Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska

November 2011

Prepared by
National Marine Fisheries Service, Alaska Region

This document is the update to Appendix G of the 2005 Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. The following people contributed to this update (listed in alphabetical order): Erika Ammann, Chiska Derr, Matthew Eagleton, Jeanne Hanson, Cindy Hartmann Moore, Brian Lance, Doug Limpinsel, Katharine Miller, Linda Shaw, and Susan Walker.

National Marine Fisheries Service, Alaska Region

Table of Contents

Acronyms and Abbreviations

AAF Act	Alaska Aquatic Farming Act
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation and Public Facilities
AISWG	Alaska Invasive Species Working Group
AMD	Acid Mine Drainage
ATTF	Alaska Timber Task Force
BEACH Act	Beaches Environmental Assessment and Coastal Health Act of 2000
BMP	Best Management Practices
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CWA	Clean Water Act
CWP	Center for Watershed Protection
dB	decibel
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FL	fork length
FMC	Fisheries Management Council
FMP	Fishery Management Plan
GRS	Geographic Response Strategies
hz	hertz
LTF	log transfer facilities
LWD	large woody debris

mm	millimeter
MMS	Minerals Management Service
MSA	Magnuson-Stevens Fishery Conservation and Management Act
mph	miles per hour
nm	nautical mile
NEPA	National Enviornmental Policy Act
NMDMP	National Marine Debris Monitoring Program
NMFS	National Marine Fishery Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
OCS	outer coastal shelf
OWRRI	Oregon Water Resources Research Institute
PAH	polycyclic aromatic hydrocarbon
PFMC	Pacific Fishery Management Council
SPL	sound pressure level
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VGP	Vessel General Permit
WestGold	Western Gold Exploration and Mining Company
ZOD	zone of deposit

Chapter 1

Introduction

1.1 Background on Essential Fish Habitat

In 1996, the U.S. Congress added new habitat conservation provisions to the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the federal law that governs U.S. marine fisheries management. The renamed MSA mandated the identification of Essential Fish Habitat[1] (EFH) for federally managed species and consideration of recommendations to conserve and enhance the habitat necessary for these species to carry out their life cycles.

The MSA requires federal agencies to consult with the National Marine Fisheries Service (NMFS) on all actions or proposed actions permitted, funded, or undertaken by the agency that may adversely affect[2] EFH. Federal agencies initiate consultation by preparing and submitting to NMFS a written assessment of the effects of the proposed federal action on EFH. If a federal action agency determines that an action will not adversely affect EFH, no consultation is required. To promote efficiency and avoid duplication, EFH consultation is usually integrated into existing environmental review procedures under other laws such as the National Environmental Policy Act (NEPA), Endangered Species Act, or Fish and Wildlife Coordination Act.

The MSA requires NMFS to make conservation recommendations to federal and state agencies regarding actions that would adversely affect EFH. These EFH conservation recommendations are advisory, not mandatory, and may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects to EFH. Within 30 days of receiving NMFS' conservation recommendations, federal action agencies must provide a detailed response in writing. The response must include measures proposed for avoiding, mitigating, or offsetting the impact of a proposed activity on EFH. State agencies are not required to respond to EFH conservation recommendations. If a federal action agency chooses not to adopt NMFS' conservation recommendations, it must provide an explanation. Examples of federal action agencies that permit or undertake activities that may trigger EFH consultation include, but are not limited to, the U.S. Army Corps of Engineers (USACE), Environmental Protection Agency (EPA), Federal Energy Regulatory Commission, and Department of the Navy. Fishery Management Councils (FMCs) may also choose to comment on proposed actions that may adversely affect EFH.

---

[1] EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." "Waters" include aquatic areas and their associated physical, chemical, and biological properties. "Substrate" includes sediment underlying the waters. "Necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. "Spawning, breeding, feeding, or growth to maturity" covers habitat types utilized by a species throughout its life cycle (50 CFR 600.10).

[2] An adverse effect is any impact that reduces the quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species, and their habitat, as well as other ecosystem components. Adverse effects may be site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.910[a]).

1.2 Significance of Essential Fish Habitat

As Congress recognized in section 2(a)(9) of the MSA, “One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of the fishery resources of the United States.” EFH-designated waters and substrate are diverse and widely distributed, and also closely interconnected with other aquatic and terrestrial environments. Designated EFH is under the jurisdiction of the FMCs.

Section 303(a)(7) of the MSA requires fishery management plans (FMPs) to describe and identify EFH, minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. FMCs undertake detailed analyses to evaluate the potential adverse effects of fishing on EFH, with particular emphasis on mobile fishing gear that contacts sensitive bottom habitat features, and must act to address effects to EFH that are more than minimal and not temporary in nature. FMPs also must identify activities other than fishing that may adversely affect EFH, and for each activity describe known and potential adverse effects to EFH and identify actions to encourage the conservation and enhancement of EFH.

This document 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.

1.3 Non-fishing Activities

The waters and substrates that comprise 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 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 also could alter species distributions and complicated food web dynamics. These larger ecosystem level effects are discussed in this document where applicable within each activity type.

1.4 Purpose of the Document

The general purpose of this 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, and will be useful to NMFS biologists reviewing proposed actions that may adversely affect EFH. This document also is intended to 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. These conservation recommendations represent a short menu of actions that can contribute to the conservation, enhancement, and proper functioning of EFH. These recommendations may or may not be applicable on a site-specific basis. For each site and proposed action, different recommendations may be tailored based on the best and most current scientific information before or during EFH consultations. 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.

1.5 Overall Approach

This document 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.

EFH regulations state that FMCs and NMFS should review the EFH provisions of FMPs at least once every 5 years and that the EFH provisions should be revised or amended, as warranted, based on available information (50 CFR 600.815(a)(10)). These regulations also state that the review should evaluate published scientific literature, unpublished scientific reports, information solicited from interested parties, and previously unavailable or inaccessible data. The North Pacific Fishery Management Council completed its most recent 5-year review in April 2010 and voted to revise the EFH sections of its FMPs. This document will be used to revise the sections of the FMPs dealing with non-fishing impacts to EFH.

1.6 Effect of the Recommendations on Non-fishing Activities

The recommendations contained in this document for non-fishing activities are non-binding. They are intended to convey reasonable steps that could be taken to avoid or minimize adverse effects of categories of non-fishing activities on EFH. Their implementation is entirely at the discretion of the entities responsible for the activities and the agencies with applicable regulatory jurisdiction. NMFS habitat biologists may use these recommendations as a starting point when consulting with federal action agencies on specific activities that may adversely affect EFH. NMFS develops EFH conservation recommendations for specific activities case-by-case based on the circumstances, so the recommendations in this document may or may not apply to any particular project.

Chapter 2

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. Major sources of nonpoint pollution that are discussed in detail in this document include:

- Silviculture/Timber Harvest (Section 2.1)
- Pesticides (Section 2.2)
- Urban and Suburban Development (Section 2.3)
- Road Building and Maintenance (Section 2.4)
- Flood Control/Shoreline Protection, including channelization (Section 4.7)

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. Deegan and Buchsbaum (2005) place human impacts to marine habitats into three categories: (1) permanent loss; (2) degradation; and (3) periodic disturbance. Nonpoint source pollution may be a periodic disturbance that creates a situation of degradation and leads to permanent loss. 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.

2.1 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 2008b).

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.

2.1.1 Potential Adverse Impacts

In both small and large watersheds there are many complex and important interactions between fish and forests (Northcote and Hartman 2004). If appropriate environmental standards are not followed, forest conditions after harvest may result in altered or impaired instream habitat structure and watershed function. However, when followed appropriately, modern forestry practices avoid or minimize most of these potential effects on EFH; potential impacts to EFH have been greatly reduced by the adoption of BMPs designed to protect fish habitat.

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) (Section 4.8). 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.

2.1.1.1 *Construction of Logging Roads*

Improperly engineered, constructed, or maintained logging roads can destabilize slopes and increase erosion and sedimentation (as discussed above). Two major types of erosion may occur: mass wasting and surface erosion. Mass wasting (such as landslides, debris slides, slumps, earthflows, debris avalanches, and debris flows) can be directly or indirectly caused or exacerbated by timber harvest and road building on high-hazard soils and unstable slopes. Accelerated erosion rates from roads because of debris slides range from 30 to 300 times the natural rate in forested areas, but vary with terrain in the Pacific Northwest (Sidle et al. 1985). Erosion from roadways is most severe when construction practices do not include properly located, sized, and installed culverts; proper ditching; and ditch blocker water bars (Furniss et al. 1991). The eroded sediment can reach downslope waterways. BMPs included in current federal and state forest practices require that hazardous slopes be avoided or site-specific hazard management plans must be developed.

2.1.1.2 *Creation of Fish Migration Barriers*

Stream crossings (bridges and culverts) on forest roads that are inadequately designed, installed, or maintained can result in full or partial barriers to both upstream and downstream fish migration. For example, between 10 percent and 13 percent of the stream crossing structures installed since 1997 on the Tongass National Forest do not meet juvenile fish passage standards for upstream migration (USDA 2004). Forest Plan standards stipulate that juvenile fish will have unrestricted upstream passage within a defined range of stream flows (USDA 2004). Current fish passage standards on the Tongass National Forest stipulate that juvenile fish be able to successfully swim through culverts approximately 98 percent of the year (USDA 2004).

Perched and undersized culverts can accelerate stream flows so that these structures become velocity barriers for migrating fish. However, perched culverts are prohibited under current BMPs, and all culverts are now subject to sizing requirements designed to allow passage of fish and significant flood events.

Blocked culverts result from undersized designs or inadequate maintenance to remove debris. When a culvert is blocked, it can result in displacement of the stream from the downstream channel to the roadway or roadside ditch, resulting in dewatering of the downstream channel and increased erosion of the roadway. Under modern BMPs, however, culverts must be properly sized and maintained.

Culverts and bridges deteriorate structurally over time. Failure to replace or remove them at the end of their useful life may cause partial or total fish passage blockage. Current BMPs require removal of culverts upon road closure unless other measures are warranted. Channel incision can often occur downstream of a culvert and generally moves upstream. An existing culvert can act as a grade control, halting the upstream progression of a head cut and causing further channel regrade (Castro 2003); therefore caution should be used when removing culverts, as the unchecked upstream progression of a head cut can cause further damage to EFH. Additional information on culverts is available in the August 2001 Alaska Department of Fish and Game (ADF&G) and Alaska Department of Transportation and Public Facilities (ADOT&PF) Memorandum of Agreement for the Design, Permitting, and Construction of Culverts for Fish

Passage (ADF&G and ADOT&PF 2001) and the 2008 NMFS Northwest Region's Anadromous Salmonid Passage Facility Design (NMFS 2011).

2.1.1.3 Removal of Watershed and Streamside Vegetation

Removing streamside vegetation increases the amount of solar radiation reaching the stream and can result in warmer water temperatures, especially in small, shallow streams of low velocity. In southeast Alaska, Meehan et al. (1969) found that maximum temperature in logged streams without riparian buffers exceeded that of unlogged streams by up to 2.3 ºC, but did not reach lethal temperatures. In cold climates, the removal of riparian vegetation can result in lower water temperatures during winter, increasing the formation of ice, and damaging and delaying the development of incubating fish eggs and alevins. Current BMPs require retention of riparian buffers for shade, which should limit changes in water temperature and dissolved oxygen.

By removing watershed or streamside vegetation, timber harvest reduces transpiration losses from the landscape and decreases the absorptive capability of the groundcover. These changes can result in increased surface runoff during periods of high precipitation and decreased base flows during dry periods (Heifetz et al. 1986; Myren and Ellis 1984). Reduced soil strength can result in destabilized slopes and increased sediment and debris input to streams (Swanston 1974). Sediment deposition in streams can reduce benthic community production (Culp and Davies 1983), cause mortality of incubating salmon eggs and alevins (Koski 1981), and reduce the amount of habitat available for juvenile salmon (Heifetz et al. 1986). Cumulative sedimentation from logging activities can significantly reduce the egg-to-fry survival of coho and chum salmon (Cederholm and Reid 1987). Reductions in the supply of LWD also result when old-growth forests are removed, with resulting loss of habitat complexity that is critically important for successful salmonid spawning and rearing (Bisson et al. 1988: Murphy and Koski 1989). These effects are felt when vegetation is removed within a stream's watershed, but are intensified when streamside vegetation is removed. Current riparian buffer standards and BMPs are being implemented in most instances (USDA 2008a) and long-term effectiveness studies are being conducted to determine if timber harvest has any effect on habitat condition (Martin and Grotefendt 2001; Martin and Shelly 2004).

2.1.1.4 Hydrologic Changes and Sedimentation

According to the Tongass Land Management Plan Revision, forest management activities affect water quality and quantity and the timing of water flows, through alteration of soil and watershed conditions. Most watersheds are in a state of dynamic equilibrium where changes occur naturally because of changes in weather patterns. Because of the overriding influence of climate and basin resiliency, changes in streamflow and sediment delivery resulting from management activities (e.g. timber harvest) are difficult to measure.

Sediment is water-transported earth material. Sediment may be transported as either suspended load or bedload. Suspended load is carried within the water column, while bedload material moves (rolls or bounces) along the bottom of the stream or riverbed. Suspended load causes water to have a turbid or murky appearance. Under natural conditions, the great majority of suspended load and bedload transport occurs during storm runoff events (USDA 2003).

The mass wasting of soil, streams cutting new channels, and bank erosion are the main natural processes creating sediment. Landslides cause large, but temporary, increases in suspended and bedload sediments. Stream and riverbed or bank erosion may contribute to sedimentation over long periods of time. Steep terrain and large amounts of rainfall make the land sensitive to natural sediment production, and to sediment produced by road construction and timber-harvesting activities.

Forest management activities that have the greatest potential to affect soil erosion, including sheet rill, gully, or mass wasting erosion, are associated with timber-harvest and include road and log-landing construction, rock pit development, and some yarding methods. As discussed in Section 2.1.1.1, road construction increases soil erosion because of the destabilizing effect of cuts, fills, and drainage alteration and the lack of protective vegetation cover on road surfaces and other disturbed areas. The actual amount of erosion caused by roads is not known or reliably quantifiable (USDA 2003).

Sediment that settles on, or penetrates into, the stream bed is of more concern than suspended sediment, and can lead to long-term deleterious changes to fish and invertebrate populations. Soil mass wasting constitutes the most potentially damaging type of erosion, and is thought to be the major cause of accelerated erosion resulting from silvicultural activities. Although mass wasting has the potential positive effect of providing new sources of woody debris and gravel, it also negatively affects aquatic habitats by destroying viable eggs by smothering and bed load overturn, and by destroying habitat elements for fish (pools, riffles, log discharge, etc…) (USDA 2003). Standards and guides, Best Management Practices, and other relevant mitigation measures are applied to minimize potential adverse effects.

2.1.2 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. The following references apply to all conservation recommendations.

- For all potential adverse impacts to EFH from silviculture/timber harvest, the current standards and guidelines for the Tongass National Forest in Southeast Alaska can be found at: http://tongass-fpadjust.net/Documents/2008_Forest_Plan.pdf.
- The current standards and guidelines for the Chugach National Forest including soils and fish, water, and riparian areas can be found at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm8_028736.pdf.
- The Forest Service Region 10 Best Management Practices Policy, Soil and Water Conservation Handbook, FSH 2509.22 can be found at: http://www.fs.usda.gov/wps/portal/fsinternet/!ut/p/c4/04_SB8K8xLLM9MSSzPy8xBz9CP0os3gjAwhwtDDw9_AI8zPyhQoY6BdkOyoCAGixyPg!/?ss=1110&navtype=BROWSEBYSUBJECT&cid=fsbdev2_038796&navid=160000000000000&pnavid=null&position=Not Yet Determined.Html&ttype=detail&pname=Region 10- Land & Resource Management.
- The State of Alaska Forest Resources & Practices Regulations dated June 2004 can be found at: http://forestry.alaska.gov/pdfs/forpracregs.pdf.

- The State of Alaska riparian management standards can be found at: http://forestry.alaska.gov/pdfs/fprachrt.pdf.

2.1.2.1 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. In Alaska, buffer width is site-specific and varies by stream class (Class I, II, III, IV, Non-streams), stream process groups (flood plain, glacial outwash, alluvial fan, low gradient contained, moderate gradient/mixed control, moderate gradient contained, high gradient contained, palustrine, and estuarine), channel type (AF1, AF@, AF8, ES1, ES2, ES3, ES4, ES8, FP0, FP1, FP2, FP3, FP4, FP5, GO1, GO2, GO3, GO4, HC0, HC1, HC2, HC3, HC4, HC5, HC6, HC8, HC9, LC1, LC2, MC1, MC2, MC3, MM0, MM1, MM2, PA0, PA1, PA2, PA3, PA4, and PA5), and stream gradient and is dependent on use by anadromous and resident fish. Riparian management standards differ on public and private lands. Riparian buffers required on federal lands can be found in the Tongass and Chugach National Forests Resource Management Plans. Riparian management on the Tongass National Forest is also done in accordance with the Tongass Timber Reform Act, by which no commercial harvest is allowed within 100 feet horizontal distance either side on Class I streams, and Class II streams that flow directly into a Class I stream. Riparian buffers required on other lands must comply with the Alaska Forest Resources & Practices Regulations. See the links listed above for more details.

2.1.2.2 Estuary and Beach Fringe

For timber operations adjacent to estuaries or beaches, maintain vegetated buffers as needed to protect EFH. Estuaries are ecological systems at the mouths of streams where fresh and salt water mix, and where salt marshes and intertidal mudflats are present. The landward extent of an estuary is the limit of salt-tolerant vegetation (not including the tidally influenced stream or river channel incised into the forested uplands), and the seaward extent is a stream’s delta at mean low water. The estuary fringe is an area of approximately 1,000 feet slope distance around all identified estuaries and should be maintained as unmodified forest. The beach fringe is an area of approximately 1,000 feet slope distance inland from mean high tide around all marine coastlines. The beach fringe should be maintained as mostly undisturbed forest that contributes to maintenance of the ecological integrity of the biologically rich tidal and intertidal zone.

2.1.2.3 Watershed Analysis

A watershed analysis is a procedure for assessing important riparian and aquatic values and processes in a watershed context. It is designed to:

- Help set the stage for project-level planning and decisions;
- Strengthen the project NEPA analysis and decision; and
- Focus interdisciplinary discussion on key watershed resources (USDA 2008a).

The scope and intensity of the watershed analysis should be commensurate with the level of risk associated with the NEPA decision, and the information necessary to support the decision. Watershed analysis requires site-specific field-based site evaluations. Watershed analysis includes: field inventory of all affected stream reaches to verify fish presence, stream classes, and channel types; consideration of cumulative effects of past, present, and future timber sales within the watershed; assessment of current condition; and additional analyses. A watershed analysis should be incorporated into timber and silviculture projects whenever practicable.

2.1.2.4 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. Recommended conservation measures include but are not limited to the following:

- Incorporate erosion control and stabilization measures in project plans for stabilizing all human-caused soil disturbances.
- Avoid construction on highly unstable uplifted marine sediment and on slopes in excess of the soil's internal angle of friction. Avoid locating roads and landings on a slope greater than 67 percent, on an unstable slope, or in a slide-prone area.
- Avoid construction of roads across alluvial floodplains, mass wastage areas, and braided bottom lands.
- Seek road locations that avoid fish streams, crossing streams when other locations are not feasible and fish habitat can be protected. Where roads are located near fish streams, avoid the introduction of sediment during clearing, construction, and operation activities. Excess excavation material must not encroach upon the stream course. Leave as much undisturbed ground cover between the road and the stream as feasible. Require complete end haul of excess excavation where there is the probability of downhill movement of that material into the stream.
- Meet fish passage direction at locations where roads cross fish streams. Specify permissible uses of heavy machinery and the timing of road construction activities.
- Slope drainage ditches along the roadbed to the nearest relief culvert. Discharge from road ditches should be cross drained to filter on natural forest floor, rather than flowing directly into streams.
- Avoid the introduction or spread of invasive species during road construction, reconstruction, and maintenance.

2.2 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). In Alaska, the pesticide control program is administered by the Alaska Department of Environmental Conservation's (ADEC's) Division of Environmental Health (http://www.dec.state.ak.us/EH/pest/index.htm). Nationwide, the most comprehensive environmental monitoring efforts have been conducted by the U.S. Geological Survey as part of the National Water Quality Assessment Program.

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).

2.2.1 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.

Fish kills are generally rare when pesticides are used according to their labels. For fish, most effects from pesticide exposures are sublethal. Sublethal effects are a concern if they impair the physiological or behavioral performance of individual animals in ways that will decrease their growth or survival, alter migratory behavior, or reduce reproductive success. In addition to early development and growth, many pesticides have been shown to impair fish’s endocrine, immune, nervous, and reproductive systems (Moore and Waring 2001). Historically, sublethal impacts of pesticides on fish health were rarely addressed and therefore are poorly understood. Over the past few years, study of acetylcholinesterase-inhibiting insecticides has shown that sublethal exposures affect fitness of exposed salmonids and ultimately may result in population level consequences (NMFS 2008, 2009; Baldwin et al. 2009). Understanding the consequences of sublethal impacts to fish remains a focus of recent and ongoing National Oceanic and Atmospheric Administration (NOAA) research (Scholz et al. 2000; Sandahl et al. 2005; Laetz et al. 2009).

The effects of pesticides on ecosystem structure and function can be key factors in determining the cascading impacts of those chemicals on fish and other aquatic organisms at higher trophic levels (Preston 2002). This includes impacts on primary producers (Hoagland et al. 1996) and aquatic microorganisms (DeLorenzo et al. 2001), as well as on macroinvertebrates that are prey species for fish. For example, many pesticides are specifically designed to kill insects. Not surprisingly, these chemicals are toxic to insects and crustaceans that inhabit river systems and estuaries. Overall, pesticides will have an adverse impact on fish habitat if they reduce the productivity of aquatic ecosystems.

Some herbicides are toxic to aquatic plants that provide shelter for various fish species. A loss of aquatic vegetation could damage nursery habitat or other sensitive habitats, such as eelgrass beds and emergent marshes.

2.2.2 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 to ensure the reduction of pesticide contamination in EFH (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. Follow local, supplemental instructions such as state-use bulletins where they are available.
- Avoid the use of pesticides within 500 linear feet and/or 1000 aerial feet of anadromous fish bearing streams.
- For forestry vegetation management projects, follow the ADEC measures that 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. http://www.dec.state.ak.us/regulations/pdfs/18%20AAC%2090.pdf
- 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.

2.3 Urban and Suburban Development

Urban and suburban development is most likely the greatest non-fishing threat to EFH (NMFS 1998 a, b). 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).

2.3.1 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 (Section 4.1), wetland fill, and shoreline construction (Section 4.2).

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).

The loss of hyporheic zones and riparian and shoreline habitat and vegetation can increase water temperatures and remove sources of cover. Such impacts can alter the structure of benthic and fish communities. Shoreline stabilization projects (Section 4.7) that alter reflective wave energy can impede or accelerate natural movements of shoreline substrates, thereby affecting intertidal and sub-tidal habitats. Channelization of rivers causes loss of floodplain connectivity and simplification of habitat. The resulting sediment runoff can also restrict tidal flows and elevations, resulting in losses of important fauna and flora (e.g., submerged aquatic vegetation).

Runoff from impervious surfaces is the most widespread source of pollution into the nation’s waterways (USEPA 1995). Runoff from urban development is an emerging threat, particularly to ecosystems along all coastal margins of the United States (McCarthy et al. 2008; Weiss et al. 2008), as urban and suburban development in the United States continues to expand in coastal areas at a rate approximately four times greater than in non-coastal areas. Impacts from urban and suburban development are generally difficult to control because of the intermittent nature of rainfall and runoff, the large variety of pollutant source types, and the variable nature of source loadings (Safavi 1996). Such runoff includes pollutants such as construction sediments, oil from vehicles, road salts, bacteria from failing septic systems, and heavy metals. The 2000 National Water Quality Inventory (USEPA 2002) reported that runoff from urban areas is the leading source of impairment in surveyed estuaries and the third largest source of impairment in surveyed lakes. While our understanding of the individual, cumulative, and synergistic effects of all contaminants on the coastal ecosystem are incomplete, pollution discharges may cause organisms to be more susceptible to disease or impair reproductive success (USEPA 2005). Urban areas can have a chronic and insidious pollution potential that one-time events such as oil spills do not.

Salmonids and other anadromous fish appear to be particularly impacted by the proportion of impervious cover in a watershed (CWP 2003). In a study in the Pacific Northwest, coho salmon were seldom found in watersheds above 10 percent or 15 percent impervious cover (Luchetti and Feurstenburg 1993). Other studies have shown that impacts to stream quality can be expected when a watershed exceeds 10 percent impervious cover (CWP 2003). Key stressors in urban streams, such as higher peak flows and reduction in habitat complexity (e.g., fewer pools, LWD, and hiding places), as well as changes in water quality, are believed to change salmon species composition, favoring cutthroat trout populations over the natural coho populations (Horner et al. 1999; May et al. 1997).

Stormwater management systems are often built to move water quickly away from roads, resulting in increased velocities and higher peak volume of water into streams. Uncontrolled higher velocities and higher peak flow volumes of urban stormwater have a greater erosive capacity than stormwater from a forested watershed. Higher velocities and flow volumes erode streambanks and increase stream sediment loads. In a simulation model comparing an urban watershed with a forested watershed, Corbett et al. (1997) demonstrated that runoff from an urban watershed had volume and sediment yield 5.5 times greater than that from a forested watershed. Additionally reduced canopy cover can often cause higher stream temperatures. Literature reviews and ongoing research illustrate the adverse impacts of urban stormwater discharge and growing communities on fresh water and marine invertebrate, fish and marine mammal populations (Weiss 2008, LaLiberte 2006, Beach 2002, Neff 2002).

Urban stormwater also discharges nonpoint pollutants to soil and water, leading to their eventual bioaccumulation in aquatic species, which is also well documented in these and numerous other reports. Polycyclic aromatic hydrocarbons (PAHs) are among the most toxic to aquatic life and can persist for decades (Short et al. 2003). Waterborne PAH levels are often significantly higher in urbanized than non-urbanized watersheds (Fulton et al. 1993). Petroleum-based contaminants contain PAHs, which when released into the environment through spill, combustion, and atmospheric deposition can cause acute toxicity to managed species and their prey, as some PAHs are known carcinogens and mutagens (Neff 1985).

Sublethal effects of fish exposure to many chemical and metal pollutants often associated with urban stormwater over time may prove more deleterious than concentrations that are immediately lethal. Subtle sublethal effects on the fish may alter their behavior, feeding habits, and reproductive success (Murty 1986). Stormwater contaminants have been shown to negatively alter cellular function and biochemical machinery in many aquatic organisms, giving rise to the incidence of carcinogenesis through oxidized metabolites, interfering with DNA repair mechanisms, and/or initiating teratogenesis (prenatal toxicity that causes structural or functional defects in the developing embryo or fetus), all of which can increase mortality in fish species. Some stormwater contaminants disrupt neurotoxic and olfactory responses that maintain normal homing, predator avoidance, and spawning behavior. They can weaken immune system response, and inadvertently increase susceptibility and mortality from diseases. These conclusions are well documented in a variety of fish species (Sandahl 2007b; Baldwin et al. 2003; Dethloff et al. 1999; Hansen et al. 1999a, 1999b; Muir et al. 1988; Neff 1985).

