National Marine Fisheries Service

Northwest Fisheries Science Center

Nonfishing Impacts on Essential Fish Habitat

NOAA White Paper NMFS-NWFSC-WP-2022-01

December 2022

https://doi.org/10.25923/zxz1-m712

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

NOAA White Paper Series NMFS-NWFSC

Reference this document as follows:

Kiffney, P., J. Thompson, B. Blaud, and L. Hoberecht. 2022. Nonfishing Impacts on Essential Fish Habitat. U.S. Department of Commerce, NOAA White Paper NMFS-NWFSC-WP-2022-01.

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https://doi.org/10.25923/zxz1-m712

December 2022

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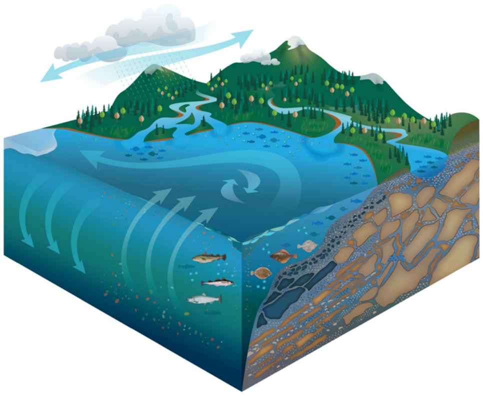
Plain Language Summary



In order to survive and thrive, fish and other marine species need access to clean, healthy habitats. From streams and tributaries to large rivers, lakes and reservoirs—from estuaries to the coast and the open ocean—marine fish, shellfish, mammals, and birds depend on these habitats for every stage of their life cycles. Essential fish habitat, or EFH, refers to the water and substrate that fish require in order to successfully spawn, breed, feed, and grow to maturity.

In the United States, the Magnuson–Stevens Act governs marine fishery management. In addition to establishing and defining EFH, the act requires federal agencies to consult with NOAA Fisheries on all actions or proposals that a) are permitted, funded, or undertaken by the agency, and b) may negatively impact EFH.

Whenever NOAA Fisheries learns of an action by a federal or state agency that may adversely affect EFH, it is required to provide conservation recommendations on how to avoid, minimize, or otherwise offset the effects of the action. State agencies are not required to respond to these recommendations, though federal agencies must do so within 30 days.

This document serves several purposes. Its main goal is to assist NOAA Fisheries biologists in providing appropriate EFH conservation recommendations. However, federal action agencies can also use it in preparing EFH assessments. We hope that this advice may help prevent habitat damage before it occurs, rather than having to restore it after the fact. Ideally, this will save American taxpayers millions of dollars in habitat restoration funds.

EFH can be harmed by a wide variety of human activities that are unrelated to fishing. This document examines 19 non-fishing impacts to EFH—from climate change and aquaculture to road construction, mining, dredging, noise pollution, and many more. For each activity, we describe the known and potential impacts to EFH, and provide proactive conservation measures designed to minimize or avoid them.

Links used in this section:

- Essential fish habitat: https://www.fisheries.noaa.gov/national/habitat-conservation/essential-fish-habitat
- Thumbnail image: https://www.fisheries.noaa.gov/resource/document/essential-fish-habitat-ecosystem-approach
- Magnuson–Stevens Act: https://www.fisheries.noaa.gov/topic/laws-policies/magnuson-stevens-act
- Consult with NOAA Fisheries: https://www.fisheries.noaa.gov/national/habitat-conservation/consultations-essential-fish-habitat
- Habitat restoration: https://www.fisheries.noaa.gov/video/habitat-restoration-noaa

Abstract

The Magnuson–Stevens Fishery Conservation and Management Act of 1976 (MSA; amended 1996 and 2007) mandated the identification of essential fish habitat (EFH) for federally managed species and consideration of measures to conserve and enhance the habitat necessary for these species to carry out their life cycles.

The MSA also requires federal agencies to consult with the National Marine Fisheries Service (NOAA Fisheries) on all actions or proposed actions permitted, funded, or undertaken by the agency that may adversely affect EFH—such as EFH necessary for anadromous salmonids—which use both fresh- and saltwater habitats. Federal agencies do this by preparing and submitting EFH assessments to NOAA Fisheries.

NOAA Fisheries' biologists review proposed projects under the EFH provisions to ensure that they provide appropriate EFH conservation recommendations. It is challenging during the consultation phase to consider all potential non-fishing impacts to EFH so that the appropriate mix of recommendations can be made. Because impacts that may adversely affect EFH can be direct, indirect, and cumulative, the biologists must consider and analyze these interrelated impacts. This reference document was prepared to assist NOAA Fisheries biologists in reviewing proposed projects and considering potential impacts (e.g., barriers, stormwater runoff) that may adversely affect EFH, and to provide consistent and substantiated EFH conservation recommendations.

This document provides an update and reorganization to Hanson et al. (2003), including new chapters and updated reference lists.

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Hanson, J., M. Helvey, and R. Strach, editors. 2003. Non-Fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures. National Marine Fisheries Service, Seattle.

Glossary

EFH	essential fish habitat
entrainment	The passage of fish through fish screens at water diversions.
ESA	Endangered Species Act of 1973
impingement	Prolonged whole-body contact with a fish screen.
marine vibroseis	A sound-generating system that uses a large oscillating mass to emit a range of frequencies. Offers an alternative to air-gun seismic sources and may have fewer environmental effects on marine biota.
MSA	Magnuson–Stevens Fishery Conservation and Management Act of 1976
TMDL	total maximum daily load

Acknowledgments

We would like to acknowledge the valuable contributions of our NOAA colleagues who wrote the earlier version of this report, as well as the reviewers of this update, including: Jennifer Ruesink, University of Washington; Jim Laughlin, Washington State Department of Transportation; Chris Mebane, United States Geological Survey; and Lisa Abernathy, Morgan Bond, Correigh Greene, Britta Timpane-Padgham, Eric Shott, Gretchen Hanshew, Matt Goldsworthy, Rosalie del Rosario, Mike Kelly, Eric Chavez, Stephanie Ehinger, Laura Hoberecht, Lyndal Johnson, Mike Grady, Gayle Kreitman, Beth Sanderson, Johnathan Schram, Steven Smith, Tim Beechie, and Michael Pollock, National Marine Fisheries Service.

We acknowledge the foundational contributions of the original writers of this document, including the editors—Jeanne Hanson, Mark Helvey, and Russ Strach—and the contributors: Lt. Mark Boland, Tracy Collier, Bob Donnelly, Jeanne Hanson, Mark Helvey, Ron A. Heintz, Thom Hooper, DeAnee Kirkpatrick, Brian Lance, Marc Liverman, Matt Longenbaugh, Kristin McCully, Nancy Munn, Ben Meyer, Ken Phippen, Nat Scholz, John Stadler, Dan Tonnes, and Susan Walker.

Introduction

Background on Essential Fish Habitat

In 1996, the United States 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 Magnuson–Stevens Act mandated the identification of essential fish habitat (EFH)[1] for federally managed species, and consideration of measures to conserve and enhance the habitat necessary for these species to carry out their life cycles.

The act also requires federal agencies to consult with the National Marine Fisheries Service (NOAA Fisheries) on all actions, or proposed actions, permitted, funded, or undertaken by the agency, that may adversely affect EFH.[2] Federal agencies do this by preparing and submitting an EFH Assessment to NOAA Fisheries. The EFH Assessment is a written assessment of the effects of any proposed federal action(s) on EFH. Regardless of federal agency compliance to this directive, the act requires NOAA Fisheries to provide conservation recommendations to federal as well as state agencies once it receives information or determines from other sources that EFH may be adversely affected. These EFH conservation recommendations are provided to conserve and enhance EFH by avoiding, minimizing, mitigating, or otherwise offsetting the adverse effects to EFH.

By providing EFH conservation recommendations before an activity begins, NOAA Fisheries may help prevent habitat damage before it occurs, rather than restoring it after the fact—which is less efficient, unpredictable, and often more costly. This could ultimately save American taxpayers millions of dollars in habitat restoration funds, and could save industries from having to remedy environmental problems down the road. Furthermore, EFH conservation will lead to more robust fisheries, providing benefits to coastal communities and commercial and recreational fishers alike (Benaka 1999).

Activities proposed to occur in EFH areas do not automatically require consultation. Consultations are triggered only when the proposed action may adversely affect EFH, and then, only federal actions require consultation.

This consultation process is usually integrated into existing environmental review procedures in accordance with the

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[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 all habitat types utilized by a species throughout its life cycle.

[2] *Adverse effect* is any impact which 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, and other ecosystem components. Adverse effects may be site-specific or habitatwide impacts, including individual, cumulative, or synergistic consequences of actions [50 CFR 600.910(a)].

National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), or the Fish and Wildlife Coordination Act (FWCA), for instance, to provide the greatest level of efficiency.

Within 30 days of receiving NOAA Fisheries' conservation recommendations, federal action agencies must provide a detailed response in writing to NOAA Fisheries. 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 the federal action agency chooses not to adopt NOAA Fisheries' conservation recommendations, it must provide an explanation, including the scientific justification for any disagreements with NOAA Fisheries over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects. Examples of federal action agencies that permit or undertake activities that may trigger the EFH consultation process include, but are not limited to, the U.S. Army Corps of Engineers (USACE), the U.S. Environmental Protection Agency (EPA), the Federal Energy Regulatory Commission, and the Department of the Navy (DoN). Fishery Management Councils (FMCs) may also choose to comment on proposed actions that may adversely impact EFH, and must do so for any activity that is likely to substantially affect the habitat, including EFH, of an anadromous fishery resource under FMC authority. The waters and substrate that comprise EFH designations under the jurisdiction of the FMCs are diverse and widely distributed. They are also closely interconnected with other aquatic and terrestrial environments.

From a broad perspective, EFH typically encompasses the geographic area where the species occurs at any time during its life. This area can be described in terms of ecological characteristics, location, and time. Ecologically, EFH includes waters and substrate that focus distribution (e.g., migration corridors, spawning and rearing areas, rocky reefs, intertidal salt marshes, or submerged aquatic vegetation) and other characteristics that are less distinct (e.g., turbidity zones, salinity gradients). Spatially, habitats are dynamic and shift with seasons and hydrologic events, and EFH may comprise multiple habitat types to form a habitat mosaic. The importance and use of EFH may shift over time due to climate change, human activities, and geologic events. The type of habitat available, its attributes, and its functions are important to species productivity, diversity, health, and survival.

Essential Fish Habitat Characterization

Essential fish habitat includes uplands—river or riverine, estuary or estuarine, and coastal or marine. Riverine habitats provide important habitat that serves multiple purposes for anadromous species such as salmon. These purposes include migration, feeding, spawning, nursery, and rearing functions. Protecting these functions is vital to providing for a productive system and a healthy fishery. Important components of a river system also include the riparian corridor and floodplain. *Riparian* refers to the land directly adjacent to a stream, lake, or estuary. A healthy riparian area has vegetation harboring prey items (e.g., insects), contributes necessary nutrients, provides large woody debris (LWD) that creates channel structure and covers for fish, and provides shade, which controls stream temperatures (Bilby and Ward 1991). When vegetation is removed from riparian areas, waters are heated, and LWD is less common. This results in less refuge for fish, fundamental changes in channel structure (e.g., loss of pool habitats), instability of streambanks, and alteration of nutrient and prey sources within the river system. *Floodplain* refers to the land adjacent to the stream channel, composed of unconsolidated alluvial sediments, extending laterally to the base of the valley wall, which is periodically flooded during high discharge. When floodplains are constrained or damaged by human activities, river hydrology is altered, leading to a variety of biophysical changes in freshwater EFH, including reductions in important rearing and spawning habitat (Sedell and Frogatt 1986, Hein et al. 2016).

