. Committee on Hardrock Mining. Hardrock Mining on Federal Lands. Appendix B. Potential Environmental Impacts of Hardrock Mining. ([http://www.nap.edu/html/hardrock\\_fed\\_lands/appB.html](http://www.nap.edu/html/hardrock_fed_lands/appB.html)).
- Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). *Estuaries* 14(3):318-31.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. "The impact of dredging on biological resources of the sea bed." *Oceanography and Marine Biology Annual Review*. 36:127-178.
- Nightingale, B. and C.A. Simenstad. 2001a. Dredging activities: Marine issues. Washington State Transportation Center, University of Washington, Seattle, WA 98105. (Document available through the National Technical Information Service, Springfield, VA 22616).
- Nightingale, B. and C.A. Simenstad. 2001b. Overwater Structures: Marine Issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. [www.wa.gov/wdfw/hab](http://www.wa.gov/wdfw/hab). 133 pp.
- North Pacific Fishery Management Council and NMFS. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010 Summary Report: Final. April 2010. <http://alaskafisheries.noaa.gov/habitat/efh/review.htm>.
- Northcote, T.G. and G.F. Hartman. 2004. *Fishes and Forestry - Worldwide Watershed Interactions and Management*, Blackwell Publishing, Oxford, UK, 789 pp.
- Omori, M., S. Van der Spoel, C.P. Norman. 1994. Impact of human activities on pelagic biogeography. *Progress in Oceanography* 34 (2-3):211-219.
- Oregon Water Resource Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health, volume 1. Summary report. Oregon State University, Corvallis, Oregon. (Also available Vol. II: Technical background report). Available from Oregon Division of State Lands, Salem, Oregon, 503-378-3805.
- OSPAR Commission. 2009. Assessment of Impacts of Mariculture . Publication Number: 442/2009. London, UK
- Pacific Fishery Management Council. 1999. Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. Portland, OR. 146 pp.
- Packer, D.B., Griffin K., McGlynn K.E. 2005. National Marine Fisheries Service national gravel extraction guidance. Washington (DC): US Department of Commerce. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: <http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>.
- Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24. 85 pp.

- Ralph, S., G. Poole, L. Conquest, and R. Naiman. 1994. "Stream channel morphology and woody debris in logged and unlogged basins in western Washington." *Can. J. Fish. Aquatic Sciences*. 51:37-51.
- Reyff, J.A and P. Donovan. 2003. Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data. Memo to Caltrans dated January 31, 2003. 3 pp.
- Robinson W.E., and Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.
- Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of *Pseudorabara parva*, an exotic fish species introduced into lake Mikri Prespa (northwestern Greece). *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:223-231.
- Roy Consultants Ltd., NATECH Environmental Services Inc. and OCL Group. Environmental Management Consultants. 2003. Lamèque Bay environmental management study. Report No. 133-01.
- Scott G.I., M.H. Fulton, D.W. Moore, E.F. Wirth, G.T. Chandler, P.B. Key, J.W. Daugomah, E.D. Strozier, J. Devane, J.R. Clark, M.A. Lewis, D.B. Finley, W. Ellenberg, and K.J. Karnaky. 1999. "Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems." *Toxicology and Industrial Health*. 15:200-213.
- Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), Acquisition and utilization of aquatic habitat inventory information, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.
- Sengupta, M. 1993. Environmental Impacts of Mining: Monitoring, Restoration, and Control. CRC Press, Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL. 33431. p.1.
- Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. 356 pp. (Available from the NMFS Habitat Branch, Portland, OR).
- Stadler, J.H. 2002. Personal observation of fish-kill occurring during pile driving activity at the Winslow Ferry Terminal, Winslow, WA. October 7, 2002. Fish Biologist, DOC/NOAA/National Marine Fisheries Service/HCD, Lacey, WA.
- Stiles, S., J. Choromanski, D. Nelson, J. Miller, R. Grieg, and G. Sennefelder. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. *Estuaries* 14(3):332-42.
- Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.
- Therriault, M.H., S.C. Courtenay, C. Godin and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. *Can. Tech. Rep. Fish. Aquat. Sci.* 2649: vii + 60 p.
- Thurberg, F.P., and E. Gould. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.



- Trombulak, S.C. and C.A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology*. 14(10):18-30. February.
- USDA Forest Service. 2008. Tongass Monitoring and Evaluation Report – Appendix B  
[http://www.fs.fed.us/r10/tongass/projects/tlmp/2008\\_monitoring\\_report/index2008.shtml](http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml)
- USEPA. 2000a. Environmental Screening Checklist and Workbook for the Water Transportation Industry. August 2000.
- USEPA, Region 10. 2000b. Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) for Section 402 modifications of Section 404 permits for log Transfer Facilities which received a Section 404 permit prior to October 22, 1985. NPDES Permit Number AK-G70-0000. March 2000. 1200 Sixth Avenue, OW-130 Seattle, Washington 98101.
- USEPA. 1993. Guidance for specifying management measures for sources of nonpoint pollution in coastal waters. EPA Office of Water. 840-B-92-002. 500+ pp.
- Washington Department of Fish and Wildlife. 2009. Gold and fish. Rules for mineral prospecting and placer mining. 2nd edition. April 2009. Olympia, WA.
- Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energetics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) 220 transplanted along a contamination gradient in Bermuda. *Journal of Experimental Marine Biology and Ecology* 138:99-117.
- Williams, G.D. and R.M. Thom. 2001. Marine and estuarine shoreline modification issues. White paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation. [www.wa.gov/wdfw/hab/ahg](http://www.wa.gov/wdfw/hab/ahg). 99 pp.