Failing septic systems and combined sewer overflows are an outgrowth of urban development. EPA estimates that 10 percent to 25 percent of all individual septic systems are failing at any one time, introducing excrement, detergents, chlorine and other chemicals into the environment. Even treated wastewater from urban areas can alter the physiology of intertidal organisms

(Moles and Hale 2003). Sewage discharge is a major source of coastal pollution, contributing 41, 16, 41, and 6 percent of the total pollutant load for nutrients, bacteria, oils, and toxic metals, respectively (Kennish 1998). Nutrients such as phosphorus concentrations, in particular, are indicative of urban stormwater runoff (Holler 1990) and as a limiting nutrient for plant growth may lead to algal blooms, eutrophication, loss of biodiversity, and expansion of invasive species. Sewage wastes may also contain significant amounts of organic matter that exert a biochemical oxygen demand (Kennish 1998). Organic contamination contained within urban runoff can also cause immunosuppression (Arkoosh et al. 2001).

2.3.2 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). These can include: avoiding ground-disturbing activities during the wet season; minimizing exposure time of disturbed lands; using erosion prevention and sediment control methods; minimizing the spatial extent of vegetation disturbance; maintaining buffers of vegetation around wetlands, streams, and drainage ways; and avoiding building activities in areas with steep slopes and areas prone to mass wasting events with highly erodible soils. Use of structural BMPs such as sediment ponds, sediment traps, vegetated swales, or other facilities designed to slow water runoff and trap sediment and nutrients is recommended.
- Avoid using hard engineering structures for shoreline stabilization and channelization when possible. Use bioengineering approaches (i.e., approaches with principles of geomorphology, ecology, and hydrology) to protect shorelines and riverbanks, such as using native vegetation for soil stabilization. Naturally stable shorelines and river banks should not be altered.
- Encourage comprehensive planning for watershed protection, and avoid or minimize filling and building in coastal and riparian areas affecting EFH. Development sites should be planned to minimize clearing and grading, cut-and-fill, and new impervious surfaces.
- Where feasible, remove obsolete impervious surfaces such as abandoned parking lots and buildings 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 in accordance with state and federal water laws.

- 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. Locate them away from open waters, wetlands, and floodplains.
- Where vegetated swales are not feasible, install oil/water separators to treat runoff from impervious surfaces in areas adjacent to marine or anadromous waters. Ensure that oil/water separators are regularly maintained such that they do not become clogged and function properly on a continuing basis.

2.4 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 impacts to EFH associated with building and maintenance of paved and unpaved roads are discussed in the following section.

2.4.1 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; (6) changes in channel configuration; and (7) the concentration and introduction of PAHs, heavy metals, and other pollutants.

Road building and maintenance can affect aquatic habitats by increasing rates of natural disturbances such as landslides and sedimentation, and even properly designed and constructed roads can become sources of landslides and sedimentation if they are not maintained. Streams, wetlands, or other sensitive areas located near roads may experience increased sedimentation from general road maintenance and use, as well as from storm and snowmelt events. Poorly surfaced or unpaved roads can substantially increase surface erosion. The rate of erosion is primarily a function of storm intensity, surfacing material, road slope, and traffic levels. This surface erosion results in an increase in fine sediment deposition (Cederholm and Reid 1987; Bilby et al. 1989; MacDonald et al. 2001). Increased fine sediment deposition in stream gravels has been linked to decreased fry emergence and juvenile densities, loss of winter carrying capacity, and increased predation of fishes. Increased fine sediment can reduce benthic production or alter the composition of the benthic community. For example, embryo-to-emergent fry survival of incubating salmonids is negatively affected by increases in fine sediments in spawning gravels (Chapman 1988; Everest et al. 1987; Koski 1981; Scrivener and Brownlee 1989; Weaver and Fraley 1993; Young et al. 1991). Road crossings also affect benthic communities of stream invertebrates. Additionally, studies show that populations of non-insect invertebrates tend to increase the farther away they are from a road (Luce and Crowe 2001).

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

Roads can also degrade aquatic habitat through improperly placed culverts at road-stream crossings that reduce or eliminate fish passage (Belford and Gould 1989, Clancy and Reichmuth 1990, Evans and Johnston 1980, Furniss et al. 1991).

Roads have three primary effects on hydrologic processes and therefore streamflow. First, they intercept rainfall directly on the road surface, in road cutbanks, and as subsurface water moving down the hillslope. Second, they concentrate flow, either on the road surfaces or in adjacent ditches or channels. Last, they divert or reroute water from flowpaths that would otherwise be taken if the road were not present (Furniss et al. 1991). Another possible consequence of road building is the destabilization of the stream channel by intercepting groundwater flow and channeling water directly into the stream; thus, increasing the frequency and volume of floods as well as erosion and other associated natural processes. Erosion is most severe when poor construction practices are allowed, combined with inadequate attention to proper road drainage and maintenance practices.

Roads can serve as vectors to introduce invasive species to a watershed by creating suitable habitat for invasive species; planting invasive species along roadsides for erosion control; and serving as a vector for accidental introduction from vehicular or other traffic traveling along the road system. (Trombulak and Frissell 2000)

Pavement and many paving compounds used in road construction, surfacing, and resurfacing, such as asphalt, bitumen, and especially pavement sealing and repair products, contain high levels of PAHs, (Mahler et al. 2005; Teaf 2008 Barsh et al. 2007; Grosenheider et al. 2005). The friction between road and tire surfaces erodes and liberates asphalt, rubber material and chemical compounds. Further contributions of automotive fluids, fuel, and brake linings concentrate on or near road surfaces and eventually reach streams and the ocean (Weiss et al. 2008; Simon and Sobieraj 2006; Grosenheider et al. 2005). PAHs and heavy metals are toxic to aquatic species such as fish and invertebrate populations (Logan 2007; Rand 1995), and accumulate in estuarine, near shore and marine fish and invertebrate species (Kennish 2001; Johnson et al. 2002; Kennish 1997).

2.4.2 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.

1. 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, and they should be large enough to provide for migratory passage of adult and juvenile fishes. If appropriate, use the 2011 NMFS Northwest Region's Anadromous Salmonid Passage Facility Design (NMFS 2011) or the culvert guidelines contained in the August 2001ADF&G and the ADOT&PF Fish Pass Memorandum of Agreement) (ADF&G and ADOT&PF 2001).

- 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). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Maintain roadway and associated stormwater collection systems properly.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats. Snow-melt disposal areas should be silt-fenced and include a collection basin. Roads should be swept after break up to reduce sediment loading in streams and wetlands.

Chapter 3

Riverine Activities

3.1 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 mining 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 [NRC] 1999). (For additional information on mining impacts in the marine environment please see Section 5.6.)

3.1.1 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 (Section 5.6). The process for mineral extraction involves exploration, mine development, mining (extraction), processing, and reclamation.

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

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.

Scientific literature has many examples of spawning substrate selection by salmonid species being influenced by chemical and physical variables such as instream and inter-substrate flow (hyporheic zone), dissolved gases, nutrient exchange, and temperature. Mining activities may disrupt these physical and geochemical systems initiating and promulgating mineral dissolution or precipitation reactions that can alter pre-mining ground water quality and chemistry in ways that may be difficult to predict (Lewis-Russ 1997).

Recent studies suggest that diffuse mining-related pollution in rivers may significantly contribute to the loading of metals, principally because mine water contribution may be influenced by altered water tables (Younger 2000). Minerals and metals liberated from rock and soil substrates interact with atmospheric oxygen and water (Jennings et al. 2000, 2008; Younger et al. 2002). The introduction of this metal and mineral rich runoff or acid mine drainage (AMD) into the aquatic ecosystem can have adverse impacts on the ecology of entire watersheds. AMD has been demonstrated to be toxic to fish and aquatic invertebrate populations at the ecosystem, metabolic and cellular level (Buhl and Hamilton 1991; Saiki et al. 1995; West et al. 1995; Barry et al. 2000; Hansen et al. 2002; Peplow and Edmonds 2004). The hyporheic zone is especially vulnerable since this zone supports salmon spawning and incubating eggs as well as production of aquatic insects and aquatic vegetation. Groundwater may enter the hyporheic zone in an undiluted condition, leading to injury and mortality of aquatic organisms (including fish) prior to benefiting from the dilution effects of the overlying streamflow (Brunke and Gonser 1997; Gandy 2007).

Metal contamination and exposure has been shown to influence simple migratory behavior and avoidance mechanisms in fish populations (Goldstein et al. 1999; Hansen et al. 1999a; Brix et al. 2001; Farag et al. 2003; Sandahl et al. 2007a). Additional studies indicate that salmonids exposed to sub-lethal levels of metals are susceptible to increasing levels of fish pathogens due to stressed immune responses and metabolisms (Spromberg and Meador 2005; Peplow and Edmonds 2004; Jacobson et al. 2003).

The ability to treat or neutralize AMD is very site specific, and often unpredictable. Mine waste will be exposed to the natural elements of weathering for a long time (CSS 2002). Studies on rivers recovering from metal and mineral contamination concluded that, despite efforts to remediate surface water pollution, community recovery in the hyporheic zone may take longer than surface macroinvertebrate recovery due to the continued release of metals by reductive dissolution and exposure to AMD. Depending on the scale of the mining operation and associated topography and hydrogeomorphic processes, active treatment to neutralize AMD may need to last in perpetuity to be effective (Jennings et al. 2008; Kuipers 2000).

In addition, physical changes can be profound. The creation of waste dumps, tailings impoundments, mine pits, and other facilities that become permanent features of the post-mining landscape can cause fundamental changes in the physical characteristics of a watershed (O'Hearn 1997). Mining and placement of spoils in riparian areas can cause the loss of riparian vegetation and changes in heat exchange, leading to higher summer temperatures and lower winter stream temperatures (Spence et al. 1996). Bank instability can also lead to altered width-to-depth ratios, which further influence temperature (Spence et al. 1996). Mining efforts can also bury productive habitats near mine sites. Although reclamation efforts and mitigation practices may restore topographic land forms to mine sites, these efforts generally fail to restore natural hydrogeomorphic and aquatic function, and associated water quantity and quality within measurable time frames (Mutz 1998, Kilmartin 1989). Additionally, commercial operations may also involve road building (Section 2.4), tailings disposal (Section 4.2), and leaching of extraction chemicals, all of which may affect EFH.

In accessing mineral and ore deposits, many mining methods require withdrawals from groundwater aquifers. These naturally occurring, often saturated, ground water aquifers sustain instream flows. Altered water regimes may change instream channel morphologies, stream gradients, and bank and benthic substrates and disrupt the equilibrium between flow and sediment transport in tributaries (Sophocleous 2002; Johnson et al. 1999). Often these impacts are seen many miles upstream and downstream of the actual mine site, thus impacting EFH and anadromous species by limiting access to migratory corridors and reducing available spawning and rearing habitat.

3.1.1.2 Recommended Conservation Measures

The following measures are adapted from recommendations in Spence et al. (1996), NMFS (2004), and Washington Department of Fish and Wildlife (1998). 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 wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on site to minimize discharge to streams. Test wastewater before discharge for compliance with federal and state clean water standards.
- Minimize the effects of sedimentation on fish habitat. Use methods such as contouring, mulching, and construction of settling ponds to control sediment transport. Additionally, use methods such as sediment curtains to limit the spread of suspended sediments. 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 for an appropriate time to evaluate performance and implement corrective measures if necessary.
- Minimize the aerial extent of ground disturbance (e.g., through phasing of operations) and stabilize disturbed lands to reduce erosion.
- For large scale mining operations, stochastic models (as tools for estimating probability distributions of potential outcomes) should be employed to make predictions of ground and surface hydrologic impacts and acid generating potential in mine pits and tailing impoundments. The model used should describe how the data was collected and put in the model and include the governing equations and defense of assumptions made with a sensitivity analysis.

3.1.2 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.

3.1.2.1 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 (1) alteration of migration patterns, (2) physical and thermal barriers to upstream and downstream migration, (3) increased fluctuation in water temperature, (4) decrease in dissolved oxygen, (5) high mortality of early life stages, (6) increased susceptibility to predation, (7) loss of suitable habitat (Packer et al. 2005), (8) decreased nutrients (from loss of floodplain connection and riparian vegetation), and (9) decreased food production (loss of invertebrates) (Spence et al. 1996).

Turbidity plumes (Section 4.1) can cause spawning habitat to be moved several kilometers downstream. Sand and gravel mining in riverine, estuarine, and coastal environments can also suspend materials at the sites. Sedimentation may be delayed because gravel removal typically occurs at low flow when the stream has the least capacity to transport fine sediments out of the system. Another delayed sedimentation effect results when freshets inundate extraction areas that are less stable than they were before the activity occurred. In addition, for species such as salmon, gravel operations can interfere with migration past the site if they create physical or thermal changes, either at or downstream from the work site (OWRRI 1995).

Extraction of sand and gravel in riverine ecosystems can reduce or eliminate spawning gravels if the extraction rate exceeds the deposition rate of new gravel in the system, reduces gravel depth, or exposes bedrock (Spence et al. 1996). Gravel excavation also reduces the local supply of gravel to downstream habitats. In addition, mechanical disturbance of spawning habitat by mining equipment can lead to high mortality rates in early life stages.

Mining can alter channel morphology by making the stream channel wider and shallower. Consequently, the suitability of stream reaches as rearing habitat for federally managed species may be decreased, especially during summer low-flow periods when deeper waters are important for survival. Similarly, a reduction in pool frequency may adversely affect migrating adults that require holding pools (Spence et al. 1996). Changes in the frequency and extent of bed load movement and increased erosion and turbidity can also remove spawning substrates, scour redds (resulting in a direct loss of eggs and young), or reduce their quality by deposition of increased amounts of fine sediments. Deep pools created by material removal in streams appear to attract migrating adult salmon for holding. These concentrations of fish may result in high losses as a result of increased predation or recreational fishing pressure. Examples of using gravel removal to improve habitat and water quality are limited and isolated (OWRRI 1995).

3.1.2.2 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 (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

3.2 Organic and Inorganic Debris

Organic and inorganic debris, and its impacts to EFH, extend beyond riverine systems into estuarine coastal and marine systems. For ease in organization of this document we have placed this topic where impacts first occur in the document, however 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.

3.2.1 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.

3.2.1.1 Potential Adverse Impacts

The removal of organic debris from natural systems can reduce habitat function, adversely impacting habitat quality. For example, in parts of the Pacific Northwest, reduction in LWD inputs to estuaries has reduced the number of spatially complex and diverse channel systems that provide productive salmon habitat (NRC 1996). 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.

3.2.1.2 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). (See ADF&G brochure, "Harvesting Kelp and other Aquatic Plants in Southcentral Alaska, www.sf.adfg.state.ak.us.)

3.2.2 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.

Congress has passed numerous laws intended to prevent the disposal of marine debris in U.S. ocean waters. These include the Marine Protection, Research, and Sanctuaries Act, Titles I and II (also known as the Ocean Dumping Act). The Ocean Dumping Act implements the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention) , commonly known as the MARPOL Annex V (33 CFR 151) for the U.S. The MARPOL Annex V is intended to protect the marine environment from various types of garbage by preventing ocean dumping if the ship is less than 25 nautical miles (nm) from shore. Dumping of unground food waste and other garbage is prohibited within 12 nm from shore, and ground non-plastic or food waste may not be dumped within 3 nm from shore.

Laws and regulations that address land-based sources of inorganic debris include the Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act), the Shore Protection Act of 1988, and the CWA. The BEACH Act authorizes EPA to fund state, territorial, Tribal, and local government programs that test and monitor coastal recreational waters near public access sites for microbial contaminants and to assess and monitor floatable debris. The Shore Protection Act contains provisions to ensure that municipal and commercial solid wastes are not deposited in coastal waters during vessel transport from source to the waste receiving station. The CWA regulates discharges of pollutants into U.S. waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1977. Under the CWA, EPA implements pollution control programs such as setting wastewater standards for industry, and water quality standards for all contaminants in surface waters. Laws and regulatory programs also prevent or control debris disposal from ocean-sources, including commercial merchant vessels (e.g., galley waste and other trash), recreational boaters and fishermen, offshore oil and gas exploration, development and production facilities, military and research vessels, and commercial fishing vessels (NMFS 2008).

Despite these laws and regulations, marine debris continues to adversely impact our waters. The National Marine Debris Monitoring Program (NMDMP) was a 5-year study, conducted from 2001 to 2006, designed to provide statistically valid estimates of marine debris affecting the entire U.S. coastline and to determine the main sources of the debris. Results from the study indicate that marine debris continues to plague the United Stated, and that certain regions face larger problems than others (Sheavly 2007). Alaska was not included in the results of the study because an insufficient number of surveys were conducted that did not meet the sampling criteria. Hawaii was the only location to demonstrate a significant decrease in all debris. Generally, marine debris from both ocean and land-based activities increased across the United States by more than 5 percent each year over the study period. The most abundant debris items surveyed nationally were straws, plastic beverage bottles, and plastic bags.

3.2.2.1 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 the 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.

3.2.2.2 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 (e.g., implementation of a deposit on all plastic bottles).
- 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, such as trash racks, mesh nets, bar screens, and trash booms, concentrate floating debris and trash, and prevent it from traveling downstream.
- Consider the use of centrifugal separation to physically separate solids and floatables from water in combined sewer outflows by increasing the settling time of trash and particles.
- Encourage the development of incentives and funding mechanisms to recover lost fishing gear.
- Require all existing and new commercial construction projects near the coast (e.g., marinas and ferry terminals, recreational facilities, boat building and repair facilities) to develop and implement refuse disposal plans.

3.3 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, chemical processes that, in turn, can have effects on water quality, timing, quantity, and alter sediment transport.

3.3.1 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 [PFMC] 1999). The construction of a dam can fragment habitat, resulting in alterations to both upstream and downstream biogeochemical processes.

An understanding of the hydrologic system, including timing and annual variation of flows, as well as longer term trends in hydrology and climate, are necessary to understand how changes could alter habitat, habitat flow needs, and project operations.

Dam operations alter downstream water velocities and change discharge patterns. Water-level fluctuations, altered seasonal and daily flow regimes, and reduced water velocities discharge volumes can affect the migratory behavior of juvenile salmonids and reduce the availability of shelter and foraging habitat (PFMC 1999) and these modifications can increase migration times (Raymond 1979). Dam operation effects include pulse type flows, with sudden changes in flow over short periods of time, most often occurring in regulated rivers associated with hydroelectric operations and water resource needs. Pulse type flows can affect fish communities and benthic macro-invertebrates. The effects on anadromous fish can include stranding and trapping, isolation of habitat features, disruption of spawning, dewatering of redds, scour and flushing of redds, and food chain disruption (Reiser et al. 2005).

Many dams have multiple functions including flood control and water storage. Dams that are used for flood control are designed to decrease peak flows; dams that are designed for water storage use the reservoir capacity to store peak flows to increase water supply during normally low flow periods. The result of flood control and water storage is a reduction in the range of flows in the river, which can result in a loss of hydrologic and geomorphic functions. The width of the active portion of the watershed is reduced and the river channel shrinks (Heinz Center 2002).

The effects on migratory behavior on anadromous species are additionally complicated by development of reservoirs associated with dams. Reservoir affects include impediments to migration such as increased migration times, thermal barriers, increased predation, and loss of riparian habitat due to the large range of water level fluctuation.

Changes to the natural flow regime have effects on sediment and large wood transport as well as to seasonal icing. Ice formation and breakup is important to flood hazards, fluvial morphology, and fish habitat. An understanding of the relationship between the natural flow regime, ice development and function is necessary to assess how dam operations will affect these processes. An understanding of sediment and large wood transport, geomorphic influence, and an overall sediment budget is also import to understand dam effects. Dam operation can limit the natural processes associated with flooding, breakup, and can limit or alter natural sediment and LWD transport processes by impeding the high flows needed to scour fine sediments and move gravel and woody debris downstream. Floods transport sediments like silt, sand, and gravel, as well as aquatic plants and animals, leafy debris, and large woody debris. Curtailing these resources will affect the availability of spawning gravels and simplify channel morphology (Spence et al. 1996).

Changes to the timing and quantity of flow in rivers may result in the loss of riparian wetlands when water levels increase upstream and result in flow alterations downstream of the dam. In general, the greater the storage capacity of a dam, the more extensive downstream geomorphologic and biological impacts (Heinz Center 2002). Lost wetlands result in a loss of floodplain and flood storage capacity, and thus a reduced ability to provide flood control during storm event (NMFS 2008).

Dams can affect the thermal regimes of streams by raising or lowering water temperatures. Reductions in river water temperatures are common below dams if the intake of the water is from lower levels of the reservoir. Stratification of reservoir water not only affects temperature but can create oxygen-poor conditions in deeper areas and, if these waters are released, can degrade the water quality of the downstream areas (NMFS 2008).

3.3.2 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 the 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 to mimic the natural hydrograph, allow for sediment and wood transport, and consider and allow for natural ice function. Run-of-river dam operation is optimal, such that the volume of water entering an impoundment exits the impoundment with minimal change in storage, and is the preferred mode of operation for fishery and aquatic resource interests. Water flow monitoring equipment should be installed upstream and downstream of the facility. Reservoir level fluctuation should also be monitored.
- 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 operations of dams to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- 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. If possible, relocate debris as opposed to removing it completely. Remove LWD only to prevent damage to property or threats to human health and safety.

- 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.

3.4 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).

3.4.1 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).

Water withdrawal alters natural flow, stream velocity, and channel depth and width. Water withdrawal can also change sediment and nutrient transport characteristics (Christie et al. 1993; Fajen and Layzer 1993), increase deposition of sediments, reduce water depth, and accentuate diel temperature patterns (Zale et al. 1993). Loss of vegetation along streambanks and coastlines due to fluctuating water levels can decrease the availability of fish cover and food, and reduce bank stability (Christie et al. 1993). Changes in the quantity and timing of stream flow alters the velocity of streams, which, in turn, affects the composition and abundance of both insect and fish populations (Spence et al. 1996). Returning irrigation water to a stream, lake, or estuary can substantially alter and degrade habitat (NRC 1989). Problems associated with return flows include increased water temperature, increased salinity, introduction of pathogens, decreased dissolved oxygen, increased toxic contaminants from pesticides and fertilizers, and increased sedimentation (Northwest Power Planning Council 1986). Diversions can also physically divert or entrap EFH-managed species (Section 5.3).

Responsible water utilization can help reduce domestic and commercial water usage (Flowers 2004), which minimizes the effects to EFH. In 1990, industry and mining was the major commercial water use category in Alaska (Solley 1997). Prudent planning and water usage at the commercial scale also has the advantage of being cost effective.

3.4.2 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. Mitigation can include water conservation measures that reduce the volume of water diverted or impounded.

Chapter 4

Estuarine Activities

A large portion of Alaska's population resides near the state's 33,904-mile coastline (NOAA 2010). Historically, coastal features such as estuaries and embayments have been ideal for fishing, farming, or hunting and provided sheltered waters with access to rivers and the ocean for transportation purposes. Nationally, urban development in coastal areas is growing at a rate approximately five times that of other areas of the country and over one-half of all Americans live within 50 miles of the coast (Markham 2006). The expansion of port facilities, urbanization, filling of aquatic habitat and wetlands, and other forms of development surrounding estuaries and other coastal areas can have adverse impacts on fish habitat.

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).

4.1 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. Port expansion has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel size (Section 4.3). (Impacts from dredging from marine mining are also addressed in Section 5.6.).

4.1.1 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.

Many managed species forage on infaunal and bottom-dwelling organisms. Dredging may adversely affect these prey species by directly removing or burying them (Newell et al. 1998; Van der Veer et al. 1985). Similarly, dredging may also force mobile animals such as fish to migrate out of the project area. Recolonization studies suggest that recovery may not be straightforward. Physical factors, including particle size distribution, currents, and compaction/stabilization processes can limit recovery after dredging events. Rates of recovery listed in the literature range from several months for estuarine muds to up to 2 to 3 years for sands and gravels. Recolonization can take up to 1 to 3 years in areas of strong current, but up to 5 to 10 years in areas of low current. Additionally, post-dredging recovery in cold waters at high latitudes may require additional time because these benthic communities can be composed of large, slow-growing species (Newell et al. 1998). Thus, forage resources for benthic feeders may be substantially reduced in dredged areas.

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

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

Suspended material from dredging may react with dissolved oxygen in the water and result in short-term oxygen depletion to aquatic resources (Nightingale and Simenstad 2001a). Dredging can also disturb aquatic habitats by resuspending bottom sediments and recirculating toxic metals (e.g., lead, zinc, mercury, cadmium, copper), hydrocarbons (e.g., polyaromatics), hydrophobic organics (e.g., dioxins), pesticides, pathogens, and nutrients into the water column (USEPA 2000a). Toxic metals and organics, pathogens, and viruses may become biologically available to organisms either in the water column or through food chain processes.

Entrainment is the direct uptake of aquatic organisms by the suction field created by hydraulic dredges. Benthic infauna is particularly vulnerable to entrainment by dredging, although some mobile epibenthic and demersal species such as shrimp, crabs, and fish can be susceptible to entrainment as well (Nightingale and Simenstad 2001b).

Fish detect and respond to sounds for many life history requirements (NMFS 2008). The noise generated by pumps, cranes, and the mechanical action of the dredge has the ability to alter the behavior of fish and other aquatic organisms. The noise levels and frequencies produced from dredging depend on the type of dredging equipment being used, the depth and thermal variations in the surrounding water, and the topography and composition of the surrounding sea floor (Nightingale and Simenstad 2001b; Stocker 2002). Dredging activities from both mechanical and hydraulic dredges produce sounds that are strongest at low frequencies. Due to rapid attenuation of low frequencies in shallow water, dredge noise normally is undetectable underwater at ranges beyond 20 km to 25 km (Richardson et al. 1995). While noise levels from large ships may exceed those from dredging, single ships usually do not produce strong noise in one area for a prolonged period of time (Richardson et al. 1995). Noise from dredging may be continuous impacts for extended time periods (Nightingale and Simenstad 2001b).

Dredging and dredging equipment, such as pipelines, may damage or destroy spawning, nursery, and other sensitive habitats such as emergent marshes and subaquatic vegetation, including eelgrass beds and kelp beds. Dredging may also modify current patterns and water circulation by modifying substrate morphology. This can cause changes in the direction or velocity of water flow, water circulation, or dimensions of the waterbody traditionally used by fish for food, shelter, or reproductive purposes. Altered hydrodynamics can affect estuarine circulation, including short-term (diel) and longer term (seasonal or annual) changes (Deegan and Buchsbaum 2005).