Estuaries are the bays and inlets influenced by both the ocean and rivers, and they serve as the transition zone between fresh and saltwater (Botkin et al. 1995). Estuaries support a community of plants and animals that are adapted to the zone where fresh and salt waters mix (Zedler et al. 1992). Estuarine habitats fulfill fish and wildlife needs for reproduction, feeding, refuge, and other physiological necessities (Phillips 1984, Watson and Byrne 2009). Healthy estuaries include submerged aquatic vegetation, including eelgrass beds and kelp forests, which store carbon, protect young fish from predators, provide food and habitat for fish and wildlife including NOAA trust resources, improve water quality, and influence hydrology and sediments (Phillips 1984, Thayer et al. 1984, Hoss and Thayer 1993, Baeta et al. 2009, Lemons et al. 2011, Shelton et al. 2017). In addition, shorelines, mud flats, high salt marsh, and saltmarsh creeks and associated riparian vegetation and shorelines also provide productive shallow-water habitat for epibenthic fishes and decapods (Sogard and Able 1991, Currin et al. 2010). While large woody debris in streams provides a number of ecological functions important for healthy EFH, so does LWD along marine shorelines, where it provides a key biogenic habitat (Heerhartz et al. 2014).

Coastal or marine habitats comprise a variety of habitat types for EFH-managed species, including sandy bottoms, rocky reefs, and submarine canyons. When rocky reefs support kelp stands, they become exceptionally productive. Relative to other habitats, including wetlands, shallow and deep sandy bottoms, and rocky-bottom artificial reefs, giant kelp habitats are substantially more productive in the fish communities they support (Bond et al. 1999, Schaffer et al. 2020). In particular, their three-dimensional structure can provide exemplary marine habitat (Graham 2004). Foster and Schiel (1985) reported that the net primary productivity of kelp beds may be the highest of any marine community, and this theory has been continually supported by scientific research (Tegner and Dayton 2000, Deza and Anderson 2010). Lush kelp forest communities (e.g., giant kelp, bull kelp, elk kelp, and feather boa kelp) are found relatively close to shore along the open coast. These subtidal communities provide vertically structured habitat through the water column on the rocky shelf, made up of: a canopy of tangled stipes from the water line to a depth of 10 ft; a mid-kelp, water-column region; and the bottom, holdfast region. The stands provide nurseries, feeding grounds, and/or shelter to a variety of groundfish species and their prey (Feder et al. 1974, Ebeling et al. 1980, Bodkin 1988, Nelson 2000, Schroeder 2016). Furthermore, coastal and marine ecosystems are the most vulnerable to human impacts within the California Current, specifically mudflats, beach, salt marsh, and rocky intertidal habitats (Teck et al. 2010).

Nonfishing Impacts

The diversity, widespread distribution, and ecological linkages with other aquatic and terrestrial environments make the waters and substrates that comprise EFH susceptible to a wide array of human activities unrelated to fishing.

Nonfishing activities have the potential to adversely affect the quantity or quality of EFH-designated areas in riverine, estuarine, and marine systems. Broad categories of such activities include, but are not limited to, mining, dredging, fill, impoundment, discharge, water diversions, thermal additions, actions that contribute to non-point 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. For each activity, this document describes known and potential adverse impacts to EFH. The descriptions include an explanation of the potential mechanisms or processes that may cause the adverse effects on EFH and how these may affect habitat function.

The report also provides proactive conservation measures designed to minimize or avoid the adverse effects of these nonfishing activities on EFH. These measures should be viewed as options to avoid, minimize, or compensate for adverse impacts, and to promote the conservation and enhancement of EFH. However, it is worth noting that site-specific considerations are often important when evaluating nonfishing impacts and developing appropriate EFH conservation recommendations. The conservation measures presented in this report will likely need to be adjusted to suit site-specific needs.

Purpose of Document

It is of paramount importance that NOAA Fisheries' biologists review proposed projects under the EFH provisions to ensure that they provide appropriate EFH conservation recommendations. It is equally challenging during the consultation phase to consider all potential nonfishing impacts to EFH so that the appropriate mix of recommendations can be made. Because impacts that may adversely affect EFH can be direct, indirect, and cumulative, the biologist must consider and analyze these interrelated impacts. This reference document was prepared to assist NOAA Fisheries biologists in reviewing proposed projects and considering potential impacts that may adversely affect EFH, and to provide consistent and substantiated EFH conservation recommendations.

The document should also be useful for federal action agencies undertaking EFH consultations, and especially in preparing EFH assessments. For instance, action agencies can use this document for assistance in identifying and describing potential adverse effects associated with a particular activity type. In addition, incorporating appropriate conservation measures from this document into a project description could reduce the number of, or even obviate the need for, additional EFH conservation recommendations provided by NOAA Fisheries biologists during the consultation process.

Each chapter briefly describes the potential effects of nonfishing impacts on EFH and a list of potential conservation measures to minimize these impacts. Because a variety of nonfishing impacts are considered, it was not feasible to go into great detail on each activity. If more details on a particular activity are needed to complete an EFH consultation (e.g., for an action agency to accomplish the EFH assessment or a NOAA Fisheries biologist to develop an EFH response), the reference section of each chapter provides a list of key papers or reports on that topic. In addition, a number of chapters are linked, as some nonfishing activities have similar impacts on EFH. For example, Chapter 6 (Dam Operations and Removal) addresses the impacts of dams, etc., on EFH, including effects on fish migration, which are also addressed in Chapter 3 (Road Construction and Operation), as road crossings and culverts also constrain or sever fish migration. Therefore, it may be beneficial to consult multiple chapters when assessing impacts of nonfishing activities on EFH. Given the pervasive effects of climate change across all EFH (from uplands to the open ocean), assessment of the various nonfishing activities should explicitly consider how these activities might interact with climate change to impact EFH. A short chapter on climate change is included, providing some very simple examples of how these interactions might occur.

The EFH conservation recommendations included with each activity present a series of specific measures that can be undertaken by the action agency to avoid, offset, or mitigate impacts to EFH. Our lists of recommendations are by no means complete, nor are all of these suggested measures necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information and project-specific considerations should be developed prior to, or during, the EFH consultation process and communicated to the appropriate agency. The conservation recommendations provided represent a short menu of general types of conservation measures that can contribute to the conservation and enhancement of properly functioning EFH. As such, they can help form the starting point for the development of conservation measures.

Generally, non-water-dependent actions should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse impacts 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 are not possible, or will not adequately protect EFH, compensatory mitigation to conserve and enhance EFH is recommended. To help inform managers on the effectiveness of conservation measures in protecting EFH from the adverse effects of nonfishing activities, an adaptive management approach is recommended (Walters 1986).

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1. Climate Change

Human activities (e.g., burning of fossil fuels, clearing of forests, and development of land) that emit greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases contribute to a rapidly changing global climate (Oreskes 2004, Hansen et al. 2006, Rosenzweig et al. 2008) that is and will continue to impact EFH from headwaters to the open ocean. Thus, those tasked with the conservation and management of EFH will need to consider the multiple pathways by which climate change will impact marine, freshwater, and terrestrial ecosystems. First, current and projected changes in global climate have wide-ranging effects on a variety of environmental conditions (water chemistry, temperature, water flow, precipitation, disturbance regimes, etc.) that will directly affect EFH and associated food webs (Beechie et al. 2010, Davis et al. 2013). Climate models predict that the region supporting Pacific coastal EFH is expected to warm in all seasons, but the greatest warming, 1.9–5.2°C (3.4–4.9°F), is projected for summer 2041–70 (Miller et al. 2003, Marcarelli et al. 2010). Warmer water temperatures will increase metabolic demands of aquatic ectotherms, potentially leading to changes in life history (e.g., delayed migration) and making them more susceptible to other stressors (e.g., Gale et al. 2013). Second, changes in these environmental conditions and processes will interact with climate-induced changes on land (e.g., reductions in forest cover due to changes in precipitation and temperature patterns) and in oceans (e.g., circulation) to affect EFH possibly in a synergistic manner (Doney et al. 2012, Gale et al. 2013). For instance, climate warming has increased water temperature of marine and freshwater EFH habitats, especially in summer, which is stressful for a variety of NOAA trust species and their prey base (e.g., Roessig et al. 2004). These increases in temperature as a result of global climate change may be exacerbated by human conversion of riparian forests that shade aquatic habitats from solar insolation and conversion of riparian forests east of the Cascade mountains to shrub-steppe and grasslands due to changes in precipitation patterns and disturbance regime (e.g., increased fire frequency and severity; Westerling et al. 2011, Davis et al. 2013). Third, we should expect that the complex ecological and environmental modifications resulting from climate change will interact with EFH nonfishing activities and other stressors to affect trust species and their ecosystems. Finally, we should expect that marine and freshwater species that are already threatened or endangered to be most vulnerable to climate change (e.g.,Williams et al. 2015), and thus to potential land-use activities that affect EFH used by these sensitive species, warrant a high level of scrutiny.

Climate Change Impacts on EFH

As of 2009, air temperatures in the region supporting Pacific salmon EFH had increased by about 0.8°C over the past century, and models project warming of 2.0°C by the 2040s and 3.3°C by the 2080s (e.g., Mote and Salathé 2010). Regional models predict increased water temperatures throughout EFH along the U.S. West Coast (ISAB 2007). In EFH that already experiences seasonally elevated water temperatures, warmer water could shift species composition via increasing mortality of cool-water species by exceeding thermal tolerances, increasing susceptibility to disease and contaminants, and shifting the distribution and abundance of both prey that support higher trophic levels, as well as invasive species (e.g., Sydeman et al. 2015). Climate change-associated increases in water temperature could also increase the frequency and duration of low dissolved oxygen events leading to the persistence of ecological dead zones (e.g., Praetorious et al. 2015). In the marine environment, increased water temperatures could promote stratification between warmer surface waters and cooler, nutrient-rich deep waters. The resulting thermocline could prevent nutrient cycling, reducing growth of phytoplankton that form the base of marine food webs (CIG 2004, Scheuerell and Williams 2005). Increased marine and freshwater temperatures (as well as changes in freshwater flow) may also increase the establishment and spread of non-native species (Hoegh-Guldberg and Bruno 2010, Lawrence et al. 2015, Sydeman et al. 2015).

Precipitation patterns, including the frequency of extreme precipitation events, are also projected to change with climate change. For example, climate models predict increased variability in precipitation, with more falling as rain in winter, especially at high elevations, and less in summer, resulting in more extreme seasonal cycles and a variety of changes in terrestrial and aquatic ecosystems, including changes in discharge regime (Cayan et al. 2008, Davis et al. 2013). For example, in western Washington, autumns and winters are predicted to be warmer and wetter, summers drier, and a higher proportion of overall precipitation to fall as rain, which would reduce snowpack in the Cascade Range and water available to maintain adequate summer flows for fish populations (Mote and Salathé 2010). As the climate warms and regional snowpack is reduced, flow regimes in some snow-fed streams are expected to shift toward regimes dominated more by rainfall, which could impact EFH in a variety of ways, including altering river food web composition and productivity, phenology and life-history diversity of some salmonid species, and downstream habitats, including estuarine habitats (Mote et al. 2003, CIG 2004). For example, a warmer climate is expected to lead to less snow in the Cascade mountains and smaller snowpacks, which melt earlier and produce lower flow levels. These changes could alter flow or temperature-mediated behavioral cues in fish, such as migration timing (ISAB 2007). Changes in snowpack could also alter flow regimes such that summer low flows are reduced, decreasing habitat for rearing and migrating juvenile salmonids, thereby increasing the probability of stranding, negative biotic interactions (e.g., predation), and susceptibility to disease (Stewart 2004, Battin et al. 2007, Luce and Holden 2009).

The eastern Pacific Ocean has and will experience large changes in water temperature, pH, circulation, and sea level that will lead to major changes in EFH (Roessig et al. 2004, Hoegh-Guldberg and Bruno 2010, Nicholls and Cazenave 2010, Doney et al. 2012, Moore et al. 2015, Sydeman et al. 2015). The impacts of climate change on the oceans so far include decreased ocean productivity, altered food web dynamics, reduced abundance of habitat-forming species, shifting species distributions, loss of nearshore habitat, and a greater incidence of disease (e.g., Hoegh-Guldberg and Bruno 2010, Haigh et al. 2015). For example, the ocean is a major sink for atmospheric CO_2, and as the level of CO_2 in the atmosphere increases it will dissolve more readily in the ocean, increasing the concentration of carbonic acid and lowering the pH of seawater. Planktonic organisms that form the base of many marine food webs secrete $CaCO_3$ shells necessary for their survival. Lower pH will dissolve or prevent the formation of these shells, leading to increased mortality rates (Orr et al. 2005). These changes in ocean acidification may have profound implications for marine EFH (Haigh et al. 2015). Juvenile salmonids foraging in the ocean rely on plankton as a food source, so decreased plankton abundance could reduce salmonid growth and survival rates.