4.1.2 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. Activities that would likely require dredging (e.g., placement of piers, docks, marinas) should instead be located in deep water or designed to alleviate the need for maintenance dredging.
- 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, (e.g., kelp beds, eelgrass beds, salt marshes).
- Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation. Standard BMPs may include silt fences, coffer dams, and operational modification (e.g., hydraulic dredge rather than mechanical dredge).
- 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 to be dredged for contaminants as per EPA and 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, to curtail those causes.

4.2 Material Disposal and Filling Activities

Material disposal and filling activities can directly remove important habitat and alter the habitat surrounding the developed area. Expansion of navigable waterways is associated with economic growth and development and generally adversely affects benthic and water-column habitats. 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.

4.2.1 Disposal of Dredged Material

4.2.1.1 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).

4.2.1.2 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 and other special aquatic sites whenever possible. Study all options for disposal of dredged materials, including upland disposal sites, and select disposal sites that minimize adverse effects to EFH.
- Test sediment compatibility for open-water disposal per EPA and USACE requirements for inshore and offshore, unconfined disposal.
- Ensure that disposal sites are properly managed (e.g., disposal site marking buoys, inspectors, the use of sediment capping and dredge sequencing) and monitored (e.g., chemical and toxicity testing, benthic recovery) 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. Consider using dredging material for beach replenishment and construction where appropriate. When dredging material is placed in open water, consider the possibilities for enhancing marine habitat.

4.2.2 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. For example, the loss of wetland habitats reduces the production of detritus, an important food source for aquatic invertebrates; alters the uptake and release of nutrients to and from adjacent aquatic and terrestrial systems; reduces wetland vegetation, an important source of food for fish, invertebrates, and water fowl; hinders physiological processes in aquatic organisms (e.g., photosynthesis, respiration) because of degraded water quality and increased turbidity and sedimentation; alters hydrological dynamics, including flood control and groundwater recharge; reduces filtration and absorption of pollutants from uplands; and alters atmospheric functions, such as nitrogen and oxygen cycles (Mitsch and Gosselink 1993).

4.2.2.1 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.

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

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

Fill in coastal waters that causes the loss of low gradient habitat or native substrate will likely have a negative effect on salmon rearing in the area. Nearshore shallow slopes are important to juvenile salmonids for (1) optimal feeding habitat, (2) shelter from high currents, and (3) shelter from predators. Both the abundance and productivity of salmon and salmon food organisms are affected by habitat gradient (Celewycz and Wertheimer 1994). The abundance of food organisms for juvenile salmon appears to be affected by habitat gradient (Sturdevant et al. 1994).

In addition to affecting salmon, juvenile flatfish that rear in nearshore areas have specific depth, slope, and substrate preferences (Moles and Norcross 1995) that limit their distribution and abundance. Nearshore juvenile flatfish habitat preferences vary by species, but for those that rear in nearshore areas, can generally be described as intertidal to shallow subtidal areas with substrate conditions that allow the animal to easily bury itself.

Fill that causes a loss of circulation in the nearshore area may also diminish important food sources for juvenile salmon and other managed species. Pelagic zooplankton is an important food source for juvenile pink and chum salmon (Sturdevant et al. 1996). Zooplankton distribution and abundance depends on currents to transport the zooplankton from offshore areas to nearshore areas.

4.2.2.2 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 and consider them in the permitting process for individual projects.
- Minimize the areal extent of any fill in EFH, or avoid it entirely. Mitigate all non-avoidable adverse impacts as appropriate.
- Consider alternatives to the placement of fill into areas that support managed species. Identify and characterize EFH habitat functions/services in the project areas, so that appropriate mitigation can be determined if necessary.
- 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. This pH range, in marine waters, will maximize colonization of marine organisms. Excessively alkaline or acidic fill material should not be used.

4.3 Vessel Operations, Transportation, and Navigation

The demand for increased capacity of marine transportation vessels, facilities, and infrastructure is a global trend in response to an increase in human population in coastal areas. As coastal areas grow, there are associated increases in vessel operations for cargo handling activities, water transportation services, and recreational opportunities (NMFS 2008). 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.

4.3.1 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 (6) altered tidal, current, and hydrologic regimes.

Potential adverse impacts to EFH can occur during both the construction and operation phases. One of the most obvious habitat impacts related to the construction of a port or marina facility is alteration or loss of physical space taken up by the structures required for such a facility (Section

4.5). In Alaska, open cell sheet pile dock faces with backfill (Section 4.2.2) are often used to construct or expand existing facilities. Such designs replace existing areas of shallow slow moving water with deep fast moving water across a sheer sheet pile face. The sheltered areas of slower moving water where juvenile fish tend to be more abundant are eliminated, as are the clearer water microhabitats in the intertidal area that allow for visual feeding.

An increase in the number and size of vessels being operated can generate more wave and surge effects on shorelines. Vessel wakes can cause a significant increase in shoreline erosion, affect wetland habitat, and increase water turbidity. Vessel prop wash can also damage aquatic vegetation and disturb sediments, which may increase turbidity and suspend contaminants (Klein 1997, Warrington 1999). Mooring buoys, when anchored in shallow nearshore waters, can drag the anchor chain across the bottom, destroying submerged vegetation and creating a circular scour hole (Walker et al. 1989 *in* Shafer 2002).

Alteration of the light regimes in coastal waters can affect primary production. Docks and piers block sunlight penetration, alter water flow, introduce chemicals, and restrict access and navigation (Section 4.6). The height, width, construction materials used, and orientation of the structure in relation to the sun can influence how large a shade footprint an overwater structure may produce and how much of an adverse impact that shading effect may have on the localized habitat (Fresh 1997; Burdick and Short 1999; Fresh et al. 2001). Piling density can also affect the amount of light attenuation created by dock structures.

Nearshore temperature regimes and biological communities can be altered through the construction of seawalls and bulkheads. Shorelines that have been modified invariably contain less vegetation than do natural shorelines, which can reduce natural shading in the nearshore intertidal zone and cause increases in water temperatures. Conversely, seawalls and bulkheads constructed along north facing shorelines may unnaturally reduce light levels and reduce water temperatures in the water column adjacent to the structures (NMFS 2008).

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

Typically, large sections of shoreline associated with a port development are replaced with impervious surfaces such as concrete and asphalt. Thus, stormwater runoff is exacerbated and can increase the siltation and sedimentation loads in estuarine and marine habitats. This increase in hard surfaces close to the marine environment intensifies nonpoint surface discharges (Section 2.3), adds debris, and reduces buffers between land use and the aquatic ecosystem. These include direct, indirect, and cumulative impacts on shallow subtidal, deep subtidal, eelgrass beds, mudflats, sand shoals, rock reefs, and salt marsh habitats. Such impacts would be site-specific, but in general structures interfere with longshore sediment transport processes resulting in altered substrate amalgamation, bathymetry, and geomorphology. Changing the type and distribution of sediment may alter key plant and animal assemblages, starve nearshore detrital-based foodwebs, and disrupt the natural processes that build spits and beaches (Nightingale and Simenstad 2001a;

NMFS 2005). In addition, the protected, low energy nature of marinas and ports may alter fish behavior as juvenile fish show an affinity to structure and may congregate around breakwaters or bulkheads (Nightingale and Simenstad 2001a).

4.3.2 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; if possible, for example, avoid the disturbance of eelgrass or other submerged aquatic vegetation including macroalgae, mudflats, and wetlands as part of the project design. In situations where such impacts are unavoidable, consider mitigation as appropriate.
- 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. Vessels should be operated at sufficiently low speeds to reduce wake energy, and no-wake zones should be designated near sensitive habitats.
- 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 subsurface floats or other methods to prevent contact of the anchor line with the substrate.
- Use catchment basins for collecting and storing surface runoff from upland repair facilities, parking lots and other impervious surfaces 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. Often benches are expanded shelf features used in common toe-slope stabilization transitions within the breakwater design. Benches need to provide for unrestricted fish movement throughout all tidal stages.
- Harbor facilities should be designed to include practical measures for reducing, containing, and cleaning up petroleum spills.

4.4 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).

Ballast water, which is water that is taken in or released by cargo vessels to compensate for changes in a ship's weight as cargo is loaded or unloaded, or as fuel and supplies are consumed, is a major source of non-native species introduction into aquatic ecosystems.[3] When a vessel takes in ballast water, it also takes in aquatic organisms that may be carried from one port to another along the vessel's route. When ballast water is released, non-native or invasive species may be introduced into new environments where they can cause environmental harm. EPA has historically exempted ballast water discharges, and other discharges incidental to the normal operation of vessels ("incidental discharges") from CWA National Pollutant Discharge Elimination System (NPDES) permit requirements. However, on December 18, 2008 EPA signed the final Vessel General Permit (VGP) (73 FR 79473, December 29, 2009), with an effective date of February 6, 2009 for Alaska (74 FR 7042, February 12, 2009). Effective February 6, 2009, *all* vessels operating as a means of transportation that discharge ballast water or other incidental discharges into waters of the United States require coverage under the VGP, except for (1) recreational vessels, as defined in CWA § 502(25), and (2) vessels of the armed forces, as defined in 40 CFR § 1700.3. In addition, as required by Pub. L. No. 110-299, commercial fishing vessels and non-recreational vessels that are less than 79 feet in length are not subject to this permit, with the exception of ballast water discharges.

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 leniuaculus*), zebra mussels (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), saltmarsh cordgrass (*Spartina alterniflora*), purple loosestrife (*Lythrum salicaria*), and tunicates (*Botrylloides violaceus* and *Didemnum vexillum*).[4]

Relatively few aquatic invasive species have been documented in Alaska; although a wide diversity of non-native taxonomic groups have colonized coastal ecosystems in other parts of the United States (McGee et al. 2006). Alaska's geographic isolation, harsh climate conditions, limited number of highly disturbed habitat areas, stringent plant and animal transportation laws, and smaller human population may explain the relative lack of invasion compared to more temperate sites in North America (Fay 2002; McGee et al. 2006). As economic activity and population size increase and the climate changes, the likelihood of aquatic invasive species establishing in Alaska will increase (Grebmeier et al. 2006, McGee et al. 2006). "Potential introduction pathways include fish farms, the intentional movement of game or bait fish from one aquatic system to another, the movement of large ships and ballast water from the U.S. West Coast and Asia, fishing vessels docking at Alaska's busy commercial fishing ports, construction equipment, trade of live seafood, aquaculture, and contaminated sport angler gear brought to Alaska's world-renowned fishing sites" (Fay 2002).

---

[3] http://www.epa.gov/owow/invasive_species/factsheet.html

[4] http://www.adfg.state.ak.us/special/invasive/invasive.ph

The Alaska Invasive Species Working Group (AISWG) was formed in 2006 to minimize invasive species impacts in Alaska by facilitating collaboration, cooperation, and communication among AISWG members and the people of Alaska. The AISWG is composed of representatives from state, federal, university, citizen, native, conservation, and military organizations. Current information on invasive species in Alaska can be found at www.uaf.edu/ces/aiswg. The 2008–2012 National Invasive Species Management Plan, developed collaboratively by 13 federal departments and agencies and their partners, is the “road map” for NOAA and its federal partners to focus on five strategic goals: Prevention; Early Detection and Rapid Response; Control and Management; Restoration; and Organizational Collaboration.[5]

Invasive species pose a serious threat to Alaska’s native flora and fauna. Long borders, long coastlines, busy shipping centers, and a large amount of imported goods give invasive species a lot of ways to enter Alaskan waters. Coordination and cooperation among Alaska’s existing organizations and their available resources is critical to successfully control and prevent invasive species in Alaska.[6]

4.4.1 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.

Habitat alteration includes the excessive colonization by sessile invasive species, which precludes the growth of endemic organisms. Invasive species may alter community structure by predation on native species or by population explosions of the introduced species. Introduced organisms increase competition with indigenous species, or they may forage on indigenous species, which can reduce fish and shellfish populations. For example, in freshwater lakes on Alaska’s Kenai Peninsula, introduced northern pike have depleted local salmonid populations through rampant juvenile predation. Spatial alteration occurs when territorial introduced species compete with and displace native species. Although hybridization is rare, it may occur between native and introduced species and can result in gene pool deterioration.

Non-native plants and algae can degrade coastal and marine habitats by changing natural habitat qualities. Introduced organisms increase competition with indigenous species, or they may forage on indigenous species or their prey, which can reduce indigenous fish and shellfish populations. Over the long-term the introduction of nonindigenous species can change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce invasive lethal diseases.

Although hybridization is rare, it may occur between native and introduced species and can result in gene pool deterioration. The introduction of invasive organisms also threatens native biodiversity and could lead to changes in relative abundance of species and individuals that are of ecological and economic importance.

---

[5] http://www.invasivespecies.gov/home_documents/2008-2012%20National%20Invasive%20Species%20Management%20Plan.pdf

[6] http://www.uaf.edu/ces/aiswg/

Long-term impacts from the introduction of nonindigenous species can change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce invasive lethal diseases. The introduction of bacteria, viruses, and parasites is another severe threat to EFH as it may reduce habitat quality. New pathogens or higher concentrations of disease can be spread throughout the environment, resulting in deleterious habitat conditions.

4.4.2 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 (in accordance with the U.S. Coast Guard’s voluntary regulations) to minimize the possibility of introducing invasive estuarine species into similar habitats. Ballast water taken on in the open ocean will contain fewer organisms, and these will be less likely to become invasive in estuarine conditions than species transported from other estuaries.
- 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). Bilges should be emptied and cleaned thoroughly by using hot water or a mild bleach solution. These activities should be performed in an upland area to prevent introduction of non-native species during the cleaning process.
- Treat effluent from public aquaria displays and laboratories and educational institutes using non-native species before discharge to prevent the introduction of viable animals, plants, reproductive material, pathogens, or parasites into the environment.
- Encourage proper disposal of seaweeds and other plant materials used for packing purposes when shipping fish or other animals. These materials may harbor invasive species and pathogens and should be treated accordingly.
- Undertake a thorough scientific review and risk assessment before any non-native species are introduced.

4.5 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. Impact hammers consist of a heavy weight that is repeatedly dropped onto the top of the pile, driving it into the substrate. Vibratory hammers use a combination of a stationary, heavy weight and vibration, in the plane perpendicular to the long axis of the pile, to force the pile into the substrate. The type of hammer used depends on a variety of factors, including pile material and substrate type. Impact hammers can be used to drive all types of piles, while vibratory hammers are generally most efficient at driving piles with a cutting edge (e.g., hollow steel pipe) and are less efficient at driving displacement piles (those without a cutting edge that must displace the substrate). Displacement piles include solid concrete, wood, and closed-end steel pipe.

4.5.1 Pile Driving

4.5.1.1 Potential Adverse Impacts

Feist et al. (1996) reported that pile-driving operations had an effect on the distribution and behavior of juvenile pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*). Fish may leave an area for more suitable spawning grounds or may avoid a natural migration path because of noise disturbances. 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. SPLs are positively correlated with the size of the pile, as more energy is required to drive larger piles. Wood and concrete piles appear to produce lower sound pressures than hollow-steel piles of a similar size, although it is unclear if the sounds produced by wood or concrete piles are harmful to fishes. Hollow steel piles with a diameter of 14 inches (35.5 centimeters) in diameter have been shown to produce SPLs that can injure fish (Reyff 2003). Firmer substrates require more energy to drive piles and produce more intense sound pressures. Sound attenuates more rapidly with distance from the source in shallow water than it does in deep water (Rogers and Cox 1988).

Driving large hollow steel piles with impact hammers produces intense, sharp spikes of sound that can easily reach levels injurious to fish. Vibratory hammers, on the other hand, produce sounds of lower intensity, with a rapid repetition rate. A key difference between the sounds produced by impact hammers and those produced by vibratory hammers is the responses they evoke in fish. When exposed to sounds that are similar to those of a vibratory hammer, fish consistently displayed an avoidance response (Enger et al. 1993; Dolat 1997; Knudsen et al. 1997; Sand et al. 2000), and they did not habituate to the sound, even after repeated exposure (Dolat 1997; Knudsen et al. 1997). Fishes may respond to the first few strikes of an impact hammer with a startle response. After these initial strikes, the startle response wanes, and the fishes may remain within the field of a potentially harmful sound (Dolat 1997; NMFS 2001). The differential responses to these sounds are due to the differences in the duration and frequency of the sounds.

When compared to impact hammers, the sounds produced by vibratory hammers are of longer duration (minutes versus milliseconds) and have more energy in the lower frequencies (15 to 26 hertz [hz] versus 100 to 800 hz) (Würsig et al. 2000; Carlson et al. 2001). Studies have shown that fish respond to particle acceleration of 0.01 meter per second squared at infrasound frequencies, that the response to infrasound is limited to the nearfield (less than 1 wavelength), and that the fish must be exposed to the sound for several seconds (Enger et al. 1993; Knudsen et al. 1994; Sand et al. 2000). Impact hammers, however, produce such short spikes of sound with little energy in the infrasound range that fish fail to respond to the particle motion (Carlson et al. 2001). Thus, impact hammers may be more harmful than vibratory hammers because they produce more intense pressure waves and because the sounds produced do not elicit an avoidance response in fishes, which exposes them to harmful pressures for longer periods.

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

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

Systems using air bubbles have been successfully designed to reduce the adverse effects of underwater SPLs on fish. Both 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). When using an unconfined air bubble system in areas of strong currents, it is critical that the pile be fully contained within the bubble curtain. To accomplish this when designing the system, adequate air flow and ring spacing, both vertically and in terms of distance from the pile, are factors that should be considered.

4.5.1.2 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. When impact hammers are required due to seismic stability or substrate type, drive the pile as deep as possible with a vibratory hammer before using the impact hammer.

Implement measures to attenuate the sound should SPLs exceed the 180 dB (re: 1 ΦPa) threshold. If sound pressure levels are anticipated to exceed acceptable limits, implement appropriate mitigation measures when practicable. Methods to reduce the sound pressure levels include, but are not limited to, the following:

- Surround the pile with an air bubble curtain system or air-filled coffer dam.
- Because the sound produced has a direct relationship to the force used to drive the pile, use a smaller hammer to reduce sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided. The force of the hammer blow can be controlled with hydraulic hammers; reducing the impact force will reduce the intensity of the resulting sound.
- Drive piles when the current is reduced (i.e., centered around slack current) in areas of strong current to minimize the number of fish exposed to adverse levels of underwater sound.

4.5.2 Pile Removal

4.5.2.1 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 (Section 4.1). The methods that are generally utilized for pile removal are vibratory removal, breaking or cutting below the mudline, direct pull, and use of a clamshell. Vibratory pile removal tends to cause the sediments to slough off at the mudline, resulting in relatively low levels of suspended sediments and contaminants. Vibratory removal of piles is gaining popularity because it can be used on all types of piles, providing that they are structurally sound. 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.

4.5.2.2 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, rather than using the direct pull or clamshell method.
    - 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 to minimize the potential for the pile to break, as well as to reduce the amount of sediment sloughing off the pile during removal.
    - 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. Creosote-treated timber piles should be disposed of properly to prevent reuse in the marine environment, and all debris, including attached contaminated sediments, should be disposed of in an approved upland facility.
- 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.

4.6 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).

4.6.1 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).

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

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

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

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

Construction and maintenance of overwater structures often involve driving pilings (Section 4.5) and dredging navigation channels (Section 4.1). Both activities may also adversely affect EFH.

While the effect of some individual overwater structures on EFH may be minimal, the overall impact may be substantial when considered cumulatively.

4.6.2 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. These measures include, but are not limited to, the following:
    - Maximize the height of the structure and minimize the width to decrease the shade footprint.
    - Use reflective materials (e.g., concrete or steel instead of materials that absorb light such as wood) on the underside of the dock to reflect ambient light.
    - Use the fewest number of pilings necessary to support the structures to allow light into under-pier areas and minimize impacts to the substrate.
    - 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. If practicable, use alternative materials such as untreated wood, concrete, or steel.
- Mitigate for unavoidable impacts to benthic habitats. Mitigation should be adequate, monitored, and adaptively managed.

4.7 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.

4.7.1 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).

4.7.2 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, including encouraging coastal wetland habitat preservation.
- Do not dike or drain tidal marshlands or estuaries.
- Wherever possible, use soft approaches (such as beach nourishment, vegetative plantings, and placement of LWD) in lieu of "hard" shoreline stabilization and modifications (such as concrete bulkheads and seawalls, concrete or rock revetments).
- 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 (e.g., provide new gravel for spawning or nursery habitats; remove barriers to natural fish passage; and use of weirs, grade control structures, and low flow channels to provide the proper depth and velocity for fish) to offset impacts.
- Avoid installing new water control structures in tidal marshes and freshwater streams. If the installation of new structures cannot be avoided, ensure that they are designed to allow optimal fish passage and natural water circulation.
- 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 species critical life history stages (e.g., spawning, egg, and larval development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Address the cumulative impacts of past, present and foreseeable future development activities on aquatic habitats by considering them 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.

4.8 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.

4.8.1 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 (Section 4.6).

Bark and wood debris may accumulate as a result of the abrasion of logs from transfer equipment. After the logs have entered the water, they usually are bundled into rafts and hooked to a tug for shipment. In the process, bark and other wood debris can pile up on the ocean floor. The debris can smother clams, mussels, seaweed, kelp, and grasses, with the bark sometimes remaining for decades. Accumulation of bark debris in shallow and deep-water environments has resulted in locally decreased benthic species richness and abundance (Kirkpatrick et al. 1998; Jackson 1986).

Log storage may also result in a release of soluble organic compounds within the bark pile. Log bark may affect groundfish habitat by significantly increasing oxygen demand within the area of accumulation (Pacific Northwest Pollution Control Council 1971). High oxygen demand can lead to an anaerobic zone within the bark pile where toxic sulfide compounds are generated, particularly in brackish and marine waters. Reduced oxygen levels, anaerobic conditions, and the presence of toxic sulfide compounds can result in reduced localized habitat value for groundfish species and their forage base. In addition, soils at onshore facilities where logs are decked can become contaminated with gasoline, diesel fuel, solvents, etc., from trucks and heavy equipment. These contaminants could leach into nearshore EFH.

4.8.2 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. In 1985, the Alaska Timber Task Force (ATTF) developed guidelines to “delineate the physical requirements necessary to construct a log transfer and associated facilities, and in context with requirements of applicable law and regulations, methods to avoid or control potential impacts from these facilities on water quality, aquatic and other resources.” Since 1985, the ATTF guidelines have been applied to new LTFs through the requirements of NPDES permits and other state and federal programs (USEPA 1996). Adherence to the ATTF operational and siting guidelines and BMPs in the 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.

- 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, with the goal of eliminating in-water storage of logs.
- Also see the following link for LTF guidelines: http://www.fs.fed.us/r10/TLMP/F_PLAN/APPEND_G.PDF.

4.9 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.

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

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

Because vegetated coastal wetlands provide forage for and protection of commercially important invertebrates and fish, marsh degradation due to plant mortality, soil erosion, or submergence will eventually decrease productivity. Vegetation loss and reduced soil elevation within pipeline construction corridors should be expected with the use of double-ditching techniques (Polasek 1997). Subsea pipelines that are placed on the substrate have the potential to create physical barriers to benthic invertebrates during migration and movement. Furthermore, erosion around buried pipelines and cables can lead to uncovering of the structure and the formation of escarpments. This, in turn, can interfere with the migratory patterns of benthic species (NMFS 2008).

4.9.2 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. Avoid sensitive habitats such as hard bottom (e.g., rocky reefs), cold-water corals, submerged aquatic vegetation, oyster reefs, emergent marsh, and mud flats.
- 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. If storage in wetlands or waters cannot be avoided, use alternate stockpiles to allow continuation of sheet flow. Store stockpiled materials on construction cloth rather than bare marsh surfaces, sea grasses, or reefs.
- Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation. Restore original marsh elevations. Stockpile topsoil and organic surface material such as root mats separately, and return it to the surface of the restored site. Use adequate material so that the proper pre-project elevation is attained following settling and compaction of the material. After backfilling, implement erosion protection measures where needed.
- Use existing rights-of-way whenever possible to lessen overall encroachment and disturbance of wetlands.
- Bury pipelines and submerged cables where possible. Unburied pipelines, or pipelines buried in areas where scouring or wave activity eventually exposes them, run a much greater risk of damage leading to leaks or spills.
- Remove inactive pipelines and submerged cables unless they are located in sensitive areas (e.g., marsh, reefs, sea grass). If allowed to remain in place, ensure that pipelines are properly pigged, purged, filled with seawater, and capped before abandonment in place.
- Use silt curtains or other barriers to reduce turbidity and sedimentation whenever possible near the project site.
- Limit access for equipment to the immediate project area. Tracked vehicles are preferred over wheeled vehicles. Consider using mats and boards to avoid sensitive areas. Caution equipment operators to avoid sensitive areas. Clearly mark sensitive areas to ensure that equipment operators do not traverse them.

- Limit construction equipment to the minimum size necessary to complete the work. Use shallow-draft equipment to minimize effects and to eliminate the necessity for temporary access channels. Use the push-ditch method, in which the trench is immediately backfilled, to minimize the impact duration when possible.
- 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. If transmission lines span streams, site towers at least 200 feet from streams.
- For activities on the Continental Shelf, to avoid and minimize adverse impacts to managed species, 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. Particular considerations (i.e., currents, ice scour) may require deeper burial or weighting to maintain adequate cover. Buried pipeline and cables should be examined periodically for maintenance of adequate cover.
  - Locate alignments along routes that will minimize damage to marine and estuarine habitat. Avoid laying cable over high-relief bottom habitat and across live bottom habitats such as coral and sponge.

4.10 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).

4.10.1 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).

The rearing of non-native species may pose a risk of escape or accidental release into areas where they would adversely affect the ecological balance. Escape or other release into the environment can result in competition with native, wild species and genetic dilution (NMFS 2005). Movement of mariculture facility components (e.g. docks, cages) between locations also may be a vector for introducing non-native species. In 2010, the invasive tunicate *Didemnum vexillium* was found associated with an oyster aquaculture facility in Sitka, Alaska.

Concern has also been expressed about extensive shellfish culture in estuaries and its impact on estuarine food webs. Oysters are efficient filter feeders and reduce microalgae and zooplankton that are also food for salmon prey species. The extent to which this may adversely affect managed prey species is unknown. However, because bivalves remove suspended sediments and phytoplankton from the water column, mariculture may actually improve water quality in eutrophic areas and can assist in recycling nutrients from water column to the sediment (Emmett 2002).

Mariculture facilities can be attractive to bird and mammal species both as a food source and shelter/resting facilities. Seals in particular have been known to prey on shellfish in cages and use mariculture facilities as haul outs (OSPAR Commission 2009). This can result in economic loss to the facility, danger to employees and possibly injury or death for the offending animal(s). Diving birds may also be attracted to the cages and have been known to become entangled. Increased boat traffic, human presence, and the use of scaring devices also may adversely affect resident bird and mammal species not directly utilizing the mariculture facilities.

4.10.2 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. If mariculture operations are to be located adjacent to existing kelp or eelgrass beds, monitor these beds on an annual basis and resite the mariculture facility if monitoring reveals adverse effects.
- Do not enclose or impound tidally influenced wetlands for mariculture. Take into account the size of the facility, migratory patterns, competing uses, hydrographic conditions, and upstream uses when siting facilities.
- 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. For control of *Didemnum tunicates*, remove nets, floats,

and other structures from salt water periodically and allow them to dry thoroughly, and/or soak them in fresh water.