Future climate scenarios also predict changes in disturbance regimes (fire, landslides, floods, droughts, insect outbreaks, extreme events) that impact EFH (e.g., Davis et al. 2013). Reduced snowpack, reduced rainfall, and earlier snowmelt have increased summer drought, and the frequency and severity of extreme weather events, wildfire, and fire-related debris flows (Pierce et al. 2004, Westerling et al. 2006, Westerling and Bryant 2008, Cai et al. 2015). Models predict that the amount of land impacted by wildfire in the western United States will increase 54% due to climate change by 2050, and increased fire will likely coincide with increased incidence of debris flows (Davis et al. 2013). Debris flows also occur in unburned areas, but the magnitude of impact and probability of occurrence are larger in burned watersheds (May and Gresswell 2003). Increased drought and insect damage associated with climate change will also lead to changes in forest composition and structure, thereby increasing susceptibility to forest fires that impact EFH (e.g., Davis et al. 2013).

As climate change continues, the resultant effects on EFH through changes in water chemistry, temperature, precipitation, and stream-flow regimes will have large effects on aquatic organisms, including development, phenology, metabolism, growth, survival, reproduction, and movement, ultimately leading to changes in population dynamics, species composition, and food-web processes (Roessig et al. 2004, Crozier and Zabel 2006, Zabel et al. 2006, Battin et al. 2007, Crozier et al. 2008, Doney et al. 2012). Changes in global climate will also alter terrestrial (e.g., plant production, nutrient and organic matter flux) and ocean processes (e.g., biogeochemical cycles) that may interact with climate-induced changes in temperature, precipitation, and flow, to affect EFH and the organisms it supports (Doney et al. 2012, Davis et al. 2013). For example, drier summers could further reduce salmonid spawning habitat already reduced by anthropogenic fish passage barriers. Extreme rainfall events during winter and spring could increase flooding after the Pacific salmon spawning period, scouring redds and increasing mortality of eggs and larvae. Adult salmon use pools to rest during the pre-spawn stage, and this habitat could be reduced in some streams as flow and sediment regimes are altered. One consequence of the increased frequency of climate-induced forest fires is increased inputs of fine sediment to streams (e.g., Rhoades et al. 2011), which can reduce habitat quality for spawning and stream-rearing salmonids. Higher winter flows could also degrade valuable estuarine zones through pollution, variable freshwater influx, and physical disturbance.

Given the current and predicted future impact of climate change on terrestrial and aquatic habitats, the assessment of nonfishing activities on EFH must consider how any particular activity will interact with current landscape conditions and processes, as well as projected changes in environmental conditions (e.g., temperature, flow, pH, nutrients, contaminants; see Figure 1) resulting from climate change. Humans will be affected by the same climatic changes and reductions in suitable habitat, including the availability of water, which will likely lead to increased public conflict when making decisions about the use and protection of increasingly limited natural resources (Vicuna et al. 2007). Thus, it will be increasingly important that anthropogenic activities become progressively less intrusive on EFH, to account for the increased pressure on EFH due to climate change, so that valuable resources, such as naturally produced fisheries, remain sustainable for future generations.

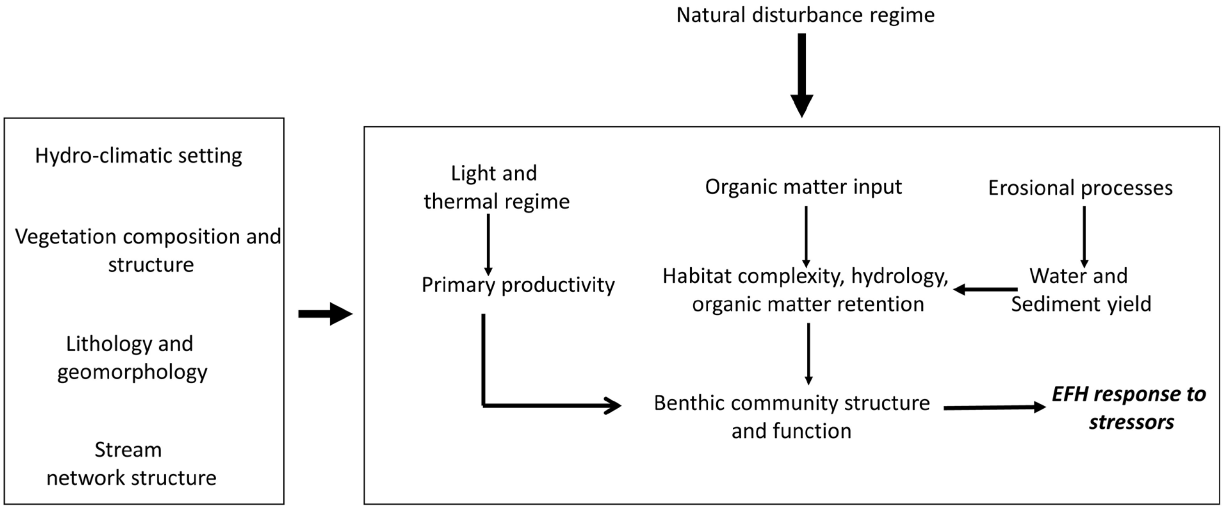

Figure 1. Conceptual model showing the hypothesized influence of landscape-level characteristics (regional climate and hydrology, riparian vegetation, lithology and geomorphology, and stream network structure) and disturbance regime on catchment-level processes. We hypothesize that how EFH responds to anthropogenic change will depend on environmental context determined by these landscape-level drivers and the local natural disturbance (e.g., fire, insects) regime. Modified from Figure 2 in Clements et al. 2015.

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2. Upland and Urban Development

A majority of land within the United States is rural; however, a growing segment of the population resides in expanding urban areas, resulting in the increased development of upland habitats and loss of open areas (Miller and Hobbs 2002, Brown et al. 2014). Globally, building activity and urbanization could be the single most important factor impacting EFH (Gregory 2006). Upland habitat is transformed from open, forested, and riparian floodplain areas containing ecologically functioning EFH into residential, urban, agricultural, or commercial areas, where functionality of EFH is generally compromised, resulting in large, quantifiable losses in EFH (Walsh et al. 2005, Lohse et al. 2008, Violin et al. 2011, Yeakley et al. 2014, Göthe et al. 2015). Remaining EFH is ecologically degraded through human activities and structures that homogenize, block, contaminate, and functionally impair hydrologic and geomorphologic processes (Booth and Jackson 1987, Beechie et al. 1994, Allan 2004, Konrad and Booth 2005, Konrad et al. 2005, Walsh et al. 2005, Chang 2007, McClure et al. 2008, Segura and Booth 2010). Water withdrawals and appropriation and urban runoff directly and indirectly impact hydrology, water chemistry, habitat, and organisms (USEPA 2002, Booth et al. 2004, McCarthy et al. 2008, Weiss et al. 2008, USEPA 2014). The area of impervious surface often increases over time (Arnold and Gibbons 1996), exacerbating impaired hydrologic and geomorphologic processes (May et al. 1997, Allan 2004, DeGasperi et al. 2009), and leading to increased concentration of contaminants in marine (Fitch et al. 2009) and freshwater (Allan 2004, Sandahl et al. 2007) EFH. Thus, landform and hydrologic changes and uses associated with upland and urban development can degrade EFH, and lead to reduced fish abundance and survival (Scott et al. 1986, Beechie et al. 1994, Bradford and Irvine 2000, Paulsen and Fisher 2001, Pess et al. 2002, Bilby and Mollot 2008, Yeakley et al. 2014).

This chapter is divided into four sections that outline some of the adverse impacts of upland and urban development on EFH, including factors associated with Commercial and Domestic Water Use, Floodplain Development, Land Clearing and Impervious Surfaces, and Stormwater and Urban Runoff. Suggestions for avoidance, minimization, and mitigation of these impacts on EFH are provided in each section.

Commercial and Domestic Water Use

Potential adverse impacts of commercial and domestic water use

The following factors associated with commercial and domestic water use can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, and entrainment and impingement. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Commercial and domestic water uses associated with upland and urban development can lead to the loss and alteration of EFH. Stream water flowing through developed areas can be relatively high in nutrients and contaminants (Bischel et al. 2013, Feist et al. 2017), which can lead to eutrophication and other water-quality impacts to downstream habitats. For example, eutrophication reduces the oxygen concentration in water, decreasing suitability of EFH (Rice 2005), which can be exacerbated by increased water temperatures (Kaushal et al. 2012). Water withdrawals for nonurban upland development purposes (e.g., agriculture) can also increase sedimentation, reducing habitat suitability for spawning salmon (Lohse et al. 2008), and associated reduced stream flows can diminish or desiccate downstream EFH (Labbe and Fausch 2000), impacting biodiversity, abundance, and size structure of invertebrate and fish populations (Lake 2003, Kanno and Vokoun 2010).

Excessive nutrients and contaminants in runoff from upland and urban development can also lead to degradation of water quality in downstream marine EFH (Schiff and Bay 2003). For example, eutrophication of nearshore habitats can reduce the functionality of critical EFH features by altering the spatial distribution (Deegan and Buchsbaum 2005) and physical structure of seagrass (MacKenzie 2005). Freshwater fluxes to nearshore zones are also impacted by commercial and domestic water use. Loss of freshwater influx in estuaries can lead to the loss of vegetation along banks and coastlines, decreasing refuge, bank stability, and food sources for fish (Christie et al. 1993, Kimmerer 2002a).

Altered hydrology and geomorphology

Instream and riparian habitat (Tabacchi et al. 1998), and survival of embryonic and larval life stages of fish (Cederholm and Reid 1987, DeVries 1997, Quinn 2005) can be negatively affected by anthropogenic changes in volume and timing of stream discharge resulting from land use change. Commercial and domestic water uses associated with upland and urban development can alter hydrologic and geomorphologic processes in EFH. Upstream water use can decrease river flows (Caldwell et al. 2012), alter the transport of sediments and organic matter (Christie et al. 1993, Fajen and Layzer 1993), reduce water depths, modify water chemistry (NPPC 1986), and exacerbate extreme diel temperature patterns (Zale et al. 1993). Alterations to instream habitat and sediment transport caused by upstream water use can lead to decreases in survival of fish embryos (Lohse et al. 2008, Deitch et al. 2009), impediments to fish migration (Deegan and Buchsbaum 2005), and reduction of invertebrate populations (McKay and King 2006) that support fish production (Deitch et al. 2009). Water withdrawals during low flow periods can lead to longitudinal and lateral disconnection of habitat, isolating fish and impairing migrations. Withdrawals can also lead to elevated stream temperatures due to loss of hyporheic or groundwater flow. In addition to physiological stress, increased temperatures can also increase colonization and contact time with invasive species (Lawrence et al. 2012).

The volume and timing of freshwater delivery to estuary EFH is also impacted by upstream water use, affecting water residence time, temperature, salinity, delivery of sediment and organic matter, water chemistry, and stratification of the water column (Kimmerer 2002a,b, Flemer and Champ 2006). Such degradation of estuary EFH can reduce the survival of estuarine-dependent species that are adapted to more dynamic freshwater influxes (Nichols et al. 1986).

Entrainment and impingement

Water diversions located in or connected to EFH can entrain (i.e., the passage of fish through fish screens at water diversions) and impinge (i.e., prolonged whole-body contact with a fish screen) fish (Zydlewski and Johnson 2002, Ellsworth et al. 2010). Entrainment can subject juvenile fish to physical abrasion and rapid pressure changes (Mussen et al. 2014, Zeug and Cavallo 2014). Intake pipes at diversions can stress or disorient fish through impingement or entrainment, and can also create conditions that favor predators such as larger fish and birds (Moyle and Israel 2005). Entrainment and impingement often result in the death of fish, and may have cumulative adverse impacts on fish populations (Swanson et al. 2005, Kimmerer 2008, Grimaldo et al. 2009).

Potential conservation measures for commercial and domestic water use

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of commercial and domestic water use on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of commercial and domestic water use on EFH.