Chapter 5

Coastal/Marine Activities

5.1 Point-Source Discharges

Contaminants enter waterways through point and nonpoint sources. Pollutants of nonpoint source origins tend to enter aquatic systems as relatively diffuse contaminant streams primarily from atmospheric and terrestrial sources (see Section 2.1 for the discussion on nonpoint source pollution). This differs from point source pollutants, which 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. Both point source and nonpoint source discharges introduce inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

The practice of disposing of waste materials into rivers, estuaries, and marine waters is not a modern phenomenon; it has been used as a preferred method since the beginning of human civilization (Ludwig and Gould 1988; Islam and Tanaka 2004). Nevertheless, when the full spectrum of emissions from land-based activities is taken into account, the use of coastal waters as a repository for anthropogenic waste has not previously been practiced on as large or intense a global scale as in recent decades (Williams 1996). Identifying the sources and effects of anthropogenic contaminants in near-coastal areas of the US is an ongoing scientific effort (USEPA 1999).

5.1.1 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 waters of the United States, 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).

The nature and extent of a pollutant's dispersal depends on a variety of factors including site-specific ecological conditions, the physical state of the contaminant introduced into the aquatic environment, and the inherent chemical properties of the substance. Soluble or miscible substances usually enter waterways in an aqueous phase, ultimately becoming adsorbed onto organic and inorganic particles (Wu et al. 2005). However, contaminants also enter aquatic systems as either particle-borne suspensions or as solutes (Bishop 1984; Turner and Millward 2002). Physical factors, such as the presence of significant currents or a strong thermocline or pycnocline, influence the spatial extent of contaminant dispersal. In particular, turbulent mixing, or diffusion, disperses contaminant patches in coastal waters resulting in larger, comparatively diluted contaminant distributions further away from the initial point source—the mixing zone (Bishop 1984). Subsequent biological activity and geochemical processes intercede and typically result in contaminant partitioning between the aqueous and particulate phases (Turner and Millward 2002).

Physical dispersion, biological activity, and other ecological factors play significant roles in the distribution of contaminants in aquatic habitats; however, the partitioning of contaminants is largely governed by certain ambient environmental conditions, notably salinity, pH, and the physical nature of local sediments (Turekian 1978; McElroy et al. 1989; Turner and Millward 2002; Leppard and Droppo 2003; Wu et al. 2005). Typically, highly reactive suspended particles serve as important carriers of aquatic contaminants and are largely responsible for their bioavailability, transport, and ecological fate as they disperse into receiving waters (Turner and Millward 2002). Additionally, hyporheic exchange between overlying water and groundwater can alter salinity, dissolved oxygen concentration, and other water chemistry aspects in ways that can influence the affinity of local sediment types for particular contaminants or otherwise affect contaminant behavior (Ren and Packman 2002).

Discharge sites may also modify habitat by creating adverse impacts to sensitive areas such as freshwater shorelines and wetlands, emergent marshes, sea grasses, and kelp beds if located improperly. Extreme discharge velocities of effluent may cause scouring at the discharge site, and may also entrain particulates and thereby create turbidity plumes. These turbidity plumes of suspended particulates can reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area while elevated turbidity persists. The contents of the suspended material can react with the dissolved oxygen in the water and result in oxygen depletion, or smother submerged aquatic vegetation sites, including eelgrass beds and kelp beds. Accumulation of outfall sediments may also alter the composition and abundance of infaunal or epibenthic invertebrate communities (Ferraro et al. 1991). Many benthic organisms are quite sensitive to grain size, and accumulation of sediments can also submerge food organisms (Section 4.2.2).

5.1.2 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 related to installation of new outfalls to facilitate monitoring of environmental changes.
- Provide for mitigation when degradation or loss of habitat occurs from placement and operation of the outfall structure and pipeline.
- Institute source-control programs that effectively reduce noxious materials to avoid introducing these materials into the waste stream.
- Ensure compliance with pollutant discharge permits, which set effluent limitations and/or specify operation procedures, performance standards, or BMPs. These efforts rely on the implementation of BMPs to control polluted runoff (USEPA 1993).
- Treat discharges to the maximum extent practicable, including up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances.
- Use land-treatment and upland disposal/storage techniques where possible. Limit the use of vegetated wetlands as natural filters and pollutant assimilators for large-scale discharges to those instances where other less damaging alternatives are not available.
- Avoid siting pipelines and treatment facilities in wetlands and streams.

5.2 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 is any activity that modifies the physical condition of a fishery resource (ADEC 2010b). With the exception of fresh market fish, some form of processing involving butchering, evisceration, precooking, or cooking is necessary to bring the catch to market. Precooking or blanching facilitates the removal of skin, bone, shell, gills, and other materials. 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; heads, fins, bones, and entrails; as well as chemicals, which are primarily disinfectants that must be used in accordance with EPA specifications.

5.2.1 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). EPA investigations illustrate that receiving water quality is directly influenced by the effluent discharge. In areas with strong currents and high tidal ranges, waste materials disperse rapidly. In areas of quieter waters, waste materials can accumulate and result in shell banks, sludge piles, dissolved oxygen depressions, and associated aesthetic problems (Stewart and Tangarone 1977). If adequate disposal technology is not available or employed in processing facilities that generate large quantities of nutrient rich fish waste, there is a potential to saturate designated mixing zones (LaLiberte and Ewing 2006; USEPA 1993).

Eventually, the chronic increase in accumulating nutrient load can cause eutrophication and create anoxic and hypoxic conditions. The impacts and effects of hypoxic conditions are well documented in coastal benthos and estuarine habitat (Rose 2009; Breitburg et al. 2009; Levin et al. 2009; Brandt et al. 2005). Seafood processing discharges influence nutrient loading, eutrophication, and anoxic and hypoxic conditions significantly influencing marine species diversity and water quality (Theriault et al. 2006; Roy Consultants 2003; Lotze et al. 2003). Ammonia, sulfides and micro toxin levels are also shown to be amplified in these areas (Lalonde et al. 2008). Impacts to marine water carrying capacity as a result of the rate of decomposition are further influenced by seasonal changes in water temperature as well as water depth (Verity et al. 2006; Ahumada et al. 2004).

Processors discharging fish waste are required to obtain permits. Various water quality standards, including those for biological oxygen demand; total suspended solids, fecal coliform bacteria, oil and grease, pHs, and temperature are all considerations in the issuance of such permits. 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). Localized effects depend upon wide differences in habitats and seafood processing methods.

In Alaska, seafood processors are allowed to deposit fish parts in a zone of deposit (ZOD) (USEPA 2001). This can alter benthic habitat, reduce locally associated invertebrate populations, and lower dissolved oxygen levels in overlying waters. Impacts from accumulated processing wastes are not limited to the area covered by the ZOD. Severe anoxic and reducing conditions occur adjacent to effluent piles (USEPA 1979). Examples of localized damage to benthic environment include several acres of bottom driven anoxic by piles of decomposing waste up to 26 feet (7.9 meters) deep. Juvenile and adult stages of flatfish are drawn to these areas for food sources. One effect of this attraction may lead to increased predation on juvenile fish species by other flatfishes, diving seabirds, and marine mammals drawn to the food source (NMFS 2005). However, due to the difficulty in monitoring these areas, impacts to species can go undetected.

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

5.2.2 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 ZODs for fish processing waste and instead seek disposal options that avoid an accumulation of waste. Explore options to eliminate or reduce ZODs at existing facilities.
- 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 (e.g., fertilizer for agriculture and animal feed).
- Explore options for additional research. Some improvements in waste processing have occurred, but the technology-based effluent guidelines have not changed in 20 years.
- Monitor biological and chemical changes to the site of seafood processing waste discharges.

5.3 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.

5.3.1 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.

Entrainment is the withdrawal of aquatic organisms along with the cooling water into the cooling system. These organisms are usually the egg and larval stages of aquatic species, including managed species and their prey. Entrainment can subject these life stages to adverse conditions resulting from the effects of increased heat, antifouling chemicals, physical abrasion, rapid pressure changes, and other detrimental effects. Long-term water withdrawal may adversely affect fish and shellfish populations by adding another source of mortality to the early life stage, which often determines recruitment and year-class strength (Travnichek et al. 1993).

Impingement occurs when organisms that are too large to pass through in-plant screening devices become stuck against the screening device or remain in the forebay sections of the system until they are removed by other means (Grimes 1975; Hanson et al. 1977; Helvey and Dorn 1987; Helvey 1985; Langford et al. 1978; Moazzam and Rizvi 1980). The organisms cannot escape due to the water flow that either pushes them against the screen or prevents them from exiting the intake tunnel. Similar to entrainment, the withdrawal of water can trap particular species, especially when visual acuity is reduced (Helvey 1985).

Thermal effluents in riverine and inshore habitats can cause severe problems by directly altering benthic communities or killing organisms, especially larval fish. Temperature influences biochemical processes of the environment, and the behavior (e.g., migration) and physiology (e.g., metabolism) of these organisms (Blaxter 1969). Power plants may use once-through cooling biocides, such as sodium hypochlorite and sodium bisulfate which are extremely toxic to aquatic life, to periodically clean the intake and discharge structures.

5.3.2 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. Locate discharge points in areas with low concentrations of living marine resources. Incorporate cooling towers at discharge points to control temperature, and use safeguards to ensure against release of pollutants into the aquatic environment in concentrations that reduce the quality of EFH.
- Design intake structures to minimize entrainment or impingement. Use velocity caps that produce horizontal intake/discharge currents and ensure that intake velocities across the intake screen do not exceed 0.5 foot (0.15 meter) per second.
- Design power plant cooling structures to meet the best technology available requirements as developed pursuant to section 316(b) of the CWA. Use alternative cooling strategies, such as closed cooling systems, to completely avoid entrainment or impingement impacts in all industries that require cooling water. When alternative cooling strategies are not feasible, other options may include fish diversion or avoidance systems; fish return systems that convey organisms away from the intake; mechanical screen systems that prevent organisms from entering the intake system; and, if impacts are unavoidable, habitat restoration measures to mitigate for expected losses of juvenile fish, larvae, and eggs.
- Regulate discharge temperatures (both heated and cooled effluent) 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. Implement technologies to diffuse heated effluent.
- Avoid the use of biocides (e.g., chlorine) to prevent fouling where possible. Implement the least damaging antifouling alternatives.

- Treat all discharge water from outfall structures to meet state water quality standards at the terminus of the pipe. Ensure that pipes extend a substantial distance offshore and are buried deep enough not to affect shoreline processes. Set buildings and associated structures far enough back from the shoreline to preclude the need for bank armoring.

5.4 Oil and Gas Exploration, Development, and Production

Two agencies, the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) are responsible for regulating oil and gas operations on the Outer Continental Shelf (OCS). These activities were formerly regulated by the Bureau of Ocean Energy Management, Regulation, and Enforcement and prior to that the Minerals Management Service (MMS). BOEM is responsible for leasing, plan administration, environmental studies, NEPA analysis, resource evaluation, economic analysis and renewable energy. BSEE is responsible for all field operations including permitting and research, inspections, offshore regulatory programs, oil spill response, and training and environmental compliance functions. The ADNR 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). Offshore exploration, development, and production of natural gas and oil reserves have been, and continue to be, important aspects of the U.S. economy. As demand for energy resources grows, the debate over trying to balance the development of oil and gas resources and the protection of the environment will also continue.

5.4.1 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

As discussed in Section 4.5 (Pile Driving), noise generates sound pressure that may disrupt or damage marine life. Oil and gas activities may generate noise from drilling activities, construction, production facility operations, seismic exploration, and supply vessel and barge movements. Research suggests that the noise from seismic surveys associated with oil exploration may cause fish to move away from the acoustic pulse and display an alarm response (McCauley et al. 2000), affecting both fish distribution and catch rates (Engas et al. 1996). However, while there is agreement that noise from seismic surveys affects the behavior of fish, there are differences of opinion regarding the magnitude of those effects (McCauley et al. 2003; Gausland 2003; Wardle 2001).

Activities such as vessel anchoring, platform or artificial island construction, pipeline laying (Section 4.9), dredging, and pipeline burial can change bottom habitat by altering substrates used for feeding or shelter. Disturbances to the associated epifaunal communities, which may provide feeding or predator escape habitat, may also result. Benthic organisms, especially prey species, may avoid recolonizing disturbed areas if the substrate composition is changed or if facilities are left in place after production ends. Dredging, trenching, and pipe laying generate spoils that may be disposed of on land or in the marine environment where sedimentation may smother benthic habitat and organisms. Most activities associated with oil and gas operations are, however, conducted under permits and regulations that require companies to minimize impacts or to avoid construction or other disturbances in sensitive marine habitats (Section 4.2.2).

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

Federal and state laws and regulations require numerous oil spill prevention and cleanup response measures. The industry takes the initiative to prevent oil spills and uses the most current BMPs and state-of-the-art technology in oil spill prevention and response. However, spills from oil and gas development remain a potential source of contamination to the marine environment. Offshore oil and gas development, in any given geographic area, may result in some amount of oil entering the environment. Most spills are small; although large spills do occur (e.g., the *Exxon Valdez* in March 1989 and the *Deepwater Horizon* in April 2010). Many factors determine the degree of damage from a spill, including the type of oil, size and duration of the spill, its geographic location, and the season. Oil is toxic to all marine organisms at high concentrations, but certain species are more sensitive than others. In general, the early life stages (eggs and larvae) are most sensitive; juveniles are less sensitive; and adults are least sensitive (Rice et al. 2000).

Both large and small quantities of oil can affect habitats and living marine resources. Oil, characterized as petroleum and any derivatives, can be a major stressor to inshore fish habitats. Oil can kill marine organisms, reduce their fitness through sublethal effects, and disrupt the structure and function of the marine ecosystem (NRC 2003). Short-term impacts include interference with the reproduction, development, growth and behavior (e.g., spawning and feeding) of fishes, especially at early life-history stages (Gould et al. 1994). Petroleum compounds are known to have carcinogenic and mutagenic properties (Larsen 1992). Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters, which disrupts the pelagic community. These impacts may eventually lead to disruption of community organization and dynamics in affected regions. Oil can persist in sediments for years after the initial contamination (NRC 2003), interfering with physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman 1996).

Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS or in nearshore coastal areas. Sources include equipment malfunction, ship collisions, pipeline breaks, other human error, or severe storms. Support activities associated with product recovery and transportation may also contribute to oil spills (NMFS 2005). Both large and small quantities of oil can affect habitats and living marine resources. Chronic small oil spills are a potential problem because residual oil can build up in sediments and affect living marine resources. Low levels of petroleum components (e.g., PAHs) from such chronic pollution may accumulate in fish tissues and cause lethal and sublethal effects, particularly during embryonic development. Low-level chronic exposure alters embryonic development in fish, resulting in reductions in growth and subsequent marine survival (Carls et al. 1999; Heintz et al. 1999, 2000).

A major oil spill (e.g., 50,000 barrels) can produce a surface slick covering several hundred square kilometers. If the oil spill moves toward land, habitats and species could be affected by oil reaching the near-shore environment. Immediately after a large spill, aromatic hydrocarbons would be toxic to some organisms. Waters beneath and surrounding the surface slick would be oil-contaminated. Physical and biological forces act to reduce oil concentrations with depth and distance (NMFS 2005); generally the lighter-fraction aromatic hydrocarbons evaporate rapidly, particularly during high winds and wave activity. Heavier oil fractions may settle through the water column. Suspended sediment can adsorb and carry oil to the seabed. Hydrocarbons may be solubilized by wave action, which may enhance adsorption to sediments. The sediments then sink to the seabed, contaminating benthic sediments.

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

Habitats that are susceptible to damage from oil spills include not just the low-energy coastal bays and estuaries where oil may accumulate, but also high-energy cobble environments where wave action drives oil into sediments. Many of the beaches in Prince William Sound with the highest persistence of oil following the *Exxon Valdez* oil spill were high-energy environments containing large cobbles overlain with boulders. These beaches were pounded by storm waves that drove the oil into and well below the surface (Michel and Hayes 1999). Oil that mixes into bottom sediments may persist for years. Subsurface oil was still detected in beach sediments of Prince William Sound 12 years after the *Exxon Valdez* oil spill, much of it unweathered and more prevalent in the lower intertidal biotic zone than at higher tidal elevations (Short et al. 2002, 2004). The unknown impact of an oil-related event near and within ice is an added concern. Should oil become trapped in ice, it could affect habitat for months or years after the initial event. It could also move into a different region (NMFS 2005).

Oil and gas platforms may consist of a lattice-work of pilings, beams, and pipes that support diverse fish and invertebrate populations and are considered de facto artificial reefs (Love and Westphal 1990; Love et al. 1994; Love et al. 1999; Helvey 2002). Because decommissioning includes plugging and abandoning all wells and removing the platforms and associated structures from the ocean, impacts to EFH are possible during removal. The demolition phase may generate underwater sound pressure waves (Section 4.5.2), impacting on marine organisms. Taking out these midwater structures may remove habitat for invertebrates and fish that associate with them. In some areas of the United States, offshore oil and gas platforms are left in place after decommissioning, thereby providing permanent habitat for some organisms.

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

5.4.2 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. Reinject produced waters into the oil formation whenever possible.
- Avoid discharge of muds and cuttings into the marine and estuarine environment. Use methods to grind and reinject such wastes down an approved injection well or use onshore disposal wherever possible. When not possible, provide for a monitoring plan to ensure that the discharge meets EPA effluent limitations and related requirements.

- 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. Identify appropriate cleanup methods and response equipment.
- Evaluate potential impacts that may result to EFH that may result from activities carried out during the decommissioning phase of oil and gas facilities. Minimize such impacts to the extent practicable.
- Vessel operations and shipping activities should be familiar with Alaska Geographic Response Strategies (GRS) which detail environmentally sensitive areas of Alaska's coastline. Currently, GRSs exist for the many different regions and areas including Southeast Alaska, Southcentral Alaska, Kodiak Island, Prince William Sound, Cook Inlet, Bristol Bay, Northwest Arctic, North Slope, and the Aleutian Islands (see http://www.dec.state.ak.us/spar/perp/grs/home.htm).

5.5 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.

5.5.1 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.

Habitat restoration activities that include the removal of invasive species may cause disturbances of native species. For example, netting and trapping of invasive fish species may result in unwanted bycatch of native fish and other aquatic species.

The temporary or permanent habitat disturbance associated with restoration or enhancement activities can cause adverse impacts. Fish passage restoration and other hydrologic restoration activities, such as the removal of culverts or other in-stream structures, installation of fishways, or other in-water activities will require temporary rerouting of flows around the project area. This could temporarily disturb on-site or adjacent habitats by altering hydrologic conditions and flows during project implementation.

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

5.5.2 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. BMPs should include, but are not limited to, the following:
  - 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. Identify and implement measures to ensure native vegetation or revegetation success (Section 4.4).
  - Establish temporary access pathways before restoration activities to minimize adverse impacts from project implementation.
- Avoid restoration work during critical life stages for fish such as spawning, nursery, and migration. Determine these periods before project implementation to reduce or avoid any potential impacts.
- Provide adequate training and education for volunteers and project contractors to ensure minimal impact to the restoration site. Train volunteers in the use of low-impact techniques for planting, equipment handling, and any other activities associated with the restoration.
- Conduct monitoring before, during, and after project implementation to ensure compliance with project design and restoration criteria.
- To the extent practicable, mitigate any unavoidable damage to EFH within a reasonable time after the impacts occur.
- Remove and, if necessary, restore any temporary access pathways and staging areas used in the restoration effort.

- Determine benthic productivity by sampling before any construction activity in the case of subtidal enhancement (e.g., artificial reefs). Avoid areas of high productivity to the maximum extent possible. Develop a sampling design with input from state and federal resource agencies. Before construction, evaluate of the impact resulting from the change in habitat (e.g., sand bottom to rocky reef). During post-construction monitoring, examine the effectiveness of the structures for increasing habitat productivity.

5.6 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).

Offshore dredging and the discharge of spoils have the potential to affect aquatic resources via habitat alteration, including turbidity; entrainment of organisms; exposure to trace metals; noise and disturbances; and fuel spills (MMS 1991). Previous mining operations off Nome resulted in considerable localized substrate alteration. Sediment fines destabilized by mining operations were redistributed by local currents and sea conditions (Jewett 1999). Further, evidence suggests that recolonization of benthic communities to their original structure may not occur after mining disturbance; instead, a somewhat different assemblage may result. Actual recovery times for a community to stabilize (i.e., recolonization of dredged sites to comparable density, biomass, and number of taxa) are unknown. Studies associated with the Nome Offshore Placer Project showed that even seven years post-mining, seafloor habitats and species assemblages had not recovered to pre-disturbance conditions (Gardner and Jewett 1994).

5.6.1 Potential Adverse Impacts

Impacts from mining on EFH include both physical impacts (i.e., intertidal dredging) and chemical impacts (i.e., additives such as flocculates) (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. Submarine mine tailings may not provide suitable habitat for some benthic organisms. In laboratory experiments, benthic dwelling flatfishes (Johnson et al. 1998a) and crabs (Johnson et al. 1998b) strongly avoided mine tailings.

During beach gravel mining, water turbidity increases and the resuspension of organic materials can affect less motile organisms (i.e., eggs and recently hatched larvae) in the area. Benthic habitats can be damaged or destroyed by these actions. Changes in bathymetry and bottom type may also alter population and migrations patterns (Hurme and Pullen 1988).

Offshore gold placer mining in the Norton Sound region has occurred for many years. Western Gold Exploration & Mining Company (WestGold) conducted the largest and most notable project. WestGold's operation, the Nome Offshore Placer Project, began in late 1985 and continued through September 1990. The project mined the seafloor with a 558 feet dredge vessel incorporating a bucket ladder system of 134 buckets. Each bucket had a 1.1 cubic yard capacity. The dredge could operate in water depths of up to 148 feet and cut to a depth of 10 feet below the seafloor. Typically, 10,000 to 20,000 cubic yards of material were processed per day and mining occurred in water depths of 20 to 60 feet.

Studies done regarding the WestGold project list several impacts offshore placer mining may have to the benthic community such as habitat loss, alteration, re-suspension of fine sediments, removal of benthic infauna and epifauna, and injured marine organisms. Injured organisms may not reach maturity to reproduce and/or be subject to increased predation. The long term result of such disturbances is an overall decrease in benthic species and their habitat.

WestGold's studies documented that deeper waters (deeper than 20 feet) support a more diverse and higher number of species complexes, especially in the cobble habitats. These studies also suggest significant storm events and longshore currents cause extensive mixing of nearshore sediments and alteration of the sea floor. These natural events occur within nearshore waters less than 25 feet in depth (Jewett 1999). Ice gouging is also a common occurrence in the region. The seaward edge of the ice typically extends to the 60 foot isobaths and may be anchored by ice keels in the depth from 30 to 60 feet (Jewett 1999).

These studies further conclude the re-colonization of species after the disturbance occurs at a slow rate and a wide range of impact occurs. Suspended sediments can travel well outside the disturbed area and settle on other undisturbed marine substrates. Sediment was found in red king crab stomachs, but whether this was due to increases in suspended sediment or associated with a food source is not known. Some sediment is probably ingested while feeding on tube worms, starfish, and sea urchins. Fine sediments may inhibit growth in some species and smother benthic organisms.

Benthic communities do not recover quickly from rapid change and effects may not be easily measured. NMFS studies related to effects on benthic substrates and their inhabitants (NMFS 2005), also find that many seafloor organisms are slow growing and reach their age of maturity (spawning age) later in their life history. Additionally, in Alaskan waters, many species' life history traits are unknown. Another important factor is that video analysis documents even the smallest of epifauna (sponge, tunicate, or sea pen) will be in association with a larger fish or crab. Direct association is unknown, however it is recognized that the larger species are often attracted to the structure, likely for cover or feeding.

5.6.2 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. Use sediment or turbidity curtains to limit the spread of suspended sediments and minimize the area affected.
- Monitor individual mining operations to avoid and minimize cumulative impacts. For instance, three mining operations in an intertidal area could impact EFH, whereas one may not. Disturbance of previously contaminated mining areas may cause additional loss of EFH.
- 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.

Chapter 6

References

References Cited

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.

Able, K.W., J.P. Manderson, and A.L. Studholme. 1998. "The distribution of shallow water juvenile fishes in an urban estuary: the effects of man-made structures in the lower Hudson River." *Estuaries.* 21:731-744.

Ahumada, R., A. Rudolf, and S. Contreras. 2004. Evaluation of Coastal Waters Receiving Fish Processing Waste: Lota Bay as a Case Study. Environmental Monitoring and Assessment. Vol 90, Numbers 1-3, pp. 89-99.

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 Fish and Game (ADF&G) and Alaska Department of Public Transportation of Public Facilities (ADOT&PF), Memorandum of Agreement for the Design, Permitting, and Construction of Culverts for Fish Passage. August 2001. http://www.sf.adfg.state.ak.us/Static/fish_passage/PDFs/dot_adfg_fishpass080301.pdf

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. 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

Arkoosh, M.R., E. Casillas, E. Clemons, P. Huffman, A.N. Kagley, T. Collier, and J.E. Stein. 2001. "Increased susceptibility of juvenile chinook salmon (*Oncorhynchus tshawytscha*) to vibriosis after exposure to chlorinated and aromatic compounds found in contaminated urban estuaries." Journal of Aquatic Animal Health. 13:257-268.

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.

Baldwin D.H., J. A. Spromberg, T. K Collier, and N. L. Scholz. 2009. A fish of many scales: extrapolating sublethal pesticide exposures to the productivity of wild salmon populations. Ecological Applications. 19(8): 2004-2015.

Baldwin, D. H., J. F. Sandahl, J. L. Labenia, and N. L. Scholz. 2003. Sublethal effects of copper on coho salmon: Impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry. 22:2266-2274.

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.

Barron, M.G., M.G. Carls, J.W. Short, and S.D. Rice. 2003. Photoenhanced toxicity of aqueous phase and chemically dispersed weathered Alaska North Slope crude oil to Pacific herring eggs and larvae. Environmental Toxicology and Chemistry. 22(3):650-660.

Barry, K. L., J.A. Grout, C.D. Levings, B.H. Nidle, and G.E. Piercey. 2000. “Impacts of acid mine drainage on juvenile salmonids in an estuary near Britannia Beach in Howe Sound British Columbia.” Canadian Journal of Fisheries and Aquatic Sciences. 57(10): 2031-2043.

Barsh, R., Bell, J., Barr, B., Taylor, S., Wilson, A., and Wilbur, R. 2007. Preliminary Evidence for Phenanthrene, A Polycyclic Aromatic Hydrocarbon (PAH), in Paving Materials used in San Juan County, WA.

Beach, D. 2002. Coastal Sprawl: the effects of urban design on aquatic ecosystems in the United States. Pew Oceans Commission, Arlington, Virginia.

Belford, D.A. and W.R. Gould. 1989. “An evaluation of trout passage through six highway culverts in Montana.” North American Journal of Fisheries Management. 9(4):437-445.

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.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. *In* Salo, E., T. Cundy, eds. Streamside management: forestry and fishery interactions. Contribution 57. Seattle: University of Washington, College of Forest Resources: 191-232. 437-445.

Bilby, R.E., K. Sullivan, and S.H. Duncan. 1989. “The generation and fate of road-surface sediment in forested watersheds of southwestern Washington.” Forest Science. 35:453-468.

Bishop, JM. 1984. Applied oceanography. McCormick ME, Bhattacharyya R, editors. New York (NY): John Wiley & Sons. 252 p.

Bisson, P.A., J.L. Nielsen, and J.W. Ward. 1988. “Summer production of coho salmon stocked in Mount St. Helens streams 3-6 years after the 1980 eruption.” Transactions of the American Fisheries Society. 117(4):322-335.

Blaxter, J. H. S. 1969. Development: Eggs and larvae. In W. S. Hoar., and D. J. Randall. eds. Fish Physiology. Vol. 3. Academic Press, Inc. New York, NY. pp. 177-252.

Brandt, S., S. Ludsin, D. Mason, B. Boicourt, M. Roman, and D. Kimmel. 2005. Hypoxia Effects on the Living Resources of the Northern Gulf of Mexico. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory. NOAA Great Lakes Research Laboratory web site: http://www.glerl.noaa.gov/res/Task_rpts/2005/epludsin05-4.html

Breitburg, D.J., Craig, J.K., Fulford, R.S., Rose, K.A., Boynton, W.R., Brady, D.C., Ciotti, R.J., Daiz, R.J., Friedland, K.D., Hagy, J.D., Hart, D.R., Hines, A.H., Houde, E.D., Kolesar, S.E., Nixon, S.W., Rice, J.A., Secor, D.H., Targett, T.E. 2009. Nutrient Enrichment and Fisheries Exploitation: Interactive Effects on Estuarine Living Resources and their Management. Hydrobiologia 629:31-47.

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.

Brunke, M. and T. Gonser. 1997. The ecological significance of exchange processes between rivers and groundwater. Freshwater Biology, vol 37, 1–33.

Buhl, KJ and S.J. Hamilton. 1991. Relative sensitivity of early life stages of arctic grayling, coho salmon, and rainbow trout to nine inorganics. Ecotoxicology and Environmental Safety. 2:184-197.

Burdick D.M. and F.T. Short. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management. 23(2):231-40.

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.

Cardwell, R.D., M.I. Carr, and E.W. Sanborn. 1980. Water quality and flushing of five Puget Sound marinas. Technical Report No. 56. Washington Department of Fisheries Research and Development. Olympia, Washington. 77 pp.

Carls, M.G., R.E. Thomas, and S.D. Rice. 2003. “Mechanism for transport of oil-contaminated water into pink salmon redds.” Mar. Ecol. Prog. Ser. 248:245-255.

Carls, M.G., S.D. Rice, and J.E. Hose. 1999. “Sensitivity of fish embryos to weathered crude oil: Part 1. Low level exposure during incubation causes malformations and genetic damage in larval Pacific herring (*Clupea pallasi*).” Environmental Toxicology and Chemistry. 18:481-493.

Carlson, T.J., G. Ploskey, R.L. Johnson, R.P. Mueller, M.A. Weiland, and P.N. Johnson. 2001. Observations of the behavior and distribution of fish in relation to the Columbia River navigation channel and channel maintenance activities. Prepared for the U.S. Army, Corps of

Engineers, Portland District by Pacific Northwest National Laboratory, U.S. Department of Energy, Richland, WA. 35 pp. + appendices.

Castro, J. 2003. Geomorphologic impacts of culvert replacement and removal: avoiding channel incision. U.S. Fish and Wildlife Service—Oregon Fish and Wildlife Office, Portland, Oregon.

Cederholm, C.J. and L.M. Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater Rivers, Washington: A project summary. *In* Streamside management: forestry and fishery interactions. Salo, E.O, and T.W. Cundy, eds. College of Forest Resources, University of Washington, Seattle, Washington. University of Washington, Institute of Forest Resources. Contribution No. 57.

Celewycz, A.G. and A.C. Wertheimer. 1994. Distribution, abundance, size, and growth of juvenile pink and chum salmon in western Prince William Sound after the Exxon Valdez oil spill. Chapter 2. In: A.C. Wertheimer, et al. (Eds.) Impact of the oil spill on juvenile pink and chum salmon and their prey in critical nearshore habitats. Exxon Valdez Oil Spill, State/Federal Damage Assessment Final Report. Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, Alaska.

Center for Streamside Studies (CSS).2002. "Environmental impacts of hardrock mining in Eastern Washington." College of Forest Resources and Ocean and Fishery Sciences, University of Washington, Seattle, WA.

Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Elliott City, MD, www.cwp.org. 141 pp.

Chapman, D.W. 1988. "Critical review of variables used to define effects of fines in redds of large salmonids." Transactions of the American Fisheries Society. 117(1):1-21.

Christie, D., E. Allen, and G. J. Jobsis. 1993. Diversions. *In* Bryan, C.F. and D.A. Rutherford eds. Impacts on warmwater streams: Guidelines for evaluation. pp. 181-186. Southern Division, American Fisheries Society, Little Rock, AR.

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.

Clancy, C.G. and D.R. Reichmuth. 1990. "A detachable fishway for steep culverts." North American Journal of Fisheries Management. 10(2):244-246.

Cloern, J.E. 1987. "Turbidity as a control on phytoplankton biomass and productivity in estuaries." *Continental Shelf Research.* 7:1367-1381.

Collins, K.J., A.C. Jensen, A.P.M. Lockwood, and S.J. Lockwood. 1994. "Coastal structures, waste materials and fishery enhancement." Bulletin of Marine Science. 55(203):1240-1250.

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

Corbett, C.W., M. Wahl, D.E. Porter, D. Edwards, and C. Moise. 1997. "Nonpoint source runoff modeling: A comparison of a forested watershed and an urban watershed o the South Carolina coast." Journal of Experimental Marine Biology and Ecology. 213(1):133-149.

Culp, J.M. and R.W. Davies. 1983. An assessment of the effects of streambank clear cutting on macroinvertebrate communities in a managed watershed. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 1208. 116 pp.

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.

DeLorenzo, M.E., G.I. Scott, and P.E. Ross. 2001. "Toxicity of pesticides to aquatic microorganisms: A review." Environmental Toxicology and Chemistry. 20:84-98.

Dennison, W.C. 1987. "Effect of light on seagrass photosynthesis, growth and depth distribution." Aquatic Botany. 27:15-26.

Dethloff, G., Schlenk, D., Khan, S., Bailey, H.C., 1999. The Effects of Copper on Blood and Biochemical Parameters of Rainbow Trout (*Oncorhynchus mykiss*) Arch. Environ. Contam. Toxicol. 36, 415–423

Dolat, S.W. 1997. Acoustic measurements during the Baldwin Bridge demolition (final, dated March 14, 1997). Prepared for White Oak Construction by Sonalysts, Inc, Waterford, CT. 34 pp. + appendices.

Duffy-Anderson, J.T., and K.W. Able. 1999. "Effects of municipal piers on the growth of juvenile fishes in the Hudson River estuary: a study across a pier edge." Mar. Biol. 133:409-418.

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.

Emmett, B. 2002. A discussion document associated with shellfish aquaculture in Baynes Sound. Prepared for Mr. Joe Truscott, Coast and Marine Planning Office, Ministry of Sustainable Resource Management, 78 Blanshard St., Victoria, B.C. V8W 9M2, Canada.

Engås, A., S. Lokkeborg , E. Ona, A.V. Soldal. 1996. Effects of seismic shooting on local abundanceand catch rates of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus). Canadian Journal of Fisheries and Aquatic Sciences. 53:2238-49.

Enger, P.S., H.E. Karlsen, F.R. Knudsen, and O. Sand. 1993. Detection and reaction of fish to infrasound. Fish Behaviour in Relation to Fishing Operations., 1993, pp. 108-112, ICES marine science symposia. Copenhagen. Vol. 196.

Evans, W.A., B. Johnston. 1980. Fish migration an fish passage: a practical guide to solving fish passage problems. Rev. ed. EM-7100-2. Washington DC. U.S. Department of Agriculture, Forest Service. 163 pp.

Everest, F.H., R.L. Beschta, J.C. Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm. 1987. Fine sediment and salmonid production B a paradox. In: Salo, E.; Cundy, T. eds. Streamside management: forestry and fishery interactions: proceedings of a symposium held at the University of Washington, February 12-14, 1986. Contribution 57. Seattle: University of Washington, Institute of Forestry Resources. pp. 98-142.

Fajen, O.F. and J.B. Layzer. 1993. Agricultural practices. *In* Bryan, C.F. and D.A. Rutherford, eds. Impacts on warmwater streams: Guidelines for evaluation. pp. 257-267. Southern Division, American Fisheries Society. Little Rock, AR.

Farag, 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.

Feist B.E., Anderson J.J., Miyamoto R. 1996. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. Seattle (WA): Fisheries Research Institute-University of Washington. FRI-UW-9603. 58 pp.

Ferraro, S.P., R.C. Swartz, F.A. Cole, and D.W. Schults. 1991. "Temporal changes in the benthos along a pollution gradient: discriminating the effects of natural phenomena from sewage-industrial wastewater effects." Estuarine Coastal Shelf Science. 33:383-407.

Flowers, B. 2004. Domestic water conservation: Greywater, rainwater and other innovations. Internet search on November 6, 2009. http://www.csa.com/discoveryguides/water/overview.php

Fresh, K.L., B.W. Williams, S. Wyllie-Echeverria, and T. Wyllie-Echeverria. 2001. Mitigating impacts of overwater floats on eelgrass *Zostera marina* L. in Puget Sound, Washington. In: Proceedings of Puget Sound Research 2001-The fifth Puget Sound Research Conference; 2001 Feb 12-14; Bellevue, WA. Olympia (WA): Puget Sound Action Team.

Fresh, K. 1997. The role of competition and predation in the decline of Pacific salmon and steelhead. *In* Stouter, D., P. Bisson, and R.J. Naiman, eds. *Pacific Salmon and Their Ecosystems: Status and Future Options.* Chapman and Hall, New York.

Fulton, M.H., G.I. Scott, A. Fortner, T.F. Bidleman, and B. Ngabe. 1993. "The effects of urbanization on small high salinity estuaries of the southeastern United States." Archives for Environmental Contamination and Toxicology. 25(4):476-484.

Furniss, M. J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. *In* Meehan W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD. American Fisheries Society. pp. 297-323.

Gandy, C.J., J.W.N. Smith, and A.P. Jarvis. 2007. Attenuation of mining derived pollutants in the hyporheic zone: A Literature Review. Science of the Total Environment. 373 pp 435-446.

Gardner, L.A. and S.C. Jewett. 1994. To Evaluate the Suitability of a Coarse-Grain Hydraulic Bucket Sampler for Marine Placer Deposits and Mine Tailings Sites. 1993 Benthic Monitoring Results Final Report. Document No. 6938-001-400 Box :16.

Gausland, Ingebert. 2003. Report for Norwegian Oil Industry Association (OLF): Seismic Surveys Impact on Fish and Fisheries. Stavanger, March 2003.

Glasby, T.M. 1999. "Effects of shading on subtidal epibiotic assemblages." J. Exp. Mar. Biol. Ecol. 234(1999). pp. 275-290.

Goldstein, J.N., D.F. Woodward, and A.M.Farag. 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.

Good, J.W. 1987. "Mitigating estuarine development impacts in the Pacific Northwest: from concept to practice." Northwest Environmental Journal. Vol. 3. No. 1.

Gould E, Clark P.E, Thurberg F.P. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Gowen, A.W. 1978. The Environmental Effects of OCS Pipelines. Initial Findings. New England River Basins Commission. Boston, MA. 4:24-43

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin, and S.L.McNutt. 2006. A major ecosystem shift in the Northern Bering Sea.

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.

Grimes, C.B. 1975. "Entrapment of fishes on intake water screens at a steam electric generating station." Chesapeake Science. 16:172-177.

Grosenheider KE, PR Bloom, TR Halbach, and Johnson, M. R. 2005. A Review of the Current Literature Regarding Polycyclic Aromatic Hydrocarbons in Asphalt Pavement. Mn/DOT Contract No. 81655. University of Minnesota, Minneapolis, MN, USA.

Groundwater Protection Council. 2010. State Groundwater Fact Sheets. http://www.gwpc.org/e-library/documents/state_fact_sheets/alaska.pdf. Ground Water Protection Council, 13308 N. MacArthur Blvd., Oklahoma City, OK 73142.

Haas, M.A., C.A. Simenstad, J.R. Cordell, D.A. Beauchamp, and B.S. Miller. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, Washington. Final Research Report No. WA-RD 550.1. Prepared for the Washington State Transportation Commission, Washington State Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. 114 pp.

Hansen, J.A., Lipton J., and Welsh P.G. 2002. Relative sensitivity of bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncorhynchus mykiss*) to acute copper toxicity. Environmental toxicology and chemistry. 21 (3): 633-639

Hansen, J. A., J. C. A. Marr, J. Lipton, D. Cacela, and H. L. Bergman. 1999a. Difference in neurobiological responses of chinook salmon (Oncorhynchus tshawytscha) and rainbow trout (Oncorhynchus mykiss) exposed to copper and cobalt: behavioral avoidance. Environmental Toxicology and Chemistry. 18:1972-1978.

Hansen, J. A., J. D. Rose, R. A. Jenkins, K. G. Gerow, and H. L. Bergman. 1999b. Chinook salmon (Oncorhynchus tshawytscha) and rainbow trout (Oncorhynchus mykiss) exposed to copper: neurophysiological and histological effects on the olfactory system. Environmental Toxicology and Chemistry.18:1979-1991.

Hanson, C.H., J.R. White, and H.W. Li. 1977. "Entrapment and impingement of fishes by power plant cooling water intakes: an overview." Marine Fisheries Review. 39:7-17.

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.

Heifetz, J., M.L. Murphy, and K.V. Koski. 1986. (Effects of logging on winter habitat of juvenile salmonids in Alaskan streams." North American Journal of Fisheries Management. *6:52-58.*

Heintz, R.A., S.D. Rice, A.C. Wertheimer, R.F. Bradshaw, F.P. Thrower, J.E. Joyce, and J.W. Short. 2000. "Delayed effects on growth and marine survival of pink salmon *Oncorhynchus gorbuscha*, after exposure to crude oil during embryonic development." Mar. Ecol. Prog. Ser. 208:205-216.

Heintz, R.A., J.W. Short, and S.D. Rice. 1999. Sensitivity of fish embryos to weathered crude oil: Part II. Incubating downstream from weathered Exxon Valdez crude oil caused increased mortality of pink salmon (*Onchorhynchus gorbuscha*) embryos. Environmental Toxicology and Chemistry. 18:494-503.

Heinz Center. 2002. Dam removal: science and decision making. Washington (DC): The H. JohnHeinz III Center for Science, Economics, and the Environment. 236 p.

Helvey, M. 2002. "Are southern California oil and gas platforms essential fish habitat?" ICES Journal of Marine Science. 59:S266-S271.

Helvey, M. and P.B. Dorn. 1987. "Selective removal of reef fish associated with an offshore cooling-water intake structure." J. Applied Ecology. 24:1-12.

Helvey, M. 1985. "Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California." Marine Fisheries Review. 47:18-26.

Herke, W.H. and B.D. Rogers. 1993. Maintenance of the estuarine environment. Pages 263-286 in C.C. Kohler and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Hicks, B.J., J.D. Hall, P.A. Bisson, and J.R. Sedell, J.R. 1991. Responses of salmonids to habitat changes. In: Meehan, W.R. (Ed.) 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD: American Fisheries Society: 483-518.

Hoagland, K.D., J.P. Carder, and R.L. Spawn. 1996. Effects of organic toxic substances. pp. 469-496. *In* Stevenson, R.J., M.L. Bothwell, and R.L. Lowe, eds. Algal Ecology: Freshwater Benthic Ecosystems. Academic Press. New York, NY.

Holler, J.D. 1990. "Nonpoint source phosphoros control by a combination wet detention/filtration facility in Kissimmee, Florida." Florida Scientist. 53(1):28-37.

Horner, R., C. May, E. Livingston, and J. Maxted. 1999. Impervious cover, aquatic community health, and stormwater BMP's: is there a relationship? *In* Proceedings of the Sixth Biennial Stormwater Research and Watershed Management Conference. Sept. 14-17, 1999. Tampa Florida. Southwest Florida Water Management District. Available on line: www.stormwater-resources.com/ proceedings_of_the_sixth_biennia.htm.

Hoss, D.E. and G.W. Thayer. 1993. The importance of habitat to the early life history of estuarine dependent fishes. American Fisheries Society Symposium. 14:147-158.

Hurme, A.K. and E.J. Pullen. 1988. Biological effects of marine sand mining and fill placement for beach replenishment: Lesson for other use. Marine Mining. Vol. 7.

Islam Md. S. and Tanaka M. 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. Marine Pollution Bulletin. 48(7-8):624-49.

Jackson, R.G. 1986. "Effects of bark accumulation on benthic infaunal at a log transfer facility in Southeast Alaska." Marine Pollution Bulletin. 17(6):258-262.

Jacobson K.C., M.R. Arkoosh, A.N. Kagley, E.R. Clemons, T.K. Collier, Casillas. 2003. Cumulative effects of natural and anthropogenic stress on immune function and disease resistance in juvenile Chinook salmon. J. Aquat. Anim. Health. 15:1–12

Jennings, S.R., D.R. Neuman, and P.S. Blicker. 2008. Acid Mine Drainage and Effects on Fish Health and Ecology: A Review. Reclamation Research Group Publication, Bozeman, MT.

Jennings, S.R., J.D. Dollhopf, and W.I. Inskeep. 2000. Acid production from sulfide minerals using hydrogen peroxide weathering. Applied Geochemistry. 15:235-243.

Jewett, S.C. 1999. Assessment of Red King Crabs Following Offshore Placer Gold Mining in Norton Sound. Reprinted from Alaska Fishery Research Bulletin. Vol. 6 No. 1, Summer 1999.

Johnson, L. L., Collier, T. K., Stein, J. E., 2002. An Analysis in Support of Sediment Quality Thresholds for Polycyclic Aromatic Hydrocarbons (PAHs) to Protect Estuarine Fish.˙Aquatic Conservation: Marine and Freshwater Ecosystems. Vol 12 Issue 5, Pages 517 – 538.

Johnson, L. 2000. An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAHs) to protect estuarine fish. White Paper from National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington. 29 p.

Johnson, L., S.Y. Sol, G.M. Ylitalo, T. Hom, B. French, O.P. Olson, and T.K. Collier. 1999. “Reproductive injury in English sole (*Pleuronectes vetulus*) from the Hylebos Waterway, Commencement Bay, Washington.” Journal of Aquatic Ecosystem Stress and Recovery. 6:289-310.

Johnson, S.W., S.D. Rice, and D.A. Moles. 1998a. Effects of submarine mine tailings disposal on juvenile yellowfin sole (*Pleuronectes asper*): a laboratory study. Marine Pollution Bulletin. 36:278-287.

Johnson, S.W., R.P. Stone, and D.C. Love. 1998b. Avoidance behavior of ovigerous Tanner crabs *(Chionoecetes bairdi*) exposed to mine tailings: a laboratory study. Alaska Fish. Res. Bull. 5:39-45.

Kahler, T., M. Grassley, and D. Beauchamp. 2000. A summary of the effects of bulkheads, piers, and other artificial structures and shorezone development on ESA listed salmonids in lakes. Final Report to the City of Bellevue, Washington. 74 pp.

Kenai Peninsula Borough. 2004. Cook Inlet Oil and Gas, Kenai Penisula Borough Oil and Gas History. http://www.cookinletoilandgas.org/kpb/history.htm

Kennish, M.J., 2001. Environmental Threats and Environmental Future of Estuaries. Environmental Conservation. 29:78-107.

Kennish, M.J. 1998. *Pollution Impacts on Marine Biotic Communities*. CRC Press, New York, NY. 310 pp.

Kennish, M.J., 1997. Practical Handbook of Estuarine and Marine Pollution. CRC Press Inc.

Kilmartin, M.P. 1989. Hydrology of reclaimed open cast coal mined land: A Review. International Journal of Surface Mining. 3:71-82

Kirkpatrick, B., T.C. Shirley, and C.E. O’Clair. 1998. Deep-water bark accumulation and benthos richness at log transfer and storage facilities. Alaska Fishery Research Bulletin. 5(2):103-115.

Klein, R. 1997. The effects of marinas and boating activities upon tidal waters. Community and Environmental Defense Services. Owings Mills, Maryland. 23 pp.

Knudsen, F.R., C.B. Schreck, S.M. Knapp, P.S. Enger, and O. Sand. 1997. “Infrasound produces flight and avoidance responses in Pacific juvenile salmonids.” Journal of Fish Biology. 51:824-829.

Knudsen, F.R., P.S. Enger, and O. Sand. 1994. “Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, Salmo salar.” Journal of Fish Biology. 45:227-233.

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.

Koski, K.V. 1981. The survival and quality of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence. Rapp. P.-v. Reun. Conx. int. Explor. Mer, 178:330-333.

Kuipers, P.E. 2000. Hardrock Reclamation Bonding Practices in the Western United States. Report To: National Wildlife Federation. 2260 Baseline Road, Suite 100, Boulder Colorado, 80302.

Laetz CA., D.H Baldwin, T. K Collier, V. Hebert, J. D.Stark, and N. L. Scholz. 2009. The Synergistic Toxicity of Pesticide Mixtures: Implications for Risk Assessment and the Conservation of Endangered Pacific Salmon. Environmental Health Perspectives. Volume 117 number 3: 348 - 353.

LaLiberte, D., and Ewing, R.D., 2006. Effects on Puget Sound Chinook Salmon NPDES Authorized Toxic Discharges. Combined Report. April 17, 2006

Lalonde, B.A., P.Jackman, K. Doe, C. Garron, and J. Aube. 2008. Toxicity Testing of Sediment Collected in the Vicinity of effluent Discharges from Seafood Processing Plants in the Maritimes. Environmental Contamination and Technology. Vol 56, Number 3, pp389-396.

Langford, T.E., N.J. Utting, and R.H.A. Holmes. 1978. Factors affecting the impingement of fishes on power station cooling-water intake screens. *In* Physiology and Behaviour of Marine Organisms. D.S. McLusky and A.J. Berry, eds. pp. 281-288. Pergamon Press, Oxford and New York.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

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.

Leppard, G.G. and I.G. Droppo. 2003. The need and means to characterize sediment structure and behaviour prior to the selection and implementation of remediation plans. Hydrobiologia. 494:313-7.

Levin, L. A., W. Ekau, A.J. Gooday, F. Jorissen, J.J. Middelburg,W. Naqvi, C. Neira, N.N. Rabalais, and J. Zhang. 2009. Effects of natural and human-induced hypoxia on coastal benthos. Biogeosciences. 6, 3563–3654.

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.

Lewis-Russ, A. 1997. Ground Water Quality. In: Marcus, J.J., ed., Mining Environmental Handbook, Effects of Mining on the Environment and American Environmental Controls on Mining, Imperial College Press, London, pp. 162-165.

Logan, D. 2007. Perspective on Ecotoxicology of PAHs to Fish. Human and Ecological Risk Assessment. Volume 13, Number 2, March 2007, pp. 302-316(15).

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.

Love, M.S., M. Nishimoto, D. Schroeder, and J. Caselle. 1999. The ecological role of natural reefs and oil and gas production platforms on rocky reef fishes in southern California: Final interim report. U.S. Geological Survey, Biological Resources Division. USGS/BRD/CR-1999-007. 208 pp.

Love, M., J. Hyland, A. Egeling, T. Herrlinger, A. Brooks, and E. Imamura. 1994. “A pilot study of the distribution and abundance of rockfishes in relation to natural environmental factors and an offshore oil and gas production platform off the coast of southern California.” Bulletin Marine Science. 55(2-3): 1062-1085.

Love, M.S. and W. Westphal. 1990. Comparison of fishes taken by a sportfishing party vessel around oil platforms and adjacent natural reefs near Santa Barbara, California. Fishery Bulletin, U.S. 88:599-605.

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.

Luchetti, G. and R. Feurstenburg. 1993. Relative fish use in urban and non-urban streams. Proceedings of a conference on Wild Salmon. Vancouver, British Columbia, Canada.

Ludwig, M. and E. Gould . 1988. Contaminant input, fate and biological effects. In: Pacheco AL, editor. Woods Hole (MA): US Department of Commerce. NOAA/NMFS/Northeast Fisheries Science Center. NOAA Technical Memorandum NMFS-F/NEC 56. p. 305-322.

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.

MacDonald, L.H., R.W. Sampson, and D.M Anderson. 2001. “Runoff and road erosion at the plot and road segment scales, St. John, U.S. Virgin Islands.” Earth Surface Processes and Landforms. 26:251-272.

Mahler B.J., P.C. Van Metre, T.J. Bashara, J.T. Wilson and D.A. Johns. 2005. Parking lot sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons. Environ. Sci. Technol. 39(15): 5560- 66.

Markham, V.D. 2006. U.S. National Report on Population and the Environment. New Canaan (CT): Center for Environment and Population. 67 pp.

Martin, D. J. and D. J. Grotefendt. 2001. Buffer Zones and LWD supply. Project Report prepared for Alaska Forest Association and Alaska Department of Environmental Conservation. Community Water Quality Grant No: NP-01-12.

Martin, D.J. and A. Shelly. 2004. Status and trends of fish habitat condition on private timberlands in southeast Alaska: 2003 Summary. Report to Sealaska Corporation and Alaska Department of Natural Resources, Juneau, Alaska.

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.

May, C., R. Horner, J. Karr, B. Mar, and E. Welch. 1997. Effects of urbanization on small streams in the Puget Sound lowland ecoregion. Watershed Protection Techniques. 2(4):483-494.

McCarthy S.G., Incardona, J.P., Scholz, N.L., 2008. Coastal Storms, Toxic Runoff, and the Sustainable Conservation of Fish and Fisheries. American Fisheries Society. Symposium 64:7–27.

McCauley, R.D., J. Fewtrell, and A.N. Popper. 2003. “High intensity anthropogenic sound damages fish ears.” J. Acoust. Soc. AM. 113 (1), January 2003. pp. 638-642.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J. D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000. Marine seismic surveys: Analysis and propegation of air-gun signals; and the effects of exposure on humpback whales, sea turtles, fishes and squid. Centre for Maine Science and Technology, Curtain University, R99-15, Perth, Western Australia. 185 pp.

McElroy A, Farrington J, and Teal J. 1989. Bioavailability of polycyclic aromatic hydrocarbons in the aquatic environment. In: Varanasi U, editor. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. Boca Raton (FL): CRC Press. pp. 2-39.

McGee, S., R. Piorkowski, R. and G. Ruiz. 2006. Analysis of recent vessel arrivals and ballast in Alaska: Toward assessing ship-mediated invasion risk. Marine Pollution Bulletin. 52 (2006) 1634-1645.