General guidelines

- Work with water trust organizations to acquire water rights or establish water banks.
- 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.
- 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.

Loss and alteration of habitat

- Maintain and restore channel, floodplain, riparian, groundwater, and estuarine conditions.

Altered hydrology and geomorphology

- Conduct water availability analyses for watersheds to determine unimpaired and current baseline flows. Determine water volumes and flows (including the range of flows) needed to achieve or maintain EFH functions that support viable invertebrate and fish populations.
- Incentivize projects, practices, and laws or regulations that result in water conservation and reduced water demand.
- Maintain appropriate flow velocity, water levels, and flow variability to support continued stream functions.
- Mimic the "pulsed" nature of rivers and estuaries in order to maintain their natural state as dynamic systems.
- Maintain water quality in source waterbodies necessary to support fish populations by monitoring water flows and temperature, sediment loads, and pollution levels.
- 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; CDFG and NMFS 2002).

Entrainment and impingement

- Design or modify existing water diversion and impoundment projects to create flow conditions that provide for adequate fish passage, particularly during critical life-history stages.
- Install screens at water diversions in fish-bearing areas, as needed. Please see the NMFS guidelines on fish screening to protect salmonids (WDFW 2000).
- Where predation is an issue, add protective refuge for fish at water diversions.
- Consolidate existing and planned diversions for facility cost savings, including fish protection facilities.

Floodplain Development

Potential adverse impacts of floodplain development

The following factors associated with floodplain development can impact EFH and are described briefly below: loss and alteration of habitat, and altered hydrology and geomorphology. Suggested conservation measures related to these factors are provided in the following section.

Loss and alteration of habitat

Floodplains are among the world's most altered habitats (Tockner and Stanford 2002) as they are transformed from diverse, broadly interconnected networks of EFH (Junk et al. 1989) into simplified, confined, armored channels, leading to degradation of EFH and subsequent reductions in invertebrate and fish populations and diversity (Sedell and Froggatt 1984, Beechie et al. 1994, Gregory and Bisson 1997, Li and Eddleman 2002). Floodplain development includes diking, draining, and filling to create agricultural fields, pastures, ports, cities, and residential and industrial lands (Sedell and Froggatt 1984, Tomlinson et al. 2011). The construction of dikes, levees, roads, and other infrastructure in floodplains can constrict channel migration and reduce interconnectivity between floodplain and main channel EFH, and among discrete EFH units within main channels (Niering 1988, Furniss et al. 1991, Mitsch and Gosselink 1993, Jones et al. 2000, Beechie et al. 2001, Rapp and Abbe 2003, Tomlinson et al. 2011). Noise from roads and other anthropogenic activities may also impact fish behavior (Holt and Johnston 2015).

Riparian floodplain habitats contribute to the formation and diversity of instream EFH (Bilby and Ward 1991, Chamberlin et al. 1991, Abbe and Montgomery 1996, Naiman et al. 1998), buffer water temperatures (Beschta et al. 1987, Clinton 2011), and can stabilize banks, reducing erosion and improving water quality (Hicks et al. 1991, Beschta et al. 2000, Tabacchi et al. 2000). Development and use of the floodplain can disturb these functions, reducing the quality and quantity of EFH (Cederholm and Reid 1987, Beechie et al. 1994).

Large woody debris (LWD) plays an important role in formation and availability of EFH (Abbe and Montgomery 1996, Beechie and Sibley 1997, McHenry et al. 1998, Roni and Quinn 2001), and helps control sediment and flow routing, nutrient cycling, and substrate availability for algae and invertebrates (Bilby 1981, Bilby and Ward 1989, Montgomery et al. 1995, Young 2000, Coe et al. 2009, Clinton 2011, Hodson et al. 2014). Development of floodplains and removal of dead and living wood can reduce the flux of wood into EFH, impairing these functions (Allan 2004, Konrad and Booth 2005, Latterell et al. 2006). Reductions in riverine LWD recruitment can also result in less LWD in the marine nearshore, and such LWD could help moderate microhabitat temperatures and increase abundance of macroinvertebrates (Tonnes 2008).

Riparian wetlands serve as a critical element of EFH (Quinn and Peterson 1996, Feist et al. 2003), and, although laws have been enacted to protect them, these wetlands continue to be lost during floodplain development (Masonis and Bodi 1998, Van Asselen et al. 2013). Loss of wetlands to development can impact water quality, flow regime, habitat structure, and food sources that support fish living in EFH (Knight 2009).

Altered hydrology and geomorphology

The integrity of flowing water systems depends largely on the dynamic character of the flow regime and subsequent geomorphic processes (Poff et al. 1997, Poff et al. 2010). Floodplain development and associated flood control and erosion control structures reduce hydrologic and geomorphic processes, resulting in impacts to connectivity, sediment dynamics, vegetation patterns, organic matter recruitment, and hyporheic exchange in EFH (Allan 2004).

Floodplain development can restrict important geomorphic processes that influence channel migration and the creation or maintenance of alcoves, groundwater channels, and side channels. Loss of such habitat functionality and features can reduce the productivity of fish populations (Beechie et al. 1994). Development of the floodplain could alter the frequency and magnitude of peak flows (Stover and Montgomery 2001, White and Greer 2006, Lane 2008) by reducing absorption of floodwater laterally into the now degraded or lost floodplain. Increased flood frequency and magnitude lead to additional demands for flood control projects, such as dams, dredging, or the building of dikes and levees (Rasmussen 1994). Increased peak flows can also mobilize sediments and increase scour depths, reducing embryo survival. Consequently, reduction of floodplain habitat decreases the availability of off-channel refuge habitat, while simultaneously increasing the need for such habitats by exacerbating high flow events. Such developments are costly, as they can compound the negative impacts of floodplain development on EFH (Beechie et al. 2010), and impacts to EFH must be mitigated for.

Potential conservation measures for floodplain development

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of floodplain development on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. These guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of floodplain development on EFH.

General guidelines

- Work with water trust organizations to acquire water rights or establish water banks.
- Minimize adverse effects on floodplains and wetlands from water-dependent uses.
- Complete compensation mitigation for unavoidable floodplain or wetland loss prior to conducting activities that may adversely affect floodplains or wetlands, and perform such mitigation only in areas that have been identified as having long-term viability and functionality.

- Design floodplain and wetland mitigation to meet specific performance objectives for function and value, and monitor to assure these objectives are achieved. Use mitigation and enhancement ratios that are sufficient to attain a net gain in acreage, as well as in function and value.
- Focus resources on conservation and restoration of upland or urban habitats on private and public lands (Burnett et al. 2007).

Loss and alteration of habitat

- Determine cumulative effects of all past and current floodplain and wetland alterations before planning activities that further alter wetlands and floodplains.
- Promote awareness and use of USDA's wetland and conservation reserve programs (also, any local conservation programs) to conserve and restore wetland and floodplain habitat.
- Incentivize restoration of degraded floodplains and wetlands, including reconnecting rivers with their associated floodplains and wetlands, and invasive species management.

Altered hydrology and geomorphology

- Avoid floodplain development, and mitigate unavoidable floodplain losses to existing floodplain functions and processes, including water quality, water storage capacity, and lateral channel movement.
- Minimize alteration of floodplains and wetlands for non-water-dependent uses.

Land Clearing and Impervious Surfaces

Potential adverse impacts of land clearing and impervious surfaces

The following factors associated with land clearing and impervious surfaces can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, sedimentation, siltation, and turbidity, and release of contaminants. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Riparian habitats contribute to the formation and diversity of instream EFH (Bilby and Ward 1991, Chamberlin et al. 1991, Abbe and Montgomery 1996, Naiman et al. 1998), buffer water temperatures (Beschta et al. 1987, Clinton 2011), and can stabilize banks, reducing erosion and improving water quality in EFH (Hicks et al. 1991, Beschta et al. 2000, Tabacchi et al. 2000). Loss and alteration of riparian habitats can disturb these functions, reducing the availability and functionality of EFH (Beechie et al. 1994; Lawrence et al. 2014). Land clearing and impervious surfaces eliminate or impair EFH by altering hydrology, increasing sedimentation and pollution, causing bank destabilization, increasing channelization, and reducing or eliminating floodplain interconnectivity (Allan 2004). Factors associated with land clearing and impervious surfaces can reduce fish production (Regetz 2003), alter fish assemblages (May et al. 1997, Wang et al. 2001), and decrease invertebrate abundance (Morley and Karr 2002).

LWD plays an important role in formation and availability of EFH (Bilby and Ward 1991, Abbe and Montgomery 1996, Beechie and Sibley 1997, McHenry et al. 1998, Roni and Quinn 2001), and helps control sediment and flow routing, nutrient cycling, and substrate habitat availability for algae and invertebrates (Bilby 1981, Bilby and Ward 1991, Montgomery et al. 1995, Young 2000, Coe et al. 2009, Clinton 2011, Hodson et al. 2014). Activities such as land clearing and development of impervious surfaces near freshwater and nearshore ecosystems can reduce the flux of wood into EFH, thereby impairing these important functions (Abbe and Montgomery 1996, Allan 2004, Coe et al. 2009). Reductions in riverine LWD recruitment can also result in less LWD in the nearshore. LWD in nearshore EFH could help moderate microhabitat temperatures and increase abundance of macroinvertebrates (Tonnes 2008).

Altered hydrology and geomorphology

Land clearing and construction of impervious surfaces can restrict important geomorphic and hydrologic processes (Poff et al. 2010) that influence channel migration and the creation or maintenance of alcoves, groundwater channels, and side channels. Loss of such habitat functionality and features can reduce the productivity of fish populations (Beechie et al. 1994). Land clearing and impervious surfaces alter the frequency and magnitude of peak flows and floods (Stover and Montgomery 2001, White and Greer 2006) by reducing absorption of floodwater laterally into the floodplain. Increased flood frequency and magnitude lead to further demand for flood-control projects, such as dams, dredging, or the building of dikes and levees (Rasmussen 1994). Such developments are costly, as they can compound the negative impacts of land clearing and impervious surfaces on EFH (Beechie et al. 2010), and impacts to EFH must be mitigated for.

Instream and riparian habitat morphology (Tabacchi et al. 1998) and survival of embryonic and larval life stages of fish (Cederholm and Reid 1987, DeVries 1997, Quinn 2005) can be affected by volume and timing of stream discharge. Presence of riparian vegetation influences hydrological processes by controlling runoff, increasing water uptake and storage, and improving water quality (Hicks et al. 1991, Tabacchi et al. 2000). Canopy interception and transpiration reduces the total volume of water infiltrating topsoil, reducing runoff during small storms (Bosch and Hewlett 1982, Rinaldi and Nardi 2013). During land-clearing activities, riparian forests are often removed, reducing or eliminating these functions (Allan 2004), and impervious infrastructure is often built, including roads, bridges, buildings, and parking lots. Increases in urban and residential land cover are correlated closely with decreases in forest cover (Gray et al. 2013), and impervious surfaces, such as parking lots and other infrastructure, can cover up to 100% of the land in urban areas (Whiley 2009).

Impervious surfaces affect hydrologic and geomorphic processes (Furniss et al. 1991) and lead to increased frequency and intensity of floods, erosion of streambeds, impacts to water quality, and displacement of sediments, impacting organisms inhabiting EFH (Allan 2004). CWP (2003) found that impervious surfaces associated with urbanization: a) caused increased runoff volume, peak discharge, and magnitude, frequency, and duration of bankfull flows; b) rendered flashier and less predictable flows; and c) decreased base flows. Hydrologic functioning can be significantly degraded when impervious surfaces cover 10% of the watershed (Arnold and Gibbons 1996, Paul and Meyer 2001), while impervious coverage ≥25% results in severe degradation of EFH (CWP 2003). Across a range of watersheds in the United States, Caldwell et al. (2012) found that the presence of impervious cover increased stream flows by about 10%. Impacts of impervious surfaces on hydrology and geomorphology may be most pronounced in urban areas because of the vast area of land covered by these surfaces (Konrad et al. 2005, White and Greer 2006).