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.

Meehan, W.R., W.A. Farr, D.M. Bishop, and J.H. Patric. 1969. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. U.S. Department of Agriculture, Forest Service. General Technical Report PNW-82. Institute of Northern Forests, Pacific Northwest Forest and Range Experiment Station.

Michel, J. and M.O. Hayes. 1999. “Weathering patterns of oil residues eight years after the Exxon Valdez oil spill.” Marine Pollution Bulletin. 38(10):855-863.

Minerals Management Service (MMS). 1991. Alaska Outer Continental Shelf (OCS) Mining Program. Norton Sound Lease Sale. Final Environmental Impact Statement. March 1991

Mitsch W.J., and Gosselink J.G. 1993. Wetlands. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 pp.

Moazzam, M. and S.H.N. Rizvi. 1980. “Fish entrapment in the seawater intake of a power plant at Karachi coast.” Environ. Biology of Fishes. 5:49-57.

Moles, A. and N. Hale. 2003. Use of physiological responses in *Mytilus trossulus* as integrative bioindicators of sewage pollution. Marine Pollution Bulletin. 46:954-958.

Moles, A. and B. Norcross. 1995. Sediment preference in juvenile pacific flatfishes. Netherlands Journal of Sea Research. Volume 34, Issues 1-3. pp. 177-182.

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.

Moore, A. and Waring, C.P. 2001. "The effects of a synthetic pyrethroid pesticide on some aspects of reproduction in Atlantic salmon (*Salmo salar* L)." Aquatic Toxicology. 52:1-12.

Muir, D. C. G., R. J. Norstrom, and M. Simon. 1988. Organochlorine contaminants in arctic marine food chains: accumulation of specific polychlorinated biphenyls and chlordan-related compounds. Environmental Science and Technology 22:1071-1078.

Murphy, M.L., S.W. Johnson, and D.J. Csepp. 2000. "A comparison of fish assemblages in eelgrass and adjacent subtidal habitats near Craig, Alaska." *AK. Fish. Res. J.* 7:11-21.Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and AlaskaCrequirements for protection and restoration. U.S. Dep. Commer., NOAA Coastal Ocean Program, Decision Analysis Series No. 7, 156 + xxii p.

Murphy, M.L. and K.V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal of Fisheries Management 9, 427-436.

Murty, A. S. 1986. Toxicity of Pesticides to Fish. Volume 2. CRC Press, Boca Raton, FL.

Mutz, M. 1998. Stream system restoration in a strip-mining region, eastern Germany: dimension, problems, and first steps. Aquatic Conservation: Marine and Freshwater Ecosystems. Aquatic Conservation, March 6. Freshwater Ecosystems. 8:159–166.

Myren, R.T. and R.J. Ellis. 1984. Evaportranspiration in forest succession and long-term effects upon fishery resources: a consideration for management of our old-growth forests. pp. 183-186. *In* Meehan, M.R., T.R. Merrill, Jr., and T.A. Hanley, eds. Fish and wildlife relationships in old growth forests. American Institute of Fishery Research Biologists.

Sheavly, S.B.. 2007. "National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary." Prepared for U.S. Environmental Protection Agency by Ocean Conservancy, Grant Number X83053401-02. 76 pp. http://www.oceanconservancy.org/site/DocServer/NMDMP Report April_2008.pdf?docID=4601

NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon. http://www.nwr.noaa.gov/Salmon-Hydropower/FERC/upload/Fish-Passage-Design.pdf

NMFS. 2009. National Marine Fisheries Service Endangered Species Act Section 7 consultation: Environmental Protection Agency registration of pesticides containing carbofuran, carbaryl, and methomyl. In *Biological Opinion*. (U.S. Department of Commerce, Silver Spring, MD). pp 591.

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. 2003. Biological Opinion for the Benicia-Martinez New Bridge Project, Southwest Region, Santa Rosa, California. Admin. Rec. 151422SWR02SR6292.

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. 2001. Biological Opinion for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. Southwest Region, Santa Rosa, California. Admin. Rec. 151422SWR99SR190.

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.

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 (NRC). 2003. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. Committee on the Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. The National Academies Press, Washington, D.C. Prepublication Copy. 452 pp. (www.nap.edu).

NRC. 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).

NRC. 1996. Upstream: salmon and society in the Pacific Northwest. Report of the committee on protection and management of Pacific Northwest anadromous salmonids. Board on Environmental Studies and Toxicology, and Commission on Life Sciences. National Academy Press. Washington, D.C. 20055.

NRC. 1989. Irrigation-induced water quality problems: what can be learned from the San Joaquin Valley experience. National Academy Press, Washington, D.C.

Neff, J. M. 2002. Bioaccumulation in Marine Organisms. Effect of Contaminants from Oil Well Produced Water. Elsevier Science Ltd: Kidlington, Oxford, UK.

Neff, J. M. 1985. Polycyclic aromatic hydrocarbons. pp. 416-454. IN: G. M. Rand and S. R. Petrocelli, eds. Fundamentals of Aquatic Toxicology. Methods and Applications. Taylor & Francis:New York.

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. 133 pp.

Northcote, T.G. and G.F. Hartman. 2004. Fishes and Forestry - Worldwide Watershed Interactions and Management, Blackwell Publishing, Oxford, UK, 789 pp.

Northwest Power Planning Council. 1986. Compilation of information on salmon and steelhead losses in the Columbia River Basin. Columbia River Basin and Wildlife Program. Portland, OR.

O'Hearn, J. 1997. Surface Water Quantity. In: Marcus, J.J., ed., Mining Environmental Handbook, Effects of Mining on the Environment and American Environmental Controls on Mining, Imperial College Press, London, pp. 221-225.

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 (PFMC). 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.

Pacific Northwest Pollution Control Council. 1971. Log storage and rafting in public waters. Task Force report. p. 56

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.

Peplow, D. and R. Edmonds. 2004. The effects of mine waste contamination at multiple levels of biological organization. Ecological Engineering. 24: 1-2, p101-119.

Peterson, C. H., S. D. Rice, J. W. Short, D. Esler, J. L. Bodkin, B. E.Ballachey, and D. B. Irons. 2003. Long-term ecosystem response to the Exxon Valdez oil spill. Science. 302: 2082-2086.

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.

Polasek, L.G. 1997. Assessment of wetland habitat alterations resulting from construction of a pipeline through coastal marshes in Orange County, Texas. Final Report: Texas Parks and Wildlife Department, Port Arthur, TX. 40 pp.

Poston, T. 2001. Treated wood issues associated with overwater structures in marine and freshwater environments. White Paper submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology and Washington Department of Transportation by Batelle. 85 pp.

Preston, B.L. 2002. "Indirect effects in aquatic ecotoxicology: implications for ecological risk assessment." Environmental Management. 29:311-323.

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.

Rand, G.M. (Editor). 1995. Fundamentals of Aquatic Toxicology: Effects, Environmental Fate and Risk Assessment. Taylor and Francis Publishing. Second Edition. Taylor and Francis, Washington, D.C

Raymond, H. 1979. "Effects of dams and impoundment on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975." Trans. Amer. Fish. Soc. 108:505-529.

Reiser, D.W., T. Nightengale, N. Hendrix, S. Beck. 2005. Effects of Pulse type Flows on Benthic Macroinvertebrates and Fish: A Review and Synthesis of Information. R2 Resources Consultants, Inc. for Pacific Gas & Electric Company.

Ren J, and Packman A. 2002. Effects of background water composition on stream-subsurface exchangeof submicron colloids. Journal of Environmental Engineering. 128(7):624-34.

Reyff, J.A. 2003. Underwater sound levels associated with seismic retrofit construction of the Richmond-San Rafael Bridge. Document in support of Biological Assessment for the Richmond-San Rafael Bridge Seismic Safety Project. January 31, 2003. 18 pp.

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.

Rice, S.D., J.W. Short, R.A. Heintz, M.G. Carls, and A. Moles. 2000. Life-history consequences of oil pollution in fish natal habitat. pp. 1210-1215. *In* Catania, P., ed. Energy 2000. Balaban Publishers, Lancaster, England.

Richardson WJ, Greene CR, Malme CI, Thomas DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.

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.

Rogers, P.H. and M. Cox. 1988. Underwater sound as a biological stimulus. pp. 131-149. *In* Sensory biology of aquatic animals. Atema, J, R.R. Fay, A.N. Popper, and W.N. Tavolga, eds. Springer-Verlag. New York.

Rose, K.A., A.T. Adamack, C.A. Murphy, S.E. Sable, S.E. Kolesar, J.K. Craig, D.J. Breitburg, P. Thomas, M.H. Brouwer, C.F. Cerco, and S. Diamond. 2009. Does hypoxia have population-level effects on coastal fish? Musings from the virtual world. Journal of Experimental Marine Biology and Ecology. In Press.

Rosecchi, E., A.J. Crivelli, G. Catsadorakis. 1993. The establishment and impact of Pseudorabora 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.

Safavi, H.R. 1996. Quality control of urban runoff and sound management. Hydrobiologia: Diapause in the Crustacea. pp. 131 -141.

Saiki, M.K., D.T. Castleberry, T.W. May, B.A. Martin, and F.N. Bullard. 1995. Copper, cadmium, and zinc concentrations in aquatic food-chains from the upper Sacramento River (California) and selected tributaries. Archives of Environmental Contamination and Toxicology. 29(4):484-491.

Sand, O., P.S. Enger, H.E. Karlsen, F. Knudsen, T. Kvernstuen. 2000. “Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla.*” Environmental Biology of Fishes. 57:327-336.

Sandahl, J.F., D. H. Baldwin, J. J. Jenkins, and N.L. Scholz. 2007a. Odor-evoked field potentials as indicators of sublethal neurotoxicity in juvenile coho salmon (*Oncorhynchus kisutch)* exposed to copper, chlorpyrifos, or esfenvalerate. Canadian Journal of Fisheries Aquatic Sciences 64, 404-413.

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007b. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science and Technology. 41:2998-3004.

Sandahl J.F., D. H. Baldwin, J. J. Jenkins, and N. L. Scholz. 2005. Comparative Thresholds for Acetylcholinesterase Inhibition and Behavorial Impairment in Coho Salmon Exposed to Chlorpyrifos. Setac Press. Vol. 24, No. 1: 136-145.

Scholz, N.L., N.K. Truelove, B.L. French, B.A. Berejikian, T.P. Quinn, E. Casillas, and T.K. Collier. 2000. "Diazinon disrupts antipredator and homing behaviors in chinook salmon (*Oncorhynchus tsawytscha*)." Canadian Journal of Fisheries and Aquatic Sciences. 57:1911-1918.

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.

Scrivener, J.T. and M.J. Brownlee. 1989. "Effects of forest harvesting on spawning gravel and incubation survival of chum (*Oncorhynchus kata*) and coho (*O. kisutch*) salmon in Carnation Creek, British Columbia." Canadian Journal of Fisheries and Aquatic Sciences. 46(4):681-696.

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.

Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 p.

Short, J. W., M. R. Lindeberg, P. M. Harris, J. M. Maselko, J. J. Pella, and S. D. Rice. 2004. Estimate of oil persisting on beaches of Prince William Sound, 12 after the Exxon Valdez oil spill. Environmental Science and Technology. 38(1): 19-25.

Short, Jeffrey W., Stanley D. Rice, Ron A. Heintz, Mark G. Carls, and Adam Moles. 2003. Long-term Effects of Crude Oil on Developing Fish: Lessons from the Exxon Valdez Oil Spill. Energy Sources. 25: 509-517.

Short, J.W., M.R. Lindeberg, P.M. Harris, J. Maselko, and S.D. Rice. 2002. Vertical Oil Distribution Within the Intertidal Zone 12 Years After the *EXXON VALDEZ* Oil Spill in Prince William Sound, Alaska. Pp. 57-72 In: Proceedings of the Twenty-fifth Arctic and Marine Oilspill Program (AMOP) Technical Seminar. Environment Canada, Ottawa, Ontario.

Sidle, R.C., A.J. Pearce, and C.L. O'Loughlin. 1985. Hillslope stability and land use. Water Resources Monograph 11. Washington D.C.: American Geophysical Union 140 pp.

Simon, J.A., and Sobieraj, J.A., 2006. Contributions of Common Sources of Polycyclic Aromatic Hydrocarbons to Soil Contamination. Journal of Remediation. Vol 16, Issue 3, p25-35

Sogard, S.M. and K.W. Able. 1991. “A comparison of eelgrass, sea lettuce macroalgae and marsh creeks as habitats for epibenthic fishes and decapods.” Estuarine, Coastal and Shelf Science. 33, 501-519.

Solley, Wayne B. 1997. Estimates of Water Use in the Western United States in 1990 and Water-Use Trends 1960-90. Report to the Western Water Policy Review Advisory Commission U.S. Geological Survey. Reston, Virginia. 19pp.

Sophocleous, M. 2002. Interactions between groundwater and surface water: The State of the Science. Hydrogeology Journal 10:52–67.

Spence, B.C., G.A. Lomnicky, 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).

Spromberg J.A. and J.P. Meador. 2005. Relating results of chronic toxicity responses to population-level effects: modeling effects on wild Chinook salmon populations. Integrated Environmental Assessment and Management. 1, 9–21.

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.

Stehr, C.M., D.W. Brown, T. Hom, B.F. Anulacion, W.L. Reichert, and T.K. Collier. 2000. “Exposure of juvenile chinook and chum salmon to chemical contaminants in the Hylebos Waterway of Commencement Bay, Tacoma, Washington.” Journal of Aquatic Ecosystem Stress and Recovery. 7:215-227.

Stewart, R. K. and D.R. Tangarone. 1977. Water Quality Investigations Related to Seafood Processing Wastewater Discharges at Dutch Harbor, Alaska - October 1975 and October 1976. Region X, U.S. Environmental Protection Agency. Working Paper #EPA 910/8-77-100. 78 pp.

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.

Stocker, M. 2002. Fish, mollusks and other sea animals' use of sound, and the impact of anthropogenic noise in the marine acoustic environment. Journal of Acoustical Society of America. 112(5):2431.

Stotz, T. and J. Colby. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 pp. + appendices.

Sturdevant, M.V., A.C. Wertheimer, and J.L. Lum. 1996. Diets of juvenile pink and chum salmon in oiled and non-oiled nearshore habitats in Prince William Sound, 1989 and 1990. pp. 578-592. In: S.D. Rice, et al. (Eds.) American Fisheries Society Symposium 18, Proceedings of the Exxon Valdez Oil Spill Symposium.

Sturdevant, M.V., A.C. Wertheimer, and J.L. Lum. 1994. Diet of juvenile pink and chum salmon in oiled and non-oiled nearshore habitats in Prince William Sound, 1989 and 1990. Chapter 4. In: A.C. Wertheimer, et al. (Eds.) Impact of the oil spill on juvenile pink and chum salmon and their prey in critical nearshore habitats. Exxon Valdez Oil Spill, State/Federal damage Assessment Final Report. Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, Alaska.

Swanston, D.N. 1974. The forest ecosystem of southeast Alaska. Soil mass movement. General Technical Report PNW-17. U.S. Department of Agriculture, Forest Service. Pacific Northwest Forest and Range Experiment Station. Portland, OR.

Teaf, C.M. 2008. "Polycyclic Aromatic Hydrocarbons (PAHs) in Urban Soil: A Florida Risk Assessment Perspective,"International Journal of Soil, Sediment and Water: Vol. 1: Iss. 2, Article 2. Available at: http://scholarworks.umass.edu/intljssw/vol1/iss2/2

Theriault, 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.

Travnichek, V.H., A.V. Zale, and W.L. Fisher. 1993. “Entrainment of ichthyoplankton by a warmwater hydroelectric facility.” Trans. Amer. Fish. Soc. 122:709-716.

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.

Turekian K. 1978. The Fate of Estuaries. Washington (DC): US Environmental Protection Agency. EPA-600/9-78-038. p 27-38.

Turner, A., and G.E. Millward 2002. Suspended particles: their role in estuarine biogeochemical cycles. Estuarine, Coastal and Shelf Science. 55:857-83.

U.S. Army Corps of Engineers (USACE). 1993. Engineering and Design: Environmental; Engineering for Small Boat Basins. EM 1110-2-1206. Dept. of the Army, CECW-EH-W. Washington DC.

US Department of Agriculture (USDA). 2008a. Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings. National Technology and Development Program, Report 0877 1801-SDTDC. May 2008.

USDA Forest Service. 2008b. Tongass Monitoring and Evaluation Report – Appendix B http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml

USDA. 2004. Tongass Monitoring and Evaluation Report – Fish Habitat http://www.fs.fed.us/r10/tongass/projects/tlmp/2004_monitoring_report/index.shtml

USDA Forest Service. 2003. R10-MB-481a. Tongass Land Management Provision. Final Supplemental Environmental Impact Statement - Roadless Area Evaluation for Wilderness Recommendations. http://www.tongass-seis.net/seis/pdf/Volume_I.pdf

US Environmental Protection Agency (USEPA). 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.

USEPA. 2002. National Water Quality Inventory: 2000 Report to Congress. EPA-841-R-02-001. EPA Office of Water, Washington, D.C.

USEPA. 2001. Reissuance of the NPDES General Permit for Seafood Processors Operating Throughout Alaska in Waters of the United States (NPDES General Permit No. AK-G52-0000) Federal Register: July 27, 2001. U.S. Environmental Protection Agency (EPA), Region X.

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. 1999. Combined sewer overflow management fact sheet: pollution prevention. Washington (DC): US EPA Office of Water. EPA 832-F-99-038. 9 p.

USEPA, Region 10. 1996. 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-G70-1000. EPA Response to Comments from September 1996 Public Notice http://info.dec.state.ak.us/DECPermit/water31rtc.pdf.

USEPA. 1995. National Water Quality Inventory: 1994 Report to Congress. EPA-841-R-95-005. EPA Office of Water, Washington, D.C.

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.

USEPA. 1979. Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Waters at Dutch Harbor, Alaska.

Vandermeulen, J.H. and D Mossman . 1996. Sources of variability in seasonal hepatic microsomal oxygenase activity in winter flounder (Pleuronectes americanus) from a coal tar contaminated estuary. Canadian Journal of Fisheries and Aquatic Sciences. 53:(8) 1741-1753, 10.1139/f96-026.

Van der Veer, H., M.J.N. Bergmen, and J.J. Beukema. 1985. “Dredging activities in the Dutch Wadden Sea effects on marcobenthic infauna.” Netherlands Journal for Sea Research. 19:183-190.

Verity, P.G., M. Alber and S.B. Bricker. 2006. Development of Hypoxia in well-mixed subtropical estuaries in the Southeastern USA. Estuaries and Coasts: Volume 29, Number 4 August, 2006 p.665-673

Walker, D., R. Lukatelich, R.G. Bastyan and A.J. McComb. 1989. "The effect of boat moorings on seagrass beds near Perth, Western Australia." Aquatic Botany. 36:69-77. *In* Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 pp.

Wardle, C.S., T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson, and D. Mackie. 2001. Effects of seismic airguns on marine fish. Fisheries Research Services, Marine Laboratory. Continental Shelf Research, 21 (8-10). pp. 1005-1027.

Warrington, P.D. 1999. Impacts of outboard motors on the aquatic environment. http://www.nalms.org/bclss/impactsoutboard.htm.

Washington Department of Fish and Wildlife. 1998. Gold and fish. Rules and regulations for mineral prospecting and mining in Washington State. Draft, February 1998. Olympia, WA.

Weaver, T.M. and J.J. Fraley. 1993. "A method to measure emergence success of westslope cutthroat trout fry from varying substrate compositions in a natural stream channel." North American Journal of Fisheries Management. 13(4):817-822.

Weiss, P.T., LeFevere, G., and Gulliver, J.S. 2008. Contamination of Soil and Groundwater Due to Stormwater Infiltration Practices: A Literature Review - Project Report No.515. University of Minnesota Stormwater Assessment Project, St. Anthony Falls Laboratory University of Minnesota. http://proteus.pca.state.mn.us/water/stormwater/index.html

West, C., L. Galloway, and J. Lyon. 1995. Mines, Stormwater Pollution, and You. Mineral Policy Center, Washington, D.C.

Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energentics (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 C. 1996. Combatting marine pollution from land-based activities: Australian initiatives. Ocean & Coastal Management. 33(1-3):87-112.

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. 99 pp.

Wu, Y., R. Falconer, and B. Lin. 2005. Modeling trace metal concentration distributions in estuarine waters. Estuarine, Coastal and Shelf Science. 64:699-709.

Würsig, B., C.R. Greene, Jr., and T.A. Jefferson. 2000. "Development of an air bubble curtain to reduce underwater noise of percussive pile driving." Marine Environmental Research. 49:79-93.

Wyllie-Echeverria, S. and R.C. Phillips. 1994. pp. 1-4. *In* Wyllie-Echeverria, S., A.M. Olson and M.J. Hershman, eds. Seagrass science and policy in the Pacific Northwest: proceedings of a seminar series (SMA 94-1) EPA 910/R-94-004. 63 pp.

Yelverton, J.T., D.R. Richmond, W. Hicks, K. Saunders, and R. Fletcher. 1975. The relationship between fish size and their response to underwater blast. Lovelace Foundation for Medical Education and Research, Albuquerque, NM.

Young, M.K., W.A. Hubert, and T.A. Wesche. 1991. "Selection of measures of substrate composition to estimate survival to emergence of salmonids and to detect changes in stream substrates." North American Journal of Fisheries Management. 11 (3):339-346.

Younger, P. L., S.A. Banwart, and R.S. Hedin. 2002. Mine Water: Hydrology, Pollution, Remediation." NY, NY, Springer Pub.

Younger, P.L. 2000. The Adoption and Adaptation of Passive Treatment Technologies for Mine Waters in the United Kingdom. – Mine Water and the Environment, 19: 84—97.

Zale, A.V., O.E. Maughan, D.J. Orth, and W. Layher. 1993. Withdrawals. *In* Bryan, C.F and D.A. Rutherford, eds. Impacts on warmwater streams: Guidelines for evaluation. Pp. 271-281. Southern Division, American Fisheries Society, Little Rock, AR.

Additional Resources

Addison, R.F. and T.G. Smith. 1996. "Trends in organochlorine residue concentrations in ringed seal (*Phoca hispida*) from Holman, Northwest Territories 1972-1991." Arctic. 51:253-561.

Agency for Toxic Substance and Disease Registry (ATSDR). 2006. 2005 CERCLA Priority List of Hazardous Substances. Available at http://www.atsdr.cdc.gov/cercla/05list.html.

Alaska Department of Fish and Game and Alaska Department of Public Transportation of Public Facilities, Memorandum of Agreement for the Design, Permitting, and Construction of Culverts for Fish Passage. August 2001. http://www.sf.adg.state.ak.us/SARR/fishpassage/pdfs/dot_adfg_ fishpass080301.pdf.

Alaska Department of Transportation and Public Facilities Annual Report on the Lynn Canal Marine Habitat Enhancement Project. 2008.

Alaska Division of Public Health. 2003. PCB blood test results from St. Lawrence Island recommendations for consumption of traditional foods. State of Alaska Epidemiology Bulletin. 7(1): 1-5.

Alaska Regulations for Pesticide Control.18 AAC 90, Pesticide Control, Effective September 30, 2007. Sarah Palin, Governor; Larry Hartig, Commissioner. http://www.nmfs.noaa.gov/pr/pdfs/pesticide_biop.pdf

Alaska Sea Grant. 2009. Marine Debris in Alaska: Coordinating Our Efforts. E. Ammann and M. Williams editors. Pub. no.: AK-SG-09-01. University of Alaska Fairbanks. 794 University Avenue, Suite 238, Fairbanks, AK 99709. 136p

Alexander, M.D. and Caissie, D., 2003. Variability and comparison of hyporheic water temperatures and seepage fluxes in a small Atlantic salmon stream. Ground Water. 41(1), 72-82.

American Association of Port Authorities (AAPA). Environmental Management Handbook. http://www.aapa-ports.org/govrelations/env_mgmt_hb.htm

Aono, S, S. Tanabe, Y. Fujise, H. Kato, and R. Tatsukawa. 1997. "Persistent organochlorines in minke whale (*Balaenoptera acutorostrata*) and their prey species from the Antarctic and the north Pacific." *Env. Poll.* 98:81-89.

Aquatic Invasive Species Research and Outreach: http://www.nsgo.seagrant.org/research/nonindigenous/.

Arctic Monitoring and Assessment Programme. 2002. Arctic pollution 2002: Persistent organic pollutants, heavy metals, radioactivity, human health, changing pathways. Arctic Monitoring and Assessment Programme. Oslo Norway. pp. iii - 111.

Baird, R.C. 1996. "Toward new paradigms in coastal resource management: Linkages and institutional effectiveness." Spagnolo, RJ; E. Ambrogio, F.J. Rielly, Jr., eds. Estuaries. 19(2A): 320-335.

Baker, R. J., M. D. Knittel, and J. L. Fryer. 1983. Susceptibility of chinook salmon (Oncorhynchus tshawytscha) and rainbow trout (Salmon gairdneri) to infection with Vibrio anguillarum following sublethal copper exposure. Journal of Fish Diseases. 6:267-275.

Barlocher, F. and Murdoch J.H., 1989. Hyporheic biofilms: a potential food source for interstitial animals. Hydrobiologia. 184, 61-67.

Bay, S. and D. Greenstein. 1994. Toxic effects of elevated salinity and desalination waste brine. *In* J. Cross, ed. Southern California Coastal Water Research Project, Annual Report 1992-93, pp. 149-153. SCCWRP, Westminster, CA.

Beasley, G. and Kineale, P. 2002. Reviewing the impact of metals and PAH's on Macroinvertabrates in Urban Watercourses. Progress in Physical Geography, vol.25, No.2 236-270.

Beckmen, K.B., K.W. Pitcher, G.M. Ylitalo, M.M. Krahn, and K.A. Burek. 2001. Contaminants in Free-ranging Steller Sea Lions, 1998-2001: Organochlorines in Blood, Blubber, Feces and Prey. Workshop to Assess Contaminant Impacts on Steller Sea Lions in Alaska. Anchorage, AK, September 5-6, 2001. Sponsored by Auke Bay Laboratory.

Beckmen, K.B. 2001. Blood organochlorines, immune function and health of free-ranging northern fur seal pups (*Callorhinus ursinus*). PhD. Dissertation. University of Alaska, Fairbanks. Fairbanks, Alaska. 151 pp.

Beckmen, K.B., K.A. Burek, K.W. Pitcher, G.M. Ylitalo, and L.K. Duffy. *In press*. Mercury concentrations in the fur of Steller sea lions and northern fur seals from Alaska. Mar. Poll. Bull.

Beckmen, K.B., G.M. Ylitalo, R.G. Towell, M.M. Krahn, T.M. O'Hara, and J.E. Blake. 1999. "Factors affecting organochlorine contaminant concentrations in milk and blood of northern fur seal (*Callorhinus ursinus*) dams and pups from St. George Island, Alaska." Sci. Total Environ. 231:183-200.