Sedimentation, siltation, and turbidity

Land clearing and impervious surfaces increase the amount of fine sediments that are transported and deposited in downstream EFH, impacting fish and their prey (Wood and Armitage 1997, Kemp et al. 2011). Excessive transport or deposition of fine sediment fills interstitial spaces in spawning gravels (Bjornn and Reiser 1991), damages or clogs gill membranes of aquatic organisms, reduces benthic production, and decreases the area of available EFH (Wagener and LaPerriere 1985, Cederholm and Reid 1987, Hicks et al. 1991, Brown et al. 1998, Smith and Wegner 2001). Increased sedimentation can alter distribution (Culp et al. 1986), abundance, and composition of invertebrates (Waters 1995), and increased turbidity can impair predator avoidance of fish. Conversely, feeding may increase (Gregory 1993) while predation by piscivores could decrease (Gregory and Levings 1998) in moderately turbid water. It is important to note that the duration and timing of exposure to increased suspended sediments could significantly alter the degree of impact on invertebrates and fish inhabiting EFH (Newcombe and MacDonald 1991).

Release of contaminants

Runoff from impervious surfaces is the most widespread source of water pollution in the United States (USEPA 1995). Pollutants associated with land clearing and impervious surfaces include sediment from construction, oil and heavy metals from vehicles, road salts, bacteria from failing septic systems, and fertilizers, herbicides, and pesticides (Groefman et al. 2002, Walsh et al. 2005). The release of such chemicals affects water quality in EFH (Norris et al. 1991, Collier et al. 1998, Allan 2004) and physiology and survival of fish (Heintz et al. 2000, Sandahl et al. 2007). Use of fertilizers, herbicides, and pesticides, and spill or leaching of petroleum products, can harm EFH and food web processes (ASMFC 1992, Stehr et al. 2009, Macneale et al. 2010). While pesticides and herbicides currently in use may not be released at levels that are acutely harmful to fish (Lisker et al. 2011, King et al. 2013), they may have chronic or indirect effects that ultimately impact fish populations (Macneale et al. 2010). Moreover, those chemicals used in the past, such as dichlorodiphenyl trichloroethane (DDT), are highly deleterious and can persist in the environment for years after application (Gould et al. 1994). Petroleum-based products (e.g., fuel, oil, hydraulic fluids) are toxic to fish and their food webs, but toxicity depends on concentration, exposure time, and other stressors (e.g., Neff 1985). It is important to note that contaminant concentrations vary widely among land types with similar amounts of impervious surface coverage (Allan 2004).

Potential conservation measures for land clearing and impervious surfaces

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of land clearing and impervious surfaces on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. These guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of land clearing and impervious surfaces on EFH.

General guidelines

- Work with water trust organizations to acquire water rights or establish water banks.
- Implement 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.
- Focus resources on conservation and restoration of upland or urban habitats on private and public lands (Burnett et al. 2007).
- Implement widespread application of innovative approaches to drainage design (Walsh et al. 2005).

Loss and alteration of habitat

- Protect and restore vegetated buffer zones of appropriate width along streams, lakes, and wetlands that include or influence EFH (Wang et al. 2001).

Altered hydrology and geomorphology

- Remove obsolete impervious surfaces, such as abandoned parking lots and buildings, from riparian and shoreline areas, and reestablish water regime, wetlands, and native vegetation.
- Use pervious, not impervious, materials.

Sedimentation, siltation, and turbidity

- Implement best management practices (BMPs) for sediment control during construction and maintenance operations. 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 drainageways; and avoiding building activities in areas with steep slopes and areas prone to mass wasting events with highly erodible soils. Use of structural BMPs (e.g., sediment ponds, sediment traps, vegetated swales) or other facilities designed to slow water runoff and trap sediment and nutrients is recommended.

Release of contaminants

- Increase requirements or incentives for use of biofiltration features to prevent lethal stormwater impacts to fish (e.g., coho salmon). These must increasingly be installed along roads and road drainage systems (Spromberg et al. 2015). Possible features include permeable pavers, bioretention swales, silt fencing, impervious containment areas, stormwater wet ponds, rain gardens, and check dams, among others (WDOE 2012).
- Allow zero net increase in annual loading of stormwater pollutants into EFH (i.e., TSS, total and dissolved Cu and Zn). This can be accomplished by retrofitting approximately 3–4 times as much existing impervious surface (IS) as the proposed new IS. Pollutant concentrations below the biological effects thresholds:
    - Dissolved Cu: 2.0 µg/L (Sandahl et al. 2007) over background levels of 3.0 µg/L or less (Baldwin et al. 2003).
    - Dissolved Zn: 5.6 µg/L over background zinc concentrations between 3.0 µg/L and 13 µg/L (Sprague 1968).

  Zero net increase can be accomplished by infiltrating or dispersing the majority of the treated stormwater such that the volume and frequency of discharges affect only a few feet of in-water habitat in the vicinity of the point of discharge. This must be demonstrated via dilution analysis, utilizing flow and discharge assumptions that are conservative for listed fish.

Stormwater and Urban Runoff

Potential adverse impacts of stormwater and urban runoff

The following factors associated with stormwater and urban runoff can impact EFH and are described briefly below: altered hydrology and geomorphology, sedimentation, siltation, and turbidity, and release of contaminants. Suggested conservation measures related to each of these factors are provided in the following section.

Altered hydrology and geomorphology

The ecological integrity of flowing water systems depends largely on the dynamic character of the flow regime and subsequent geomorphic processes (Poff et al. 1997, Poff et al. 2010). Instream and riparian habitat morphology (Tabacchi et al. 1998), and survival of embryonic and larval life stages of fish (Cederholm and Reid 1987, DeVries 1997, Quinn 2005) can be affected by volume and timing of stream discharge. Stormwater and urban runoff are characterized by increased frequency and magnitude in peak flows (Furniss et al. 1991, Luchetti and Feurstenburg 1993, Allan 2004, White and Greer 2006), and in combination with habitat alterations (i.e., levees), lateral absorption of floodwater into the floodplain can be reduced, compounding the impacts of increased magnitude and frequency of flood events (Stover and Montgomery 2001). Such negative feedbacks lead to increased demand for costly flood-control projects (Rasmussen 1994), including dams, dredging, or the building of additional dikes and levees. These projects further compound the negative impacts of stormwater and urban runoff on EFH (Beechie et al. 2010), and these impacts must be mitigated for.

Presence of riparian vegetation influences hydrological processes by controlling runoff, increasing water uptake and storage, and improving water quality (Hicks et al. 1991, Tabacchi et al. 2000). Canopy interception and transpiration reduces the total volume of water infiltrating the topsoil, reducing runoff during small storms (Bosch and Hewlett 1982, Rinaldi and Nardi 2013). Increases in urban and residential land cover are correlated with decreases in forest cover (Gray et al. 2013) and increases in stormwater and urban runoff contributions to EFH (Allan 2004; Whiley 2009). Much urban and residential land is often covered by impervious surfaces; water flows along roads and other infrastructure, ultimately flowing into EFH. Hydrologic functioning can be significantly degraded when land is 10% covered by impervious material (Arnold and Gibbons 1996; Paul and Meyer 2001), and impervious coverage of 25% or more results in severe degradation of EFH (CWP 2003). Across a range of watersheds in the United States, Caldwell et al. (2012) found that the presence of impervious cover increased stream flows by about 10%. Impacts of impervious surfaces on hydrology and geomorphology may be most pronounced in urban areas because of the vast area of land covered by impervious surfaces (Konrad and Booth 2005, White and Greer 2006).

Sedimentation, siltation, and turbidity

Stormwater and urban runoff can cause increased sedimentation in EFH (Corbett et al. 1997). Excessive transport or deposition of fine sediment can fill interstitial spaces in spawning gravels (Bjornn and Reiser 1991), damage or clog gill membranes of aquatic organisms, reduce benthic production, and decrease the area of available EFH

(Wagener and LaPerriere 1985, Cederholm and Reid 1987, Hicks et al. 1991, Brown et al. 1998, Smith and Wegner 2001, Suttle et al. 2004). Increased sedimentation can alter distribution (Culp et al. 1986), abundance, and composition of invertebrates (Waters 1995); impact fish emergence, juvenile densities, and winter carrying capacity; and increase predation on fish (Koski 1981, Chapman 1988, Scrivener and Brownlee 1989, Young et al. 1991). Increased turbidity can impair predator avoidance of fish; however, feeding may increase (Gregory 1993) while predation by piscivores could decrease in moderately turbid water (Gregory and Levings 1998). It is important to note that the duration and timing of exposure to increased suspended sediments could significantly alter the degree of impact on fish inhabiting EFH (Newcombe and MacDonald 1991).

Release of contaminants

Contaminants flow into EFH during rainfall and storm events through runoff and stormwater systems (Schueler et al. 2009; for more complete review see Foster et al. 2014). Pavement and many paving compounds used in road construction and surfacing contain high levels of polycyclic aromatic hydrocarbons, which can be toxic to aquatic life, that can persist in the environment for decades. Friction between road and tire causes surface erosion that releases asphalt, rubber material, automotive fluids and fuel, and metals from brake linings, which concentrate on or near road surfaces and are eventually flushed into stream and marine EFH (Grosenheider 2005, Simon and Sobieraj 2006, Weiss et al. 2008, Tian et al. 2021). Other pollutants commonly found in stormwater and urban runoff can impact water chemistry, and include sediment from construction, oil and metals from vehicles, road salts, bacteria from failing septic systems, and fertilizers, herbicides, and pesticides (Neff 1985, Groefman et al. 2002, Walsh et al. 2005, Sandahl et al. 2007).

The release of such chemicals impacts water quality in EFH (Norris et al. 1991, Collier et al. 1998, Allan 2004, Grosenheider 2005), impairing physiology and survival of aquatic organisms (Dethloff et al. 2001, Meador et al. 2010, Feist et al. 2011, Scholz et al. 2011) and altering food webs (ASMFC 1992, USEPA 2005, Sandahl et al. 2007, Stehr et al. 2009, Macneale et al. 2010). Stormwater and urban runoff contamination can lead to reduced primary production (Johnston et al. 2014) and alteration of cellular function and biochemical mechanisms (Poston 2001, Sethajintanin et al. 2004, Meador et al. 2010, Scholz et al. 2011, Jenkins et al. 2014, Melwani et al. 2014). For example, copper found in auto brake pads disrupts neurotoxic and olfactory receptors that control homing, predator avoidance, and spawning behavior in fish (Baldwin et al. 2011, McIntyre et al. 2012, Sovová et al. 2014).

Potential conservation measures for stormwater and urban runoff

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of stormwater and urban runoff on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. These guidelines represent a short menu of actions that could help land managers avoid, minimize, and mitigate impacts of stormwater and urban runoff on EFH.

General guidelines

- Work with water trust organizations to acquire water rights or establish water banks.
- Incentivize allocation of resources to conservation and restoration of upland or urban habitats on private and public lands (Burnett et al. 2007).
- Implement widespread application of innovative approaches to drainage design (Walsh et al. 2005).

Altered hydrology and geomorphology

- Monitor water-quality discharges following National Pollutant Discharge Elimination System requirements from all discharge points (including municipal stormwater systems, desalinization plants, and irrigation ditches).
- 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 law.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.

Release of contaminants

- Bioinfiltration features prevent lethal stormwater impacts to fish (e.g., coho salmon), and should be installed along roads and road drainage systems (Spromberg et al. 2015). Possible features include permeable pavers, bioretention swales, silt fencing, impervious containment areas, stormwater wetponds, raingardens, and check dams, among others (WDOE 2012).
- Allow zero net increase in annual loading of stormwater pollutants into EFH (i.e., TSS, total and dissolved Cu and Zn). This can be accomplished by retrofitting approximately 3 to 4 times as much existing impervious surface (IS) as the proposed new IS. Pollutant concentrations below the biological effects thresholds:
    - Dissolved Cu: 2.0 µg/L (Sandahl et al. 2007) over background levels of 3.0 µg/L or less (Baldwin et al. 2003).
    - Dissolved Zn: 5.6 µg/L over background zinc concentrations between 3.0 µg/L and 13 µg/L (Sprague 1968).

  This can be accomplished by infiltrating or dispersing the majority of the treated stormwater such that the volume and frequency of discharges affect only a few feet of in-water habitat in the vicinity of the point of discharge. This must be demonstrated via dilution analysis, utilizing flow and discharge assumptions that are conservative for listed fish.
- Implement management measures developed for controlling pollution from runoff in coastal areas to all watersheds affecting salmon EFH.
- Establish total maximum daily loads and develop appropriate management plans to attain management goals.
- Allocate increasing amounts of resources to complete existing and future total maximum daily loads (TMDLs) established on waterbodies designated as water quality-limited in EFH habitat.
- Establish and update pollution prevention plans, spill control practices, and spill control equipment for the handling or transporting of toxic substances in EFH. Consider bonds or other damage compensation mechanisms to cover clean-up, restoration, and mitigation costs.
- Actively reduce the size of mixing zones that discharge to coastal areas and watersheds.

- Utilize biological effects thresholds (e.g., those recently established for dissolved copper) for transportation facilities that discharge to EFH habitat.
- Design and install proper wastewater treatment systems. Locate them away from open waters, wetlands, and floodplains.
- 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.
- Where vegetated swales are not feasible, install oil/water separators to treat runoff from impervious surfaces in areas adjacent to EFH. Ensure that oil/water separators are regularly maintained such that they do not become clogged and function properly on a continuing basis.

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3. Road Construction and Operation

Potential Adverse Impacts of Road Construction and Operation

The following factors associated with road construction and operation can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, sedimentation, siltation, and turbidity, release of contaminants, invasive organisms, impaired fish passage, and increased mass wasting. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Roads built alongside streams can prevent channel migration (Furniss et al. 1991), reducing important channel features and habitat connectivity (Niering 1988, Mitsch and Gosselink 1993, Pechenick et al. 2014). Roads located in the floodplain can reduce or eliminate connectivity to floodplain habitats, such as alcoves and groundwater channels (Rapp and Abbe 2003), and removal of vegetation for road construction can lead to increased sediment inputs and water temperatures, reducing the suitability of EFH (Beschta et al. 1987, Hicks et al. 1991). Furthermore, roads near stream channels are often armored to prevent road damage by bank erosion and channel migration, resulting in loss of important habitat-forming features such as large woody debris (LWD; Latterell et al. 2006) and the homogenization of otherwise heterogeneous EFH used by rearing and migrating fish (Li and Eddleman 2002).

Roads and crossings impair longitudinal and lateral connectivity, resulting in the isolation and decline of floodplain habitat and fish populations (Perkin et al. 2013). Poorly designed or improperly installed culverts degrade EFH (Evans and Johnston 1980, Belford and Gould 1989, Clancy and Reichmuth 1990, Furniss et al. 1991). For example, culverts can trap sediment and LWD that would otherwise enhance downstream habitat processes and diversity (Ralph et al. 1994, Abbe and Montgomery 1996, Spence et al. 1996) and provide structure for lower-trophic organisms such as algae, bacteria, fungi, and invertebrates (Coe et al. 2009). Reduction of LWD inputs to estuaries, as a result of coastal road crossings, also reduces habitat for brackish or marine microorganisms, invertebrates, and fish (Tonnes 2008), and fragments watersheds by restricting the movement of organisms and matter between freshwater and marine ecosystems.

Altered hydrology and geomorphology

Roads can constrain floodplains and create impervious or semipervious surfaces that intercept rainfall, reduce water storage capacity, concentrate flows, and divert or reroute water from original flow paths (Furniss et al. 1991, Wickham et al. 2014). Such alterations can impact hydrologic (McKay et al. 2013) and geomorphologic regimes (Jones 2000) by destabilizing stream channels, altering runoff (Konrad and Booth 2005), and increasing the frequency and magnitude of flooding (NRC 1996, Spence et al. 1996). Adams and Ringer (1994) demonstrated a strong correlation between peak discharge and road coverage. Even road coverage densities as low as 4% of the drainage surface area can significantly alter hydrologic processes (King and Tennyson 1984). Increased cover of impervious surfaces and associated changes in hydrology are associated with reduction in fish diversity via the loss of sensitive species and replacement by tolerant species (Wenger et al. 2008).

Road crossings, such as bridges and culverts, can also alter stream hydrologic and geomorphic processes (Trombulak and Frissell 2000, Konrad 2003). For example, structures trap wood and sediment on the upstream side, while increasing erosion on the downstream side through downcutting (Castro 2003). Furthermore, undersized culverts increase water velocity, scouring, and erosion in downstream EFH (Vaughan 2002).

Sedimentation, siltation, and turbidity

Streams, estuaries, and other EFH (e.g., riparian areas) located near roads may experience increased surface erosion and sedimentation (Beechie et al. 2008, Beechie et al. 2010). Semi- or unpaved roads can significantly increase surface erosion (Cederholm and Reid 1987, Bilby et al. 1989, MacDonald et al. 2001), which can result in increased transport and deposition of sediments to streams affecting rearing and spawning habitat for stream- and estuarine-associated salmonids (Bilby et al. 1989, MacDonald et al. 2001, Ziegler et al. 2011). Furniss et al. (1991) found that roads contributed more sediment than all other forest activities combined on a per-area basis. Roads also increase sedimentation over the long term as, over time, the surface breaks down into fine sediments that flow into EFH (Murphy 1995).

Excessive transport or deposition of fine sediment can fill interstitial spaces in spawning gravels (Bjornn and Reiser 1991), damage or clog gill membranes of aquatic organisms, reduce benthic production, and reduce growth and survival of juvenile salmon (Suttle et al. 2004), resulting in a decrease in the quality and area of available EFH (Cederholm and Reid 1987, Hicks et al. 1991, Smith and Wegner 2001). Increased sedimentation can alter distribution (Culp et al. 1986), abundance, and composition of invertebrates (Waters 1995, Suttle et al. 2004), and increased turbidity can impair foraging ability and predator avoidance. Conversely, feeding may increase (Gregory 1993) while predation by piscivores could decrease (Gregory and Levings 1998) in moderately turbid water. It is important to note that the duration and timing of exposure to increased suspended sediments could significantly alter the degree of impact on fish inhabiting EFH (Newcombe and MacDonald 1991).

Release of contaminants

Runoff from impervious surfaces such as roads is the most widespread source of water pollution in the United States (USEPA 1995). Pollutants from roads and impervious surfaces include sediment from eroding surface material, oil and heavy metals from vehicles, road salts, herbicides, and pesticides (Furniss et al. 1991, Groefman et al. 2002, Walsh et al. 2005, Cooper et al. 2014, Hintz and Reylea 2017). Road surfacing compounds such as asphalt, bitumen, pavement sealing, and repair products contain high levels of polycyclic aromatic hydrocarbons (PAHs; Grosenheider 2005, Mahler et al. 2005, Teaf 2008). PAHs and metals are toxic to aquatic species such as fish and invertebrate populations (Rand 1995, Logan 2007), and accumulate in nearshore and marine food webs (Kennish 1997, Johnson 2002, Kennish 2001). The friction between road and tire surfaces erodes and releases asphalt, rubber material, and associated chemical compounds, and automotive fluids and brake lining metals concentrate on or near road surfaces and flow into EFH, leading to fish mortality, especially during high precipitation events following a prolonged dry period (Grosenheider 2005, Simon and Sobieraj 2006, Weiss et al. 2008, Feist et al. 2017). The release of such chemicals affect water quality in EFH (Collier et al. 1998, Allan 2004), and physiology and survival of fish (Sandahl et al. 2007). Use of herbicides and pesticides, and spill or leaching of petroleum products, can kill species directly, in addition to altering food web processes that support trust resources (ASMFC 1992, Stehr et al. 2009, Macneale et al. 2010). Petroleum-based products (e.g., fuel, oil, hydraulic fluids) are toxic to invertebrates and fish, but toxicity depends on concentration and exposure time (Neff 1985).

Invasive organisms

Roads are dispersal corridors for invasive species, and invasive species are sometimes planted along roadsides for erosion control (Trombulak and Frissell 2000). For example, roads can be the first point of entry for invasive, opportunistic plant or invertebrate species (e.g., the New Zealand mud snail; Davidson et al. 2008) that are seeded along road cuts or introduced from propagules transported by boats, tires, and shoes (Lonsdale and Lane 1994, Greenberg et al. 1997, Johnson et al. 2001, Davidson et al. 2008). Invasive plants and invertebrates may spread away from introduction sites, where they may out-compete native species and alter the structure and function of aquatic and riparian EFH (Trombulak and Frissell 2000, Zedler and Kercher 2004, Mortensen et al. 2009, Urgenson et al. 2009).

Impaired fish passage

Connectivity of complex EFH is critical to migratory fish (Fagan 2002, Hoffman and Dunham 2007), and inadequate road crossing structures can impair this connectivity (Pess et al. 2005, Sheer and Steel 2006).

Poorly designed or improperly installed or maintained crossing structures can impact EFH by blocking fish access to important spawning and rearing habitats and constraining the downstream movement of important habitat-forming materials (Evans and Johnston 1980, Belford and Gould 1989, Furniss et al. 1991, Eaglin and Hubert 1993, Taylor 2000, NMFS 2001, Castro 2003, Kiffney et al. 2009, McKay et al. 2013, Khodier and Tullis 2014). Blockage of fish migrations can also have negative impacts on aquatic and riparian EFH by reducing the exchange of ecologically important organic matter delivered by spawning adult salmon (Roni et al. 2002, Davis and Davis 2011, Kiffney et al. 2014, Morley et al. 2016).

The impacts of road crossing structures vary with the fish species, life stage, and phenotype, as some individuals may be better adapted to move upstream through hydrological obstructions, such as culverts and other types of road obstructions, than other species (e.g., pink salmon) and smaller individuals (Davis and Davis 2011, Peterson et al. 2013, Miyoshi et al. 2014). Smaller juveniles of some species can be blocked from moving upstream into EFH used for seasonal rearing (Peterson 1980, Davis and Davis 2011), reducing the productive capacity of EFH by nearly 60% in some studies (Beechie et al. 1994, Roni et al. 2002, Pess et al. 2003), and potentially limiting upstream spatial expansion of recolonizing salmonids (Anderson et al. 2013).

Increased surface erosion and mass wasting

Surface erosion and mass wasting can be exacerbated by road construction (Brardinoni et al. 2002). Roads built on steep or unstable slopes can increase the occurrence of mass wasting events (Furniss et al. 1991). Slopes can become unstable when tree roots are removed near roads

(Sidle et al. 1985, Montgomery et al. 1998, Montgomery et al. 2000, Sidle 2005). Diversion of subsurface flow paths can increase pore pressure on steep slopes (Dutton et al. 2005). Landslides can also occur as a result of debris dams that block the upstream side of culverts (Sidle et al. 1985). The sudden increase in sediment load following a mass wasting event degrades salmon spawning and rearing habitats (Cederholm and Reid 1987, Hicks et al. 1991, Smith and Wegner 2001), and could have adverse impacts on fish physiology (Cederholm and Reid 1987, Bilby et al. 1989). Deep pools and other important habitat features that provide refuge may be filled or removed following such mass wasting events (Hicks et al. 1991). Climate change is predicted to change disturbance regimes, including increasing the abundance, frequency, and intensity of mass wasting events (Davis et al. 2013, Knapp 2018).

Increased surface erosion and mass wasting events can severely impact water quality in EFH (Anderson and Potts 1987, Cederholm and Reid 1987, Platts et al. 1989, Hicks et al. 1991, Reid 1993, Montgomery et al. 1998, Dhakal and Sidle 2004, Kreutzweiser et al. 2005). Mass wasting can increase the delivery of fine sediment loading in EFH, which can increase turbidity, decrease volume of EFH and delivery of dissolved oxygen, and alter behavior of invertebrates, causing reduced feeding, growth, and survival of juvenile salmonids (Hicks et al. 1991, Barrett et al. 1992, Smith and Wegner 2001, Suttle et al. 2004, Klein et al. 2011). Reduction of dissolved oxygen delivery to developing embryos and larval fish can lead to premature hatching, reduced size at emergence, and reduced viability (Chapman 1988, Hicks et al. 1991, DeVries 1997, Quinn 2005). In juvenile and adult fishes, suspended sediments can abrade or clog gill membranes (Bilby et al. 1989, Cederholm and Reid 1987).