Beechie, T., E. Beamer, and L. Wasserman. 1994. “Estimating coho rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration.” North American Journal of Fisheries Management. 14(4):797-811.

Benaka, L., ed. 1999. Fish Habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland, 459 pp.

Beschta, R.L., M.R. Pyles, A.E. Skaugset, and C.G. Surfleet. 2000. “Peakflow response to forest practices in the western Cascades of Oregon, U.S.A.” Journal of Hydrology. 233:102-120.

Bettinger, P., J. Sessions, and K.N. Johnson. 1998. “Ensuring the compatibility of aquatic habitat and commodity production goals in eastern Oregon with a Tabu search procedure.” Forest Science. 44(1):96-112.

Bilby, R.E. and J.W. Ward. 1991. “Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington.” Canadian Journal of Fisheries and Aquatic Sciences. 48:2499-2508.

Bjornn, T.C., and Reiser, D.W. 1991. Habitat requirements of salmonids in streams. *In* Influences of forest and rangeland management on salmonid fishes and their habitats. *Edited by* W.R. Meehan. *Am. Fish. Soc. Spec*. Publ. 19: 83–138.

Blanton, S.L., R.M. Thom, A.B. Borde, H. Diefenderfer, and J.A. Southard. 2002. Evaluation of methods to increase light under ferry terminals. Final Research Report prepared for Washington State Department of Transportation by Battelle, Pacific Northwest Division of Battelle Memorial Institute. PNNL-13714. 26 pp.

Blanton, S.L., R.M. Thom, J.A. Southard. 2001. Documentation of ferry terminal shading, substrate composition, and algal and eelgrass coverage. Letter Report prepared for University of Washington, School of Aquatic and Fishery Sciences, Seattle, Washington by Battelle Marine Sciences Laboratory, Sequim, Washington. 17 pp.

Bureau of Ocean Energy Management, Regulation and Enforcement. 2010 http://www.boemre.gov/DeepwaterHorizon.htm

Bond, A.B., J.S. Stephens, Jr, D. Pondella, II, M.J. Allen, and M. Helvey. 1999. “A method for estimating marine habitat values based on fish guilds, with comparisons between sites in the Southern California Bight.” Bull. Mar. Science. 64:219-242.

Botkin, D., K. Cummins, T. Dunne, H. Regier, M. Sobel, L. Talbot, and L. Simpson. 1995. Status and Future of salmon of Western Oregon and Northern California: Findings and Options. Report #8. The Center for the Study of the Environment, Santa Barbara, California. 300 pp.

Boulton, A.J., Findlay, S., Marmonier, A., Stanley, E.H., Valett, H.M., 1998 The Functional Significance of the Hyporheic Zone in Streams and Rivers. Annual Review of Ecology and Systematics. Vol. 29: 59-81.1998

Boxall, G.D., Guillermo R., Li H. W., Landscape Topography and the Distribution of Lahontan Cutthrout Trout *(Oncorhynchus clarki henshawi*) in a high desert stream. Environmental Biology of Fishes. Vol 82 Number 1, May 2008

Brady, N.C. and R.R. Weil. 1996. The nature and properties of soils. 11th ed. Prentice-Hall, Inc. Upper Saddle River, New Jersey 07458. 740 pp.

Breitburg, D.L., Hondorp, D.W., Davias, L.A., and Diaz, R.J. 2008. Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes. Annual Review of Marine Science Vol. 1: 329-349

Brown, A. 1997. Groundwater Quantity. In: Marcus, J.J., ed., Mining environmental handbook, effects of mining on the environment and American environmental controls on mining, Imperial College Press, London, pp. 244-248.

Bryant, M. D., M. D. Lukey, J.P. McDonell, R. S. Gubernick, and R. S. Aho. 2009. Seasonal Movement of Dolly Varden and Cutthroat Trout with Respect to Stream Discharge in a Second-Order Stream in Southeast Alaska. North American Journal of Fisheries Management. 29:1728-1742.

Bue, B.G., S. Sharr, and J.E. Seeb. 1998. “Evidence of damage to pink salmon populations inhabiting Prince William Sound, Alaska, two generations after the *Exxon Valdez* oil spill.” Transactions of the American Fisheries Society. 127: 35-43.

Burroughs, E.R. Jr., G.R. Chalfant, and M.A. Townsend. 1976. Slope stability in road construction: a guide to the construction of stable roads in western Oregon and northern California. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 102 pp.

Carr, M.H., T.W. Anderson, and M.A. Hixon. 2002. Biodiversity, population regulation, and the stability of coral-reef fish communities. Proceedings of the National Academy of Sciences. 99:11241-11245.

Cederholm, C.J., D.B. Houston, D.L. Cole, and W.J. Scarlett. 1989. “Fate of coho salmon (*Oncorhynchus kisutch*) carcasses in spawning streams.” Canadian Journal of Fisheries and Aquatic Sciences. 46, 1347-1355.

Cederholm, C.J. and N.P. Peterson. 1985. “The retention of coho salmon (*Oncorhynchus kisutch*) carcasses by organic debris in small streams.” Canadian Journal of Fisheries and Aquatic Sciences. 42:1222-1225.

Chabreck, R.H. 1972. Vegetation, water and soil characteristics of the Louisiana coastal region. Louisiana State University Agriculture Experiment Station. Baton Rouge, LA.

Chambers, J.R. 1992. Coastal degradation and fish population losses. pp 45-51. *In* Stroud, R.H. ed. Stemming the tide of coastal fish habitat loss. Proceedings of a symposium on conservation of coastal fish habitat. National Coalition for Marine Conservation, Inc., Savannah GA.

Clayton, J.L. 1983. Evaluating slope stability prior to road construction. Res. Pap. INT-307. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 pp.

Coffin, B.A. and R.D. Harr. 1992. Effects of forest cover on volume of water delivery to soil during rain-on-snow. Washington Department of Natural Resources Timber/Fish/Wildlife Program. TFW-SH1-92-001.

Collins, B.D., D.R. Montgomery, and A.J. Sheikh. 2003. Reconstructing the historic riverine landscape of the Puget Lowland. pp 79-128. *In* Bolton, S, D.R. Montgomery, and D. Booth, eds. Restoration of Puget Sound Rivers. University of Washington Press. Seattle, WA.

Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. "Historical changes in the distribution and functions of large wood in Puget Lowland rivers." Canadian Journal of Fisheries and Aquatic Sciences. 59:66-76.

Collins, M.A. 1995. Dredging-induced near-field re-suspended sediment concentration and source strengths. Miscellaneous Paper D-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A299 151.

Craig, N.J., R.E. Turner, and J.W. Day, Jr. 1979. "Land loss in coastal Louisiana." Environmental Management. 3:134-144

Cross, J.N. and L.G. Allen. 1993. Fishes. *In* Dailey, M.D. D.J. Reish, and J.W. Anderson,eds. Ecology of the Southern California Bight, Univ. Calif. Press, Berkeley, CA. Pp.459-540.

Dahm, C. N., and H. M. Valett, Hyporheic zones, in *Methods in Stream Ecology*, edited by F. R. Hauer and G. A. Lamberti, pp. 107–119, Academic, San Diego, Calif., 1996.

de Brito, A.P.X., D. Ueno, S. Takahasi, and S. Tanabe. 2002. "Contamination by organochlorine compounds in walleye pollock (*Theragra chalcogramma*) from the Bering Sea, Gulf of Alaska, and the Japan Sea." Marine Pollution Bulletin. 44:164-177.

DeMaster, D., S. Atkinson, and R. Dearborn. 2001. Is it food? II Workshop. Alaska Sea Life Center, Seward, Alaska. May 30-31. Sponsored by National Marine Fisheries Service and Alaska Sea Grant Office.

Department of Fisheries and Oceans Canada. 2007. Characterization of Existing Conditions in Lamèque Bay, New Brunswick.

Department of the Interior, Bureau of Land Management, in cooperation with the Minerals Management Service. 1998. Northeast National Petroleum Reserve-Alaska, Final Integrated Activity Plan/Environmental Impact Statement. Table II.F.1. "Federal, State, and North Slope Borough Permits and/or Approvals for Oil and Gas Exploration and Development/Production Activities."

Dooley, K.M., F.C. Knopf, and R. P. Gambrell. 1999. Final Report, ph Neutral Concrete for attached microalgae and enhanced carbon dioxide fixation – phase I. Submitted to Department of Energy, Award Number DE-AC26-98FT40411—01. 38 pp.

Drinkwater, K.F. and K.T. Frank. 1994. "Effects of river regulation and diversion on marine fish and invertebrates." Aquatic Conservation.: Mar. Freshwat. Ecosyst. 4(2):135-151.

Dsa, J.V., Johnson, K.S., Lopez, D., Kanuckel, C. and Tumlinson, J. 2008. Residual toxicity of acid mine drainage-contaminated sediment to stream macroinvertebrates: Relative contribution of acidity vs. metals. Water Air and Soil Pollution. Vol 194, Number 1-4, 185-197.

Ebeling, A.W., R.J. Larson, and W.S. Alevizon. 1980. Annual variability of reef-fish assemblages in kelp forest off Santa Barbara, California. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 78:361-377.

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.11).

Ellis, D.V. 1982. *Marine Tailings Disposal*. Ann Arbor Science Publishers. Ann Arbor, Michigan. 368 pp.

Engås, Arill, Svein Løkkeborg, Egil Ona, and Aud Vold Soldal. 1996. "Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)." Can. J. Fish Aquat. Sci. 53: 2238-2249.

Ewald, G., P. Larsson, H. Linge, L. Okla, and N. Szarzi. 1998. "Biotransport of organic pollutants to an inland Alaska lake by migrating sockeye salmon (*Oncorhynchus nerka*)." Arctic. 51:40-47.

Ewing, R.D. 1999. Diminishing returns: salmon decline and pesticides. Oregon Pesticide Education Network, Eugene, Oregon. 52 pp.

Faris, T.L. and K.D. Vaughan. 1985. Log transfer and storage facilities in Southeast Alaska: a review. USDA Forest Service General Technical Report PNW-174. Portland, OR.

Farnworth, E.G., M.C. Nichols, C.N. Vann, L.G. Wolfson, R.W. Bosserman, P.R. Hendrix, F.B. Golley, and J.L. Cooley. 1979. Impacts of sediment and nutrients on biota in surface waters of the United States. U.S. Environmental Protection Agency. Athens, GA (USA), Oct 1979. Ecol. Res. Series. 331 pp.

Fawcett, J.A. and H.S. Marcus. 1991. Are port growth and coastal management compatible? Coastal Management. Vol. 19. pp. 275-295.

Feder, H.M., C.H. Turner, and C. Limbaugh. 1974. Observations on fishes associated with kelp beds in southern California. California Department of Fish and Game, Fish Bull. 160. 144 pp.

Findlay, S. and Sobczak, W.V., 2000. Microbial communities in hyporheic sediments. In: *Streams and Ground Waters* (Jones, J.B. and Mulholland, P.J., Eds), pp. 287-306. Academic Press, London.

Flanders, L.S. and J. Cariello. 2000. Tongass Road Condition Survey Report. Alaska Department of Fish and Game, Southeast Regional Office of the Habitat and Restoration Division, Alaska Department of Fish and Game, 802 3rd Street, Douglas, AK., 99824. Technical Report 00-7. 48 pp.

Franco, J., S. Schad, and C.W. Cady. 1994. "California's experience with a voluntary approach to reducing nitrate contamination of groundwater: The Fertilizer Research and Education Program." J. Soil and Water Conser. 49: S76.

Gayaldo, P., S. Wyllie-Echeverria, and K. Ewing. 2001. Transplantation and alteration of submarine environment for restoration of Zostera marina (eelgrass); a case study at Curtis Wharf (Port of Anacortes), Washington. Presented at Puget Sound Research 2001, February 12-14, 2001, Bellevue, WA.

Gayraud, S. and Philippe, M., 2003. Influence of bed-sediment features on the interstitial habitat available for macroinvertebrates in 15 French streams. International Review of Hydrobiology. 88, 77-93.

Geist, D.R., T.P. Hanrahan, E.V. Arntzen, G.A. McMichael, C.J. Murray, and Y. Chien. Pacific Northwest National Laboratory, Physicochemical characteristics of the hyporheic zone affect redd site selection of chum and fall chinook salmon, Columbia River, Report to Bonneville Power Administration. 2001.

Geist, D.R., Jones, J., Murray, C.J., and Dauble, D.D.. Suitability criteria analyzed at the spatial scale of redd clusters improved estimates of fall chinook salmon (*Oncorhynchus tshawytscha*) spawning habitat use in the Hanford Reach, Columbia River. Can. J. Fish. Aquat. Sci. 57: 1636–1646. 2000

Geist, D.R., and Dauble, D.D. Redd site selection and spawning habitat use by fall chinook salmon: the importance of geomorphic features in large rivers. Environ. Manage. 22: 655–669. 1998.

Gende, G.M., Edwards, R.T., Willson, M.F., Wipfli M.S.. Pacific Salmon in Aquatic and Terrestrial Ecosystems. BioScience. Vol 52, No. 10, p. 917-928 Oct 2002

Gibbons, D.R., W.R. Meehan, K.V. Koski, and T.R. Merrell, Jr. 1987. History of fisheries and forestry interactions in southeastern Alaska. *In* Salo, E.O. adn T.W. Cundy, eds. Streamside Management: Forestry and Fishery Interactions. Contribution No. 57, University of Washington, College of Forest Resources, Seattle. pp. 297-329.

Greenberg, C.H., S.H. Crownover, and D.R. Gordon. 1997. "Roadside soils: a corridor for invasion of xeric scrub by nonindigenous plants." Natural Areas Journal. 17(2):99-109.

Gregory, R.S. 1993. "Effect of turbidity on the predator avoidance behavior of juvenile chinook salmon (*Oncorhynchus tshawytcha*)." Canadian J. Fish. Aquatic Sciences. 50:241-246.

Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes. 2000. Forest Roads: A Synthesis of Scientific Information, USDA Forest Service. June 2000. 117 pp.

Hall, J.D., C.J. Cederholm, M.L. Murphy and KV. Koski. 2004. Fish-foresrty interactions in Oregon, Washington, and Alaska, USA. In T.G. Northcote and G.F.Hartman, editors, Fishes and Forestry Worldwide Watershed Interactions and Management, Blackwell Publishing, pp365-412.

Hammond, C.J., S.M Miller, and R.W. Prellwitz. 1988. Estimating the probability of landslide failure using Monte Carlo simulation. In Proceedings of the 24th symposium on engineering geology and soils engineering. Febrary 29, 1988. Coeur d'Alene, ID. Utah State University, Department of Civil and Environmental Engineering, Logan, UT. pp. 319-331.

Hanrahan, L., C. Falk, H.A. Anderson, L. Draheim, M. S. Kanarek, J. Olson, and The Great Lakes Consortium. 1999. "Serum PCB and DDE levels of frequent Great Lakes sport fish consumers - a first look." *Env. Res.* Section A. 80:S26-S37.

Hancock, P.. Human Impacts on the Stream-Groundwater Exchange Zone. Environmental Management. Vol. 29, No. 6 p. 763-781, 2002

Harvey, B.C. and T.E. Lisle. 1998. "Effects of suction dredging on stream: A review and an evaluation strategy." *Fisheries*. 23:8-17.

Hastings, K., P. Hesp, and G. Kendrick. 1995. "Seagrass loss associated with boat moorings at Rottnest Island, Western Australia." *Ocean and Coastal Management*. 26:225-246. *In* Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 pp.

Heady, H.F. and R.D. Child. 1994. Rangeland ecology and management. Westview Press, Inc., Boulder, Colorado.

Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-83, 39 p.

Heiser, D.W., and E.L. Finn, Jr., 1970. Observations of juvenile chum and pink salmon in marina and bulkhead areas. Supplemental progress report, Puget Sound studies, Washington Department of Fisheries, Management and Research Division, Olympia, Washington.

Helfman, G.S. 1981. The advantage to fishes of hovering in shade. *Copeia*. 1981(2):392-400.

Hilderbrand, R.H., A.D. Lemly, C.A. Dolloff, and K.L. Harpster. 1998. "Design considerations for large woody debris placement in stream enhancement projects." North American Journal of Fisheries Management. 18 (1):161B167.

Hoffman, D.J., Rattner, B.S., Burton, G.A., and Cairns, J. (Editors). 2003. Handbook of Ecotoxicology. CRC Press, Boca Raton, FL 1290 pp.

Humphrey, D.N., Swett, M., 2006. Literature Review of the Water Quality Effects of Tire Derived Aggregate and Rubber Modified Asphalt Pavement. Prepared for: U.S. Environmental Protection Agency.

Illinois Department of Public Health (IDPH). 2005. Environmental health fact sheet: polycyclic aromatic hydrocarbons. Available at http://www.idph.state.il.us/envhealth/factsheets/polycyclicaromatichydrocarbons.htm

Ikonomou, M.G., S. Rayne, and R.F. Addison. 2002. "Exponential increases of the brominated flame retardants, polybrominated diphenyl ethers, in the Canadian Arctic from 1981 to 2000." Environ. Sci. Technol. 36:1886-1892.

Independent Multidisciplinary Science Team. 2002. Recovery of Wild Salmonids in Western Oregon Lowlands. Technical Report 2002-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, OR.

Iwasaki, Y., Kagaya, T., Miyamoto, K., and Matsuda, H. 2009. Effects of heavy metals on riverine benthic macro-invertabrate assemblages. Environmental Toxicology and Chemistry. Vol. 28, No. 2, p354–363.

Johnson, K.L. 1992. Management for water quality on rangelands through best management practices: the Idaho approach. pp. 415-441. *In* Naiman, R.J., ed. Watershed management: Balancing sustainability and environmental change. Springer-Verlag, New York.

Johnson, S.W., M.L. Murphy, D.J. Csepp, P. M. Harris, and J. F. Thedinga. 2003. A survey of fish assemblages in eelgrass and kelp habitats of southeastern Alaska. NOAA Technical Memorandum NMFS-AFSC-139, 39 pp.

Johnson, S.W., J. Heifetz, and K.V. Koski. 1986. "Effects of logging on the abundance and seasonal distribution of juvenile steelhead in some southeastern Alaska USA streams." North American Journal of Fisheries Management. 6, 532-537.

Jordan, T.E. and D.E. Weller. 1996. "Human contributions to terrestrial nitrogen flux: Assessing the sources and fates of anthropogenic fixed nitrogen." BioScience. 46:655.

Kagan, R.A. 1991. The dredging dilemma: economic development and environmental protection in Oakland Harbor. Coastal Management. Vol. 19, pp. 313-341.

Kauffman, J.B. and W.C. Krueger. 1984. "Livestock impacts on riparian ecosystems and streamside management implications–a review." Journal of Range Management. 37:430-438.

Kawano, M., S. Matsushita, T. Inoue, H. Tanaka, and R. Tatsukawa. 1986. "Biological accumulation of chlordane compounds in marine organisms from the northern North Pacific and Bering Sea." Mar. Poll. Bull. 17:512-516.

Kimmel, W. G. 1983. The impact of acid mine drainage on the stream ecosystem. Pennsylvania Coal: Resources, Technology, and Utilization. Pennsylvania Academic Science Publications: 424-437.

King County Department of Natural Resources and Parametrix, Inc. 2002. Bioaccumulation and King County secondary treated effluent: data review, method evaluation, and potential on Puget Sound aquatic life. Unpublished paper in support of the draft Habitat Conservation Plan-in-progress. 38 pp + appendix.

Klimley, A.P. and S.C. Beavers. 1998. "Playback of ATOC-type signal to bony fishes to evaluate phonotaxis." Journal of Acoustic Society of America. 104:2506-2510.

Klinck, J., M. Dunbar, S. Brown, J. Nichols, A. Winter, C. Hughes and R. C. Playle. 2005. Influence of water chemistry and natural organic matter on active and passive uptake of inorganic mercury by gills of rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology. 72:161-175.

Kline, E.R. 1994. Potential biological consequences of submarine mine-tailings disposal: a literature synthesis. U.S. Dept. of the Interior, Bureau of Mines, Juneau, AK, OFR 36-94.

Kondolf, G.M., Larsen, E.W., and Williams, J.G. 2000. Measuring and modeling the hydraulic environment for assessing instream flows. North American Journal of Fisheries Management. 20:1016–1028.

Koski, K V. 1993. Riparian zone functions and interactions with sediment. *In* Proceedings of a Technical Workshop on Sediments, February 3-7, 1992, Corvallis, OR, Terrene Institute, Sept. 1993, pp 61-69.

Koski, K.V., J. Heifetz, S. Johnson, M. Murphy, and J. Thedinga. 1984. Evaluation of buffer strips for protection of salmonid rearing habitat and implications for enhancement. *In* Hassler, T.J., ed.

Proceedings: Pacific Northwest Stream Habitat Management Workshop, American Fisheries Society, Humboldt State University, Arcata, CA. pp.138-155.

Koski, K.V. 1975. The survival and fitness of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence in a controlled-stream environment at Big Beef Creek. Ph.D. Dissertation, University of Washington, Seattle, WA.

Kriech A.J., Kurek J.T., Osborn L.V., Wissel H.L., and Sweeney B.J. 2002. Determination of Polycyclic Aromatic Compounds in Asphalt and in Corresponding Leachate Water Polycyclic Aromatic Compounds, Volume 22, Number 3, 1 July 2002 , pp. 517-535(19).

Kuhn, E.A., Papagiannakis, A.T., and Loge, F.J. 2005. Preliminary Analysis of the Impact of Cold Mix Asphalt Concreted on Air and Water Quality. Bulletin of Environmental Contamination and Toxicology. 74:501-508.

Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements.

Larimore, R.W. and P.W. Smith. 1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. Illinois Natural History Survey Bulletin. 28:299-382.

Larsen, M.C. and J.E. Parks. 1997. How wide is a road? The association of roads and mass-wasting in a forested montane environment. Earth Surface Processes and Landlords. 22:835-848.

LaSalle, M.W., D.G. Clarke, J. Homziak, J.D. Lunz, and T.J. Fredette. 1991. A framework for assessing the need for seasonal restrictions on dredging and disposal operations. Technical Report D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A240 567.

Lee, G.F. and S. Taylor. 2000. Review of the water quality characteristics of Upper Newport Bay, Orange County CA and its Tributaries. California Coastal Conservancy, Oakland, CA 94612.

Lee, D.C., J.R. Sedell, B.E. Rieman, R.F. Thurow, J.E. Williams, D. Burns, J. Clayton, L. Decker, R. Gresswell, R. House, P. Howell, K.N. Lee, K. MacDonald, J. McIntyre, S. McGivney, T. Noel, J.E. O'Connor, C.S. Overtone, D. Perkinson, K. Tu, and P. Van Eimeren. 1997. Broadscale assessment of aquatic species and habitats. Vol III, Chapter 4. *In* Quigley, T.M. and S. J. Arbelbide, eds. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Leman, V.N. 1993. Spawning sites of chum salmon, *Oncorhynchus keta*: microhydrological regime and viability of progeny in redds (Kamchatka River Basin). J. Ichthyol. 33: 104–117.

Leonard, J.N. 1994. Ocean outfalls for wastewater discharges – meeting CWA 403C requirements. Marine Technology Soc. '94, Conference Proceedings. Challenges and Opportunities in the Marine Environment, Washington, DC, 7-9 Sept. pp. 115-120.

Lonsdale, W.N. and A.M. Lane. 1994. "Tourist vehicles as vectors of weed seeds in Dadoed National Park, northern Australia." Biological Conservation. 69(3):277-283.

Lorenz, J.M., Eiler, J.H. 1989. Spawning habitat and redd characteristics of sockeye salmon in the glacial Taku River, British Columbia and Alaska. Transactions of the American Fisheries Society 118:495-502.

Lorenz, Mitch. Review of OSI Project; Unalaska Bay 12 (DD-1982-0598), Alaska Fisheries Science Center. Enclosure to NMFS Alaska Region comments on AA-820598, Unalaska Bay 12, October 4, 2004.

Madej, M.A. 2001. "Erosion and sediment delivery following removal of forest roads." Earth Surface Processes and Landforms. 26:175-190.

Maest, A.S., Kuipers, J.R., Travers, C.L., and Atkins, D.A. 2005. Predicting water quality at hardrock mines: Methods and Models, Uncertainties, and State-of-the-Art.

Malard, F., Galassi, D., Lafont, M., Dolédec, S. and Ward, J.V., 2003. Longitudinal patterns of invertebrates in the hyporheic zone of a glacial river. Freshwater Biology, 48, 1709-1725.

Malcolm, I. A., C.Soulsby, , A. F Youngson,, D.M Hannah,., I. S McLaren, and A Thorne,. Hydrological Influences on Hyporheic Water Quality: Implications for Salmon Egg Survival Hydrological Process's, vol 18. p1543–1560, 2004

Malcolm, I. A., C. Soulsby, , A. F Youngson,., D.M Hannah,.. Spatial and Temporal Variability of Groundwater – Surface Water Interactions in an Upland Salmon Spawning Stream: Implications for Egg Survival. Hydrology: Science & Practice for the 21st century. Vol II, 2004 p. 130-138, 2004

Malcolm, I. A. , C. Soulsby, , A. F Youngson, and D.M Hannah. 2005. Catchment Scale Controls on Grounwater-Surfacewater Interactions in the Hyporheic Zone: Implications for Salmon Embryo Survival. River Research and Applications. Vol 21, 977-989, 2005

Malmström, M.E., Berglund, S., and Jarsjo, J. 2008. Combined effects of Spatial Variable Flow and Minerology on the Attenuation of Acid Mine Drainage in Groundwater. Applied Geo-Chemistry. Vol 23 Issue 6, p 1419-1436.

Marcus, M.D., M.K. Young, L.E. Noel, and B.A. Mullan. 1990. Salmonid-habitat relationships in the western United States: a review and indexed bibliography. General Technical Report RM-GTR-188. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Marshall, M.C. and Hall, R.O. Jr. 2004. Hyporheic invertebrates affect N cycling and respiration in stream sediment microcosms. Journal of the North American Benthological Society. 23(3), 416-428.

Matkin, C.O., E.L. Saulitis, G.M. Ellis, P. Olesiuk, and S.D. Rice. 2008. Ongoing population-level impacts on killer whales Orcinus orca following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. Marine Ecology Progress Series 356:269-281.May, C., R. Horner, J. Karr, B. Mar, and E. Welch. 1997. Effects of urbanization on small streams in the Puget Sound lowland ecoregion. Watershed Protection Techniques 2(4):483-494.

McFadden, J.T. 1969. Dynamics and regulation of salmonid populations in streams. In: Northcote, T.E., ed. Symposium on salmonid populations in streams. Vancouver: University of British Columbia, Institute of Fisheries. pp. 313-329.

McLusky, D.S., D.M. Bryant, and M. Elliot. 1992. "The impact of land-claim on macrobenthos, fish and shorebirds on the Forth Estuary, eastern Scotland." Aquat. Conserv.: Mar. Freshwat. Ecosyst. 2 (3):211-222.