Potential Conservation Measures for Road Construction and Operation

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of road construction and operation on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of road construction and operation on EFH.

General guidelines

- Plan and design roads to minimize damage to, and loss of, EFH (Newman et al. 2012).
- Use seasonal work 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.
- Properly maintain roadway ditches and associated stormwater collection systems.
- Address the cumulative impacts of past, present and foreseeable future

development activities on aquatic habitats by considering them in the review process for road construction projects.

- Plan road and infrastructure development within the context of climate change.
- Provide estimates for how development will impact stream hydrology (e.g., magnitude and frequency of floods).
- Conduct road maintenance using practices according to the requirements of existing NMFS rules—e.g., the July 2000 ESA 4(d) rule (Protective Regulations) for listed west coast salmon and steelhead (USOFR 2000; 10 July 2000), Limit 10, covering road maintenance. Implementing maintenance under these programs avoids exacerbating existing impacts, and protects EFH to the extent that it contributes to conserving species.

Loss and alteration of habitat

- Design bridge abutments to minimize disturbances to EFH, and place abutments outside of the current and predicted floodplain habitat when built in streams and rivers.
- Reduce and eliminate riparian corridor damage during construction of roads (and bridges, culverts, and other crossings), and avoid locating roads in floodplains or wetlands.
- Mitigate on-site for all losses in aquatic EFH and the surrounding riparian zone.
- Ensure road crossings allow for the free movement of organisms, sediment, and water.

Altered hydrology and geomorphology

- Design roadways to minimize the length of inboard ditches.
- Outslope roads for drainage, or use frequent rolling dips, waterbars, or ditch relief culverts so they do not concentrate flows and cause erosion.
- Use pipe extenders to bring flows from ditch relief culverts to grade before discharge; use T-spreaders to diffuse flows at the discharge points, or energy dissipaters to slow the initial flows at the discharge points.

Sedimentation, siltation, and turbidity

- Specify erosion control measures in road construction plans.
- Do not side-cast road materials into streams or places where they may make their way to aquatic habitats.
- Limit roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats. Snowmelt 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.
- Revegetate cut banks, road fills, bare shoulders, disturbed streambanks, etc., after construction to prevent erosion and increase nutrient assimilation and adsorption. Check and maintain sediment control and retention structures throughout the rainy season.

Release of contaminants

- Biofiltration features prevent lethal stormwater impacts to fish (e.g., coho salmon), and must be installed along roads and road drainage systems (Spromberg et al. 2015). Possible features include permeable pavers, bioretention swales, silt fencing, impervious containment areas, stormwater wetponds, rain gardens, and check dams, among others (WDOE 2012).
- Limit roadway sanding and the use of deicing chemicals during the winter

to minimize sedimentation and introduction of contaminants into nearby aquatic habitats. Snowmelt 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.

Invasive organisms

- Use only native vegetation in replantings.
- When necessary, implement invasive species monitoring to ensure road-construction activities do not accidentally introduce an invasive species. For example, if the activity involves construction activities in the water, control measures—such as placing the equipment in a freezer for 24 hr before using, or sterilizing with dilute bleach (Schisler et al. 2008)—should be taken, to prevent the spread of an invasive species attached to a boot or wader.

Impaired fish passage

- Design all road crossings for ecological connectivity, including the movement of water, sediment, organisms, and organic matter, and interactions with the riparian environment, while also accounting for anticipated changes in land use and hydrology resulting from climate change.
- Instead of utilizing culverts, build bridges for crossing aquatic environments.
- If culverts must be used, they must be sized, constructed, and maintained to match the gradient, flow characteristics, and width of the stream, so as to accommodate both current and future flood events.
- All new road crossing structures must accommodate future increased flows and changes in the disturbance regime. Climate change will alter hydraulic flow regimes (e.g., larger and more frequent high-flow events), with corresponding changes in the location, frequency, and size of debris flows; these changes will vary regionally with climate, vegetation, geology, and land use.
- Consult NMFS guidelines for stream crossings (NMFS 2001).
- Use state or federal culvert design guidelines for improved design and installations of culverts (e.g., NMFS 2001; Bates et al. 2003; Barnard et al. 2014; Gillespie et al. 2014). At a minimum, culvert diameter should be at least as wide as bankfull width (Nislow 2014).

Increased surface erosion and mass wasting

- Implement compaction techniques to reduce erosion (FAO 1998).
- Site roads to avoid sensitive areas such as riparian areas, streams, wetlands, and steep slopes.
- Abandon and remove road crossings when other existing road crossings are available, and on decommissioned roads.

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4. Stormwater and Urban Runoff

Potential Adverse Impacts of Stormwater and Urban Runoff

The following factors associated with stormwater and urban runoff can impact EFH and are described briefly below: altered hydrology and geomorphology, sedimentation, siltation, and turbidity, and release of contaminants. Suggested conservation measures related to each of these factors are provided in the following section.

Altered hydrology and geomorphology

The ecological integrity of flowing water systems depends largely on the dynamic character of flow regime and subsequent geomorphic processes (Poff et al. 1997, Poff et al. 2010). Instream and riparian habitat morphology (Tabacchi et al. 1998), survival of embryonic and larval life stages of fish (Cederholm and Reid 1987, DeVries 1997, Quinn 2005) can be heavily affected by volume and timing of stream discharge. Urbanization can modify the natural flow regime, increasing the frequency and magnitude of peak flows (Furniss et al. 1991, Luchetti and Feurstenburg 1993, CWP 2003, Allan 2004, White and Greer 2006). In combination with habitat alterations (i.e., levees, roads, increased impervious surfaces), lateral absorption of floodwater into the floodplain can be reduced, compounding the impacts of increased magnitude and frequency of flood events (Stover and Montgomery 2001, Lane 2008) and cutting off an important seasonal EFH for some managed salmonid species. Such negative feedbacks lead to increased demand for costly flood control projects (e.g., dams, dredging, or the building of additional dikes and levees; Rasmussen 1994), further compounding the negative impacts of stormwater and urban runoff on EFH (Beechie et al. 2010), impacts that require mitigation and conservation measures.

Presence of riparian vegetation influences hydrological processes by controlling runoff, increasing water uptake and storage, and maintaining water quality (Hicks et al. 1991, Tabacchi et al. 2000). Canopy interception and transpiration reduces the total volume of water infiltrating the topsoil, reducing runoff during small storms (Bosch and Hewlett 1982, Rinaldi and Nardi 2013). However, increases in urban and residential development remove or alter upland forest ecosystems (Gray et al. 2013), contributing to increases in contributions of stormwater and urban runoff to EFH (Allan 2004, Whiley 2009). Much of urban and residential land is often covered by impervious surfaces; water flows along roads and other infrastructure and ultimately into EFH, where it affects ecosystem structure and function. Hydrologic functioning can be significantly degraded when land is 10% covered by impervious material (Arnold and Gibbons 1996, Paul and Meyer 2001), and impervious coverage of 25% or more resulted in severe degradation of EFH (CWP 2003). Across a range of watersheds in the United States, Caldwell et al. (2012) found that the presence of impervious cover increased stream flows by about 10%. Impacts of impervious surfaces on hydrology and geomorphology may be most pronounced in urban areas because of the vast area of land covered by impervious surfaces (Konrad et al. 2005, White and Greer 2006).

Sedimentation, siltation, and turbidity

Stormwater and urban runoff can cause increased sedimentation in EFH (Corbett et al. 1997, Wood and Armitage 1997). Excessive transport or deposition of fine sediment can fill interstitial spaces in spawning gravels (Bjornn and Reiser 1991), damage or clog gill membranes of aquatic organisms, reduce benthic production, and decrease the area of available EFH (Wagener and LaPerriere 1985, Cederholm and Reid 1987, Hicks et al. 1991, Brown et al. 1998, Smith and Wegner 2001, Suttle et al. 2004). Increased sedimentation can alter distribution (Culp et al. 1986), abundance, and composition of invertebrates (Waters 1995); impact fish emergence, juvenile densities, and winter carrying capacity; and increase predation on fish (Koski 1981, Chapman 1988, Scrivener and Brownlee 1989, Young et al. 1991). Increased turbidity can impair predator avoidance by prey fish. It is important to note that the duration and timing of exposure to increased suspended sediments could significantly alter the degree of impact on fish inhabiting EFH (Newcombe and MacDonald 1991).

Release of contaminants

Contaminants flow into EFH during rainfall and storm events through runoff and stormwater systems (Schueler et al. 2009; for more complete review, see Foster et al. 2014). Road surfaces may contain high levels of polycyclic aromatic hydrocarbons, which can be toxic to aquatic life and that can persist in the environment for decades. Road usage releases asphalt, rubber material, automotive fluids and fuel, and metals from brake linings that concentrate on or near road surfaces and are eventually flushed into streams and marine EFH (Grosenheider et al. 2005, Simon and Sobieraj 2006, Weiss et al. 2008, Feist et al. 2017). Other pollutants commonly found in stormwater and urban runoff can impact water chemistry, and include estrogens, sediment from construction, oil and metals from vehicles, road salts, bacteria from failing septic systems or animal waste, and fertilizers, herbicides, and pesticides (Neff 1985, Groefman et al. 2002, Atkinson et al. 2003, Walsh et al. 2005, Sandahl et al. 2007, Johnson et al. 2008, Laetz et al. 2009).

The release of such chemicals impacts water quality in EFH (Collier et al. 1998, Allan 2004, Grosenheider et al. 2005), often impairing physiology and survival of aquatic organisms (Dethloff et al. 2001, Meador et al. 2010, Feist et al. 2011, Scholz et al. 2011, Feist et al. 2017) and altering food webs (USEPA 2005, Sandahl et al. 2007, Macneale et al. 2010). Stormwater and urban runoff contamination can lead to reduced primary production (Johnston et al. 2014) and alteration of cellular function and biochemical mechanisms (Poston 2001, Sethajintanin et al. 2004, Meador et al. 2010, Scholz et al. 2011, Jenkins et al. 2014, Melwani et al. 2014). For example, copper found in auto brake pads disrupts neurotoxic and olfactory receptors that control homing, predator avoidance, and spawning behavior in fish (Baldwin et al. 2011, McIntyre et al. 2012, Sovová et al. 2014). Coho salmon are particularly sensitive to chemical impacts to stormwater runoff and have been shown to die within hours of a large runoff event (Chow et al. 2019).

Potential Conservation Measures for Stormwater and Urban Runoff

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of stormwater and urban runoff on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help land managers avoid, minimize, and mitigate impacts of stormwater and urban runoff on EFH.

General guidelines

- Focus resources on conservation and restoration of upland habitats on private and public lands (Burnett et al. 2007).
- Remediate stormwater impacts through widespread application of innovative approaches to drainage design (Walsh et al. 2005, McIntyre et al. 2015).
- Size stormwater BMPs to capture all first flush flows for treatment (e.g., infiltration) and to be able to handle a set size of storm (e.g., 2-year storm). For example, see fact sheet in San Francisco Bay Region's Municipal Regional Stormwater NPDES Permit guide.[3]

Altered hydrology and geomorphology

- Decrease hydromodification by requiring infiltration of stormwater in all new developments and redevelopments. Where infiltration is no longer possible, detain runoff and release it in a manner that mimics the natural hydrograph.
- Monitor water quality discharges following National Pollutant Discharge Elimination System requirements from all discharge points (including municipal stormwater systems, desalinization plants, and irrigation ditches).
- 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.
- Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.

Sedimentation, siltation, and turbidity

- Maintain or increase riparian vegetation to reduce stream bank failures and filter overland flows.
- Increase use of infiltration or detention BMPs throughout the watershed to reduce peak flows that cause erosion, and to capture sediments before delivery to the stream network.
- Develop and enforce construction and stormwater permits that require minimization of sediment discharges.
- See state stormwater BMP manuals (CA Stormwater Quality Association, WA State Department of Ecology) for numerous other BMP possibilities.