Mermillod-Blondin, F., Gaudet, J.-P., Gérino, M., Desrosiers, G and Creuzé des Châtelliers, M., 2003. Influence of macroinvertebrates on physico-chemical and microbial processes in hyporheic sediments. Hydrological Processes. 17, 779-794.

Miller, D.J. and J.J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; A reef ecology study; and giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. California Dept. of Fish and Game, Fish Bull. 158.

Minerals Management Service (MMS). 2003. OCS EIS/EA MMS 2003-055. Alaska Outer Continental Shelf Cook Inlet Planning Area, Oil and Gas Lease Sale 191 and 199, Final Environmental Impact Statement. Volume II (Section VII and Appendices). Appendix E: "Applicable Federal laws, Regulatory Responsibilities, and Executive Orders."

Montgomery, D.R. 1994. "Road surface drainage, channel initiation, and slope instability." Water Resources Research. 30:1925-1932.

Muir, D., B. Braune, B. DeMarch, R. Norstrom, R. Wagemann, L. Lockhart, B. Hargrave, D. Bright, R. Addison, J. Payne, and K. Reimer. 1999. "Spatial and temporal trends and effects of contaminants in the Canadian Arctic marine ecosystem: a review." *Sci Total Environ.* 230:83-144.

Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and AlaskaCrequirements for protection and restoration. U.S. Dep. Commer., NOAA Coastal Ocean Program, Decision Analysis Series No. 7, 156 + xxii p.

Murphy, M.L. and K V. Koski. 1991. Reform of logging practices in Alaska. Pages 220-21 *in* B. White and I Guthrie, eds. Pro. 15th Northe. Pac. Pink and Chum Salmon Workshop, Parksville, BC. Can. Dep. Fish. Oceans, Vancouver.

Murphy, M.L. and J.D. Hall. 1981. "Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon." Canadian Journal of Fisheries and Aquatic Sciences. 38:137-145.

NMFS. 2006. Letter from National Marine Fisheries Service, Alaska Region to U.S. Army Corps of Engineers, Alaska District, dated March 22, 2006. In response to Public Notice POA-2003-502-N, Ship Creek for the Port of Anchorage Expansion project.

NMFS. 2001. Guidelines for salmonid passage at stream crossings. Southwest Region, Santa Rosa, CA. 14 pp. (http://swr.nmfs.noaa.gov/hcd/NMFSSCG.PDF).

National Oceanic and Atmoshperic Administration (NOAA) Marine Debris Program. Project Title: Temporal and Spatial Distribution of Marine Debris on Select Beaches in the Gulf of Alaska.

Reporting Period: December 1 – February 28, 2009.Date: March 15, 2009. P.I. : Jacek Maselko.

NOAA. 1991. National Status and Trends Program for marine environmental quality. Progress report on secondary summary of data on chemical contaminants in sediments from the National Status and Trends Program. Tech. Mem. NOS OMA 59. NOAA, NOS, Silver Spring, MD. 29 pp.

National Research Council. 2003. Oil in the sea III: inputs, fates and effects. Washington (DC): National Academy Press.

North Pacific Fisheries Management Council. 1999. Environmental Assessment for Amendment 55 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area; Amendment 55 to the Fishery Management Plan for Groundfish of the Gulf of Alaska; Amendment 8 to the Fishery Management Plan for the King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands; Amendment 5 to the Fishery Management Plan for Scallop Fisheries off Alaska; Amendment 5 to the Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska, Essential Fish Habitat. 605 West 4th Ave, Suite 306, Anchorage, AK 99501-2252. 20 January.

Nelson S.M., and Roline R.A. 1999. Relationships between metals and hyporheic invertebrate community structure in a river recovering from metals contamination. Hydrobiologia. 397:211–2

Nelson, R.L., M. McHenry, and W.S. Platts. 1991. Mining. Influences of forest and rangeland management in salmonid fishes and their habitats. pp. 425-457. *In*: Meehan, W. ed. Influences of forest and range management on salmonid fishes and their habitats. AFS Special Publication 19. Bethesda, MD.

North Pacific Fisheries Management Council (Council). 1999. Environmental Assessment for Amendment 55 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area; Amendment 55 to the Fishery Management Plan for Groundfish of the Gulf of Alaska; Amendment 8 to the Fishery Management Plan for the King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands; Amendment 5 to the Fishery Management Plan for Scallop Fisheries off Alaska; Amendment 5 to the Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska, Essential Fish Habitat. 605 West 4th Ave, Suite 306, Anchorage, AK 99501-2252. 20 January.

O'Hara, T. 2001. *Evaluating Environmental Contaminant Trends in Arctic Alaska Marine Mammals: Biological and Experimental Design Considerations.* Workshop to Assess Contaminant Impacts on Steller Sea Lions in Alaska. Anchorage, AK, September 5-6, 2001. Sponsored by Auke Bay Laboratory.

O'Keefe, T.C., Edwards, R.T. Evidence for Hyporheic Transfer and removal of Marine- Derived Nutrients in a Sockeye Stream in Southwest Alaska. American Fisheries Society Symposium 33:99–107, 2002

Oil and Gas Technologies for the Arctic and Deepwater. 1985. U.S. Congress, Office of Technology Assessment, OTA-O-270, May 1985. Library of Congress Catalog Card Number 85-600528. U.S. Government Printing Office, Washington, DC 20402.

Olsen, D.A., Young, R.G. 2009. Significance of River Aquifer Interactions for reach Scale Thermal Patterns and Trout Growth potential in the Motueka River, New Zealand. Hydrogeology Journal. Vol 17, p 175-183.

Olsen, D.A., C.R. Townsend. 2003. Hyporheic community composition in a gravel-bed stream: influence of vertical hydrological exchange, sediment structure and physicochemistry. Freshwater Biology. Vol 48, pp 1363–1378.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Paul, J.F., K.J. Scott, A.F. Holland, S.B. Weisberg, J.K. Summers, and A. Robertson. 1992. "The estuarine component of the U.S. EPA's Environmental Monitoring and Assessment Program." Papers from the First International Ocean Pollution Symposium, 28th April 1991--2nd May 1991. University of Puerto Rico, Puerto Rico, (Part Two). Chem. Ecol. 7 (1-4): 93-116.

Peddicord, R.K. and J. B. Herbich, ed. 1979. Impacts of open-water dredged material discharge. Proceedings of the eleventh dredging seminar. Published by TAMU, College Station, TX (USA). Oct 1979. pp. 24-40. Rep. Texas A&M University Sea Grant Program.

Pezeshki, S.R., R.D. Delaune, and W.H. Patrick, Jr. 1987. "Response of the freshwater marsh species, *Panicum hemitomon Schult*., to increased salinity." Freshwater Biology. 17:195-200.

Pickett, G.D., D.R. Eaton, R.M.H. Seaby, and G.P. Arnold. 1994. Results of bass tagging in Poole Bay, England during 1992. Laboratory Leaflet No. 74. British Ministry of Agriculture, Fisheries and Food.

Pinay, G., O'Keefe, T.C., Edwards, R.T., Naiman, R.J., Nitrate Removal in the Hyporheic Zone of a Salmon River in Alaska. *River Research and Applications. Vol* 25, Issue 4, Pg 367 – 375, 12 June 2008

Platts, W.S. 1991. Livestock grazing. pp. 389-424. *In* Meehan, W.R, ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. American Fisheries Society, Bethesda, MD.

Raco-Rands, V.E. 1996. Characteristics of effluents from power generating stations in 1994. *In* Allen, M.J, ed. Southern California Coastal Water Research Project, Annual Report 1994-95. SCCWRP, Westminster, CA. pp. 29-36.

Railsback, S. 2000. Instream Flow Assessment Methods: Guidance for evaluating instream flow needs in hydropower licensing, EPRI report 1000554, Palo Alto, CA: 2000.

Reinjders, P.J.H. 1986. "Reproductive failure in common seals feeding on fish from polluted coastal waters." *Nature*. 324:456-457

Reiser and Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in the Western United States and Canada. Meehan, W.R. ed. USDA Forest Service General

Technical Report PNW-96. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. Portland, OR.

RestoreTheGulf.gov. November 24, 2010. NOAA Closes 4,200 Square Miles of Gulf Waters to Royal Red Shrimping. http://www.restorethegulf.gov/release/2010/11/24/noaa-closes-4200-square-miles-gulf-waters-royal-red-shrimping Contact: Karrie Carnes 305-304-0179 (cell).

Rice, S.D., D.A. Moles, J.F. Karinen, S. Korn, M.G. Carls, C.C. Brodersen, J.A. Gharrett, and M.M. Babcock. 1984. Effects of petroleum hydrocarbons on Alaskan aquatic organisms: A comprehensive review of all oil-effects research on Alaskan fish and invertebrates conducted by the Auke Bay Laboratory, 1970 - 81. U.S. Department of Commerce, NOAA Technical Memorandum NMFS F/NWC-67. 128 pp.

Rich Passage Wave Action Study Team. 2001. Rich Passage Wave Action Study Final Report, WAC 197-11-970. Prepared for Washington State Ferries. August 27.

Riedman, M. 1990. *The Pinnipeds*. University of California Press. Berkeley, California. 439 pp.

Rozengurt, M.A., I. Haydock, and B.P. Anderson. 1994. Running on entropy: The effect of water diversion on the coastal zone. 37th Conference of the International Association for Great Lakes Research and Estuarine Research Federation: Program and Abstracts., Buffalo, NY (USA). 166 pp.

Ruiz, G.M., Fofonoff, P.W., Carlton, J.T., Wonham, M.J., Hines, A.H., 2000. Invasion of coastal marine communities in North America: apparent patterns, processes, and biases. *Ann. Rev. Ecol. Syst.* 31, 481-531.

Ruus, A., K.I. Ugland, and J.U. Skaare. 2002. "Influence of trophic position on organochlorine concentrations and compositional patterns in a marine food web." Env. Tox. Chem. 21(11):2356- 2364.

Sadler, R., Delamont, C., White, P., Connell, D., 1999. Contaminants in soil as a result of leaching from Asphalt. Toxicological and Environmental Chemistry. Vol. 68, no. 1-2, pp. 71-81.

Schafer, W.M. and Lewis, M., 1998. Evaluating the environmental risk of water quality Impacts at mining sites. Society for Mining, Metallurgy, and Exploration, Inc. Preprint 98-182, 9 pp.

Schaumburg, F.D. 1970. The influence of log handling on water quality, annual report 1969-1970, Department of Civil Engineering, Oregon State University. Corvallis, Oregon.

Schueler, T. 1994. The importance of imperiousness. Watershed Protection Techniques 2(4):100-111.

Schult, D.T. and D.J. McGreer 2001. Effects of forest harvesting and roads on streamflow processes and application to watersheds of Southeast Alaska. Summary of Monitoring Studies of the Effectiveness of Practices under the Alaska Forest and Resources Practices Act 1990-2002. Compiled by Alison Arians, DNR Division of Forestry, April 2003. A report funded by the Alaska Coastal Management Program, Office of the Governor, pursuant to NOAA Award No. NA17OZ1113.

Science Applications International Corporation. 2001. Information Collection Request for National Pollutant Discharge Elimination System (NPDES) and Sewage Sludge Monitoring Reports.

Prepared by the Science Applications International Corporation, 11251 Roger Bacon Drive, Reston, VA 20190, for Tetra Tech, Inc., Fairfax, VA, for the U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, D.C. EPA ICR# 0229.15. p. 11.

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.

Sea Grant. 2002. National Coastal Ecosystem Restoration Manual. Sea Grant Communications, Oregon State University, Corvallis, OR. Pacific Northwest: http://seagrant.oregonstate.edu/hot/exotics.html.

Sedell, J.R., F.N. Leone, and W.S. Duvall. 1991. Water transportation and storage of logs. *In* Meehan, W.R., ed. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication. 19:325-368.

Shafer, D.J. 2002. Recommendations to minimize potential impacts to seagrasses from single-family residential dock structures in the Pacific Northwest. U.S. Army Corps of Engineers, Seattle, WA. 28 pp.

Sheavly. S.B. 2007. "National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary." Prepared for U.S. Environmental Protection Agency by Ocean Conservancy, Grant Number X83053401-02. 76 pp.

Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. 1999. Impacts of Ferry Terminal on Juvenile Salmon Migrating along Puget Sound Shorelines Phase I: Synthesis of State of Knowledge.

Simenstad, C.A. 1994. pp. 11-19. *In* Wyllie-Echeverria, S., A.M. Olson, and M.J. Hershman, eds. Seagrass science and policy in the Pacific Northwest: proceedings of a seminar series (SMA 94-1) EPA 910/R-94-004. 63 pp.

Simenstad, C.A., C.D. Tanner, F. Weinmann, and M. Rylko. 1991. The estuarine habitat assessment protocol. Puget Sound Notes. No. 25. June 1991.

Soil Conservation Service, U.S. Department of Agriculture, Forest Service, and Economic Research Service. 1984. Southeast Washington cooperative river basin study. U.S. Department of Agriculture, Washington, D.C.

State of North Carolina. 2009. Water efficiency manual for commercial, industrial, and institutional facilities. A joint publication of the Division of Pollution Prevention and Environmental Assistance and Division of Water Resources of the N.C. Department of Environment and Natural Resources, and Land-of-Sky Regional Council. http://www.p2pays.org/ref/01/00692.pdf

Stein, J., T. Hom, T. Collier, D. Brown, and U. Varanasi. 1995. "Contaminant exposure and biochemical effects in outmigrant juvenile chinook salmon from urban estuaries of Puget Sound, WA." Environ. Toxicol. Chem. 14:1019-1029.

Steward, C. 1983. Salmonoid populations in an urban environment - Kelsy Creek, Washington. M.S. Thesis, University of Washington.

Stone, R.P. and S.W. Johnson. 1998. “Prolonged exposure to mine tailings and survival and reproductive success of ovigerous Tanner crabs (*Chionoecetes bairdi*).” Bull. Environ. Contam. Toxicol. 61: 548-556.

Stull, J.K. and C.I. Haydock. 1989. Discharges and environmental responses: the Palos Verdes case. *In* Managing inflows in California’s bays and estuaries. The Bay Institute, Sausalito, Calif. pp. 44-49.

Sundberg, K.A., 1981. Marine biology and circulation investigations in Sitka Sound, Alaska, Marine/Coastal Habitat Management, Habitat Protection Section, ADF&G, Anchorage, AK.

TAPS (Trans-Alaska Pipeline System) Draft Environmental Impact Statement. 2002. Renewal of the Federal Grant for the Trans-Alaska Pipeline System (TAPS) Right-of-Way. U.S. Dept. of the Interior, Bureau of Land Management. 4.3: 50.

Thayer, G.W., ed. 1992. Restoring the Nation’s Marine Environment. Publication UM- SG-TS-92-06. Maryland Sea Grant College, College Park, MD, 716 pp.

Thayer, G.W., W.J. Kenworthy, and M.S. Fonseca. 1984. The ecology of eelgrass meadows of the Atlantic coast: a community profile. U.S. Fish and Wildlife Service FWS/OBS-84/02. 147 pp.

Thorsteinson, F.V. and L.K. Thorsteinson. 1982. Finfish Resources. Chapter 6. *In* Hameedi, M.J., ed. The St. George Basin Environment and Possible Consequences of Planned Offshore Oil and Gas Development. Proceedings of a Synthesis Meeting. U.S. Department of Commerce, NOAA, Office of Marine Pollution Assessment.

Toft, J., J. Cordell, C. Simenstad, L. Stamatiou. 2004. Fish Distribution, abundance and behavior at nearshore habitas along City of Seattle marine shorelines, with an emphasis on juvenile salmonids. Prepared for Seattle Public Utilities, City of Seatte. Wetland Ecosystem Team, School of Aquatic and Fishery Sciences, University of Washington SAFS-US-0401 March 2004. 52p.

Trasky, L., 2008. Analysis of the Potential Impacts of Copper Sulfide Mining on the Salmon Resources of the Nushagak and Kvichak Watersheds. Sections 2 & 3 p17-41

Turek, J.G., T.E. Bigford, and J.S. Nichols. 1987. Influence of freshwater inflows on estuarine productivity. NOAA Tech. Memo. NMFS-F/NEC-46. 26 pp.

U.S. Army Corps of Engineers (USACE), Alaska District. 1999. Final Environmental Impact Statement. Beaufort Sea Oil and Gas Development/Northstar Project. P.O. Box 898, Anchorage, Alaska. February 1999.

USDA. 2008a. Tongass Monitoring and Evaluation Report – Appendix B http://www.fs.fed.us/r10/tongass/projects/tlmp/2008_monitoring_report/index2008.shtml

USDA. 2008b. Tongass National Forest Land and Resource Management Plan. R10-MB-603b. http://tongass-fpadjust.net/Documents/2008_Forest_Plan.pdf

USDA. 2003. Tongass Best Management Practice Implementation Monitoring Report.

USDA. 2002. Southern Intertie Project Final Environmental Impact Statement. U.S. Dept. of Agriculture. Rural Utilities Service. Washington D.C.

USDA. 2000. Tongass National Forest Draft Annual Monitoring Report.

USDA. 1989. The second RCA appraisal: Soil, water, and related resources on nonfederal land in the United States, analysis of conditions and trends. Washington, D.C. 280 pp.

USEPA. 2000. Scoping Document for the Proposed Pogo Mine Site. U.S. EPA, Region 10, 1200 Sixth Ave., Seattle, WA 98101. 11 August. (http://www.pogomineeis.com/documents/ScopingDraft.pdf).

USEPA. 1997. Office of Water. Guidance specifying management measures for sources of nonpoint pollution in coastal waters. Chapter 5: Management measure for marinas and recreational boating. (http://www.p2pays.org/ ref/04/03686/index-5.html).

USEPA Estuaries, 1992, Technical Guidance Manual for Performing Waste Load Allocations Book III: Estuaries, US EPA, 1992.

USEPA. 1992. Turning the Tide on Trash: Marine Debris Curriculum. A Learning Guide on Marine Debris. EPA842-B-92-003 (http://www.epa.gov/owow/OCPD/Marine/contents.html)

USEPA 1991, Technical Support Document for Water-Quality Based Toxics Control (TSD), Document No. EPA/505/2-90-001. March 1991.

USEPA. 1975. Development document for effluent limitations guidelines and new source performance standards for the fish meal, salmon, bottom fish, clam, oyster, sardine, scallop, herring, and abalone segment of the canned and preserved fish and seafood processing industry point source category. Effluent Guidelines Division, Office of Water and Hazardous Material, Washington, D.C. EPA 440/1-75/041a. 485 pp.

USEPA. 1974. Development Document for Effluent Limitations Guidelines and Standards of Performance for the Catfish, Crab, Shrimp, and Tuna segments of the Canned and Preserved Seafood Processing Industry Point Source Category. Effluent Guidelines Division, Office of Water and Hazardous Material, Washington, D.C. EPA-44011-74-020-a. 389 pp.

USEPA, Office of Water (http://www.epa.gov/water/) and Office of Pesticide Programs (http://www.epa.gov/pesticides/).

USEPA, Office of Wetlands, Oceans and Watersheds, Ocean and Coastal Protection Division, Marine Debris Abatement (http://www.epa.gov/owow/oceans/debris/)

U.S. Fish and Wildlife Service (USFWS). 1987. Polycyclic Aromatic Hydrocarbons Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85(1.11). Patuxent Wildlife Research Center, Laurel, MD, USA.

USFWS. 1980. FWS/OBS-80/09. Gravel Removal Guidelines Manual for Arctic and Subarctic Floodplains. June 1980. Prepared by Woodward Clyde Consultants. Contract Number

FWS-14-16-0008-970. Performed for the Water Resources Analysis Project, Office of Biological Services. U.S. Department of the Interior, Washington, D.C. 20240.

U.S. Geologic Survey (USGS). 1999. The quality of our nation's waters: Nutrients and pesticides. pp. 33-55. USGS, Reston, VA.

USGS. Toxic Substances Hydrology Program: Watershed Contamination from Hard Rock Mines. http://toxics.usgs.gov/regional/mining/index.html

Van Dolah, R.E., P.P. Maier, M.H. Fulton, and G.I. Scott. 1997. "Comparison of azinphomethyl toxicity to juvenile red drum (*Scianops ocellatus*) and the mummichog (*Fundulus heteroclitus*)." *Environmental Toxicology and Chemistry*. 16:1488-1493.

Vernberg F.J., W.B. Vernberg. 2001. The Coastal Zone. Past, Present, and Future. University of South Carolina.

Vetter, E.W. 1995. "Detritus based patches of high secondary production in the nearshore benthos." Mar. Ecol. Prog. Ser. 120:251-262.

Vuorinen, P.J., R. Parmanne, T. Vartiainen, M. Keinanen, H. Kiviranta, O. Kotovuori, and F. Hallig. 2002. "PCDD, PCF, PCB and thiamin in Baltic herring (*Clupea harengus* L.) and sprat (*Sprattus sprattus L.)* as a background to the M74 syndrome of Baltic salmon (Salmo salar L.)." ICES J. Mar. Sci. 59:480-496.

Waisley, S.L. 1998. Projections for U.S. and Global Supply and Demand for 2010 and 2020. presented at U.S. and China Oil and Gas Industrial Forum, Beijing, People's Republic of China, November 2-4, 1998. Office of Natural Gas and Petroleum Technology, U.S. DOE, Washington, D.C. (http://www.fe.doe.gov/oil_gas/china_forum/cl04000.html).

Wania, F. and D. Mackay. 1999. "Global chemical fate of hexachlorocyclohexane. 2. Use of a global distribution model for mass balancing, source apportionment, and trend prediction." Environ Toxicol Chem. 18: 1400B1407.

Washington State Department of Ecology, Water Quality Program, Sand & Gravel General Permit (http://www.ecy.wa.gov/programs/wq/sand/escp.html).

Washington Department of Fish and Wildlife. 1998. Gold and fish. Rules and regulations for mineral prospecting and mining in Washington State. Draft, February 1998. Olympia, WA.

Wemple, B.C., F.J. Swanson, and J.A. Jones. 2001. "Forest roads and geomorphic process interactions, Cascade Range, Oregon." Earth Surface Processes and Landforms. 26:191-204.

Wemple, B.C., J.A. Jones, and G.E. Grant. 1996. "Channel network extension by logging roads in two basins, western Cascades, Oregon." Water Resources Bulletin. 32:1195-1207.

Wertheimer, A.C., R.A. Heintz, J.F. Thedinga, J.M. Maselko, and S.D. Rice. 2000. Straying of adult pink salmon from their natal stream following exposure as embryos to weathered Exxon Valdez crude oil. Trans. Amer. Fish. Soc. 129: 989-1004.

Wicker, K.M., R.E. Emmer, D. Roberts, and J. van Beek. 1989. Pipelines, navigation channels, and facilities in sensitive coastal habitats: an analysis of Outer Continental Shelf impacts, Coastal

Gulf of Mexico. Volume I: technical narrative. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Report MMS 89-0051.

Williams, J.E., C.A. Wood, and M.P. Dombeck, eds. 1997. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, MD. 561 pp.

Williams, R.N., L.D. Calvin, C.C. Coutant, M.W. Erho Jr., J.A. Lichatowich, W.J. Liss, W.E. McConnaha, P.R. Mundy, J.A. Stanford, R.R. Whitney, D.L. Bottom, and C.A Frissell. 1996. Return to the river: restoration of salmonid fishes in the Columbia River ecosystem. Development of an alternative conceptual foundation and review and synthesis of science underlying the Columbia River Basin fish and wildlife program of the northwest power planning council by the independent scientific group. Northwest Power Planning Council, Portland, Oregon. 584 pp.

Wolkersdorfer, C. and Bowell, R. 2005. Contemporary Reviews of Mine Water Studies in Europe. Mine Water and the Environment 24: Supplementary Material © Springer Verlag.

Woltemade, C.J. 2000. “Ability of restored wetlands to reduce nitrogen and phosphorus concentrations in agricultural drainage water.” J. Soil and Water Cons. 55: 303.

Yang, J., D. Shin, S. Park, Y. Chang, D. Kim, and M.G. Ikonomou. 2002. “PCDDs, PCDFs and PCBs concentrations in breast milk from two areas in Korea: body burden of mothers and implications for feeding infants.” Chemosphere. 46(3):419-28.

Ylitalo, G.M. C.O. Matkin, J. Buzitis, M.M. Krahn, L.L. Jones, T. Rowles, and J.E. Stein. 2001a. “Influence of life-history parameters on organochlorine concentrations in fee-ranging killer whales (*Orcinus orca*) from Prince William Sound, AK.” Sci. Tot. Env. 281:183-203.

Ylitalo, G.M., J.W. Bickham, J. Buzitis, G.K. Yanagida, J.E. Stein, and M.M. Krahn. 2001b. *Contaminant Bioaccumulation and Feeding ecology of Steller Sea Lions from Alaska*. Workshop to Assess Contaminant Impacts on Steller Sea Lions in Alaska. Anchorage, AK, September 5-6, 2001. Sponsored by Auke Bay Laboratory.

York, A.E., R.L. Merrick, and T.R. Loughlin. 1996. An analysis of the Steller sea lion metapopulation in Alaska. *In* McCullough, D., ed. Metapopulations and wildlife conservation and management. Island Press, Covelo, CA. pp. 259-292.

Young, K.A. 2000. “Riparian zone management in the Pacific Northwest: who’s cutting what?” Environmental Management. 26, 131-44.

Younger P.L., Banwart S.A., and Hedin R.S. 2004. Mine water: hydrology, pollution, remediation. London: Kluwer Academic Publishers; 442 pp.

Youngson, A.F., Malcolm, I.A. Thorley, P.J., Bacon, P.J., Soulsby, C., 2004. Long Residence Groundwater Effects on Incubating Salmonid Eggs: Low Hyporheic Oxygen Impairs Embryo Development. Canadian Journal of Fisheries and Aquatic Sciences. Vol 61(12) p 2278-2287

Zedler, J.B., C.S. Nordby, and B.E. Kus. 1992. The ecology of the Tijuana Estuary, California: A National Estuarine and Research Reserve. NOAA Office of Coastal Resource Management, Sanctuaries and Reserves Division, Washington, D.C.

Zenteno-Savin, T., M. Castellini, L.D. Rea, and B.S. Fadely. 1997. “Plasma haptoglobin in threatened Alaskan pinniped populations.” J. Wildlife Dis. 33:64-71.

Zeppelin, T.K., K.A. Call, D.J. Tollit, T.J. Orchard, and C.J. Gudmundson. 2003. Estimating the size of walleye pollock and Atka mackerel consumed by the western stock of Steller sea lions. Marine Science in the Northeast Pacific. Sponsored by Exxon Valdez Oil Spill Trustee Council, GLOBEC-Northeast Pacific Program, Steller Sea Lion Investigations, North Pacific Reesarch Board, North Pacific Marine Research Institute and Pollock Conservation Cooperative. Anchorage, Alaska. January 13-17.

Zielger, A.D., R.A. Sutherland, and T.W. Gaimbelluca. 2001. “Interstorm surface preparation and sediment detachment by vehicle traffic on unpaved mountain roads.” Earth Surface Processes and Landforms. 26:235-250.