Release of contaminants

- Implement bioinfiltration features to prevent lethal stormwater impacts to fish. These should always be installed along roads and road drainage systems (Spromberg et al. 2015). Possible features include permeable pavers,

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[3] https://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/phase1r2_2009_0074

bioretention swales, impervious containment areas, stormwater wetponds, and rain gardens, among others (McIntyre et al. 2015).
- Apply the management measures developed for controlling pollution from runoff in coastal areas to freshwater EFH.
- For those waterbodies that are defined as water quality-limited (303(d) list),[4] establish total maximum daily loads and develop appropriate management plans to attain management goals.
- Require increased allocation of resources to complete existing and future TMDLs established on waterbodies designated as water quality-limited in EFH habitat.
- Establish and update pollution prevention plans, spill control practices, and spill control equipment for the handling or transporting of toxic substances in EFH. Consider bonds or other damage compensation mechanisms to cover clean-up, restoration, and mitigation costs.
- Reduce the size of mixing zones that discharge to coastal areas and watersheds.
- Utilize biological effects thresholds (e.g., those recently established for dissolved copper) for transportation facilities that discharge to EFH habitat.
- Require use of best available science and 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 or other low maintenance infrastructure is not feasible, install oil–water separators or other commercial systems to treat runoff from impervious surfaces in areas adjacent to EFH. Ensure that oil–water separators are regularly maintained to prevent clogs and ensure that they function properly on a continuing basis.

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[4] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d

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5. Silviculture

Potential Adverse Impacts of Silviculture

The following factors associated with silviculture (hereafter referred to as timber harvest) can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology, release of contaminants, impacts to water quality and food webs, impaired fish passage, and increased surface erosion and mass wasting. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Riparian habitats contribute to the formation and diversity of aquatic EFH (Bilby and Ward 1991, Chamberlin et al. 1991, Abbe and Montgomery 1996, Naiman et al. 1998, Romanuk and Levings 2006), buffer water temperatures (Beschta et al. 1987, Clinton 2011), regulate organic matter dynamics—including terrestrial invertebrate inputs—and can stabilize banks, reducing erosion and improving water quality (Hicks et al. 1991, Beschta et al. 2000, Tabacchi et al. 2000, Saunders and Fausch 2007). Timber harvest in riparian habitats can disturb these functions, reducing the quality and quantity of aquatic EFH (Cederholm and Reid 1987, Beechie et al. 1994, Lawrence et al. 2014) and contributing to reduction in fish biomass (Frazey and Wilzbach 2007). Large woody debris (LWD) also plays an important role in formation, availability, and quality of EFH (Abbe and Montgomery 1996, Beechie and Sibley 1997, McHenry et al. 1998, Solazzi et al. 2000, Roni and Quinn 2001) by controlling nutrient cycling and sediment and flow routing, and by serving as a substrate for productive biofilm and invertebrate assemblages (Bilby 1981, Montgomery et al. 1995, Young 2000, Clinton 2011, Coe et al. 2009, Hodson et al. 2014). These land use changes on stream EFH can last decades (Harding et al. 1998). Timber harvest near freshwater and nearshore ecosystems can reduce the inputs of terrestrial organic matter, including LWD, into EFH, impairing these functions (Andrus et al. 1988, Bilby and Ward 1991, Abbe and Montgomery 1996, Coe et al. 2009). Reductions in riverine-associated LWD recruitment can also result in reduced transport of LWD to nearshore EFH, where it would otherwise provide wildlife habitat and help moderate temperatures for macroinvertebrates (Tonnes 2008). Riparian buffers (areas protected from forest harvest) of at least 30 m width on both stream banks limit changes in key processes such as thermal loading and organic matter flux (Kiffney et al. 2003, Gomi et al. 2006, Kiffney and Richardson 2010).

Food web alterations

Riparian vegetation shades streams, limiting solar inputs, and provides important nutrient and organic matter inputs to streams, such as leaf litter (Cummins 1973) and terrestrial invertebrates that drop into the streams (i.e., allochthonous food subsidies). Leaf litter provides a key energy source, along with stream algal and bacterial assemblages, for aquatic macroinvertebrate communities that are part of the fundamental food source for stream salmonids (Bretscko and Moser 1993). Broadleaf, deciduous trees, such as alder, cottonwood, and willow, are one of the most important sources of leaf inputs to lower-order streams in some regions of Pacific salmon, while litter inputs from coniferous-dominated forests dominate in other regions (Harmon et al. 1986, Meehan 1991, Kiffney and Richardson 2010). This difference in vegetation composition is largely driven by precipitation, temperature, disturbance regime, and soils. Rapidly decomposing hardwood leaves and slower-decomposing evergreen needles provide important sources of nitrogen and other elements that support primary and bacterial productivity. Juvenile salmonids, particularly coho salmon and steelhead, depend on terrestrial insects as an important component of their diets, and all juvenile salmonids depend upon the food base that leaf litter provides for production of aquatic macroinvertebrates. In general, terrestrial invertebrates can comprise >33–50% of juvenile salmon diets (Allan 2003).

Timber harvest near streams increases solar inputs, which leads to a variety of changes, including increased water temperature and rates of algal and bacterial productivity (e.g., Kiffney et al. 2003). These changes can lead to short-term increases in food availability for stream salmonids, which can translate into higher fish growth rates if water temperatures or fine sediments do not exceed stressful levels (Bilby and Bisson 1992). However, growth conditions can shift once riparian trees grow tall enough to shade the stream, leading to reductions in primary and secondary productivity and salmonid biomass (Kaylor and Warren 2018). These reductions can last a decade or more depending on the forest regrowth (Warren et al. 2016).

Altered hydrology and geomorphology

The volume and timing of stream discharge can influence both instream and riparian habitat morphology (Tabacchi et al. 1998) and survival of embryonic and larval life stages of fish (Cederholm and Reid 1987, DeVries 1997, Quinn 2005). The presence and composition of riparian vegetation influences hydrological processes by reducing runoff, increasing water uptake and storage, and improving water quality (Bosch and Hewlett 1982, Hicks et al. 1991, Tabacchi et al. 2000, Jones and Post 2004, Rinaldi and Nardi 2013). Timber harvest may impact these processes, leading to reduced or excessive peaks in stream flow (Harr et al. 1975, Harr 1976, Hetherington 1982, Duncan 1986, Harr 1986, Keppler and Zeimer 1990). Roads associated with timber harvest could exacerbate peak flows (e.g., Bosch and Hewlett 1982), as water is routed rapidly through road and ditch networks in headwaters where it can capture fine sediments that are transported downstream into spawning and rearing EFH (Harr et al. 1975, Jones and Grant 1996).

The amount of timber harvested (Bosch and Hewlett 1982, Keppler and Zeimer 1990, Beschta et al. 2000) and soil disturbance from timber harvest activities within a particular watershed (Johnson and Beschta 1980, Jones and Grant 1996) could alter the frequency and magnitude of peak flows. However, the ratio of area harvested to impacts on stream flows has varied among study areas (Bosch and Hewlett 1982, Stednick and Kern 1992, Stednick 1996) due to a variety of local factors and the proportion of watershed harvested. Nonetheless, flow regimes in small stream basins are generally more vulnerable to timber harvest than are larger stream basins (Bosch and Hewlett 1982).

Release of contaminants

Chemicals used during timber harvest can impact water quality in EFH (Norris et al. 1991). Use of fertilizers, herbicides, and pesticides, and accidental spill or leaching of petroleum products can harm EFH and food web processes (ASMFC 1992, Stehr et al. 2009, Macneale et al. 2010).

While pesticides and herbicides may not be released at levels that are acutely harmful to fish (Lisker et al. 2011, King et al. 2013), those used in the past, such as dichlorodiphenyl trichloroethane (DDT), are highly deleterious and can persist in the environment for years after application (Gould et al. 1994). Petroleum-based products (e.g., fuel, oil, hydraulic fluids) are toxic to aquatic life, including fish, but toxicity depends on concentration and exposure time (Neff 1985). Nonetheless, exposure to oil can reduce growth and survival in salmonids (Heintz et al. 2000).

Impacts to water quality

The removal or disturbance of riparian vegetation that results from timber harvest activity can reduce streamside shading and cause increases in water temperatures that could be detrimental to stream-rearing salmonids (Brown and Krygier 1970, Beschta et al. 1987, Johnson and Jones 2000, Kiffney et al. 2003, Webb et al. 2008, Clinton 2011). Loss of shading may be most important in smaller channels (i.e., headwaters, side channels, floodplain channels), because in smaller channels streamside vegetation can more easily shade the entire area of stream EFH (Meehan et al. 1977, Murphy and Hall 1981). Holtby (1988) showed that increased water temperatures resulting from clear-cutting in a small stream altered the life history and reduced survival to adulthood in coho salmon. Conversely, in clear-cut coastal streams in Oregon, coho salmon were not apparently impacted, but a decline in the cutthroat trout population may have been caused by increased temperature (Ringler and Hall 1975). Thus, it is important to note that impacts of timber harvest on stream temperature in EFH can vary markedly among species of fish, life stage, and watersheds (Quinn and Wright-Stow 2008, Pollock et al. 2009, Janisch et al. 2012).

Growth of riparian vegetation influences the nutrient cycle directly through uptake of nutrients from soil and groundwater, and indirectly through organic matter input and the symbiotic associations between plants and microbes (Tabacchi et al. 2000). Nutrient uptake in trees increases with age until reaching equilibrium (Johnson et al. 1982), but storage capacity varies among species (Tabacchi et al. 2000). Regardless, without the soil stability and storage capacity provided by mature vegetation, excess sediment and nutrients can be washed into nearby waterbodies (Feller and Kimmins 1984, Kiffney et al. 2003), reducing the quality of EFH (Feller and Kimmins 1984, Hicks et al. 1991). Increased sunlight combined with increased nutrients as a result of timber harvest can elevate primary production in streams (Ensign and Mallin 2001, Kiffney et al. 2003, Kiffney 2008), which at certain levels can negatively impact EFH (Compton et al. 2003, Wurtsbaugh et al. 2019).

Impaired connectivity

Interconnectivity of EFH is important to the persistence of fishes (Waples et al. 2009). Stream crossings, such as those along timber harvest roads, can create confined, shallow, high-velocity habitats (Castro 2003, Peterson et al. 2013, Khodier and Tullis 2014) that, when perched or blocked, can impact sediment and organic matter flux and organismal connectivity in EFH (Beechie et al. 1994, Warren and Pardew 1998, Bates et al. 2003, Gibson et al. 2005, Price et al. 2010, McKay et al. 2013, Ogren and Huckins 2015). Reduced fish passage can affect fish reproduction (Sheer and Steel 2006) and render fish populations vulnerable to large-scale disturbances (Lamberti et al. 1991). Lateral riverine connectivity can be impacted by building logging roads in or close to floodplain habitat (Blanton and Marcus 2009).

Railways and roads are often built along the banks of rivers, especially in hilly or mountainous terrain where rivers provide low-gradient corridors (Forman et al. 2003).

Increased surface erosion and mass wasting

Timber harvest and associated roads, including crossing structures, can cause increased surface erosion and mass wasting events, both of which can severely impact water quality in EFH (Brown and Krygier 1971, Johnson and Beschta 1980, Sidle et al. 1985, Anderson and Potts 1987, Cederholm and Reid 1987, Platts et al. 1989, Hicks et al. 1991, Reid 1993, Montgomery et al. 1998, Montgomery et al. 2000, Dhakal and Sidle 2004, Kreutzweiser et al. 2005, Sidle 2005). Surface erosion and mass wasting exacerbated by timber harvest activity can increase the delivery of fine sediment loading in EFH, which can increase turbidity, alter behavior of invertebrates, and inhibit feeding, growth, and survival of juvenile salmonids (Barrett et al. 1992, Smith and Wegner 2001, Suttle et al. 2004, Klein et al. 2011). Excessive fine sediments can also inhibit delivery of oxygen to fish embryos, leading to premature hatching, reduced size at emergence, and reduced viability (Chapman 1988, Hicks et al. 1991, DeVries 1997, Quinn 2005). In juvenile and adult fishes, suspended sediments can abrade or clog gill membranes (Cederholm and Reid 1987).

Potential Conservation Measures for Silviculture

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate of impacts of silviculture (timber harvest) on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help foresters avoid, minimize, and mitigate impacts of timber harvest on EFH.

General guidelines

- Incorporate watershed assessment into forestry projects (Beechie et al. 1994) to evaluate the effects of past, present, and future timber sales on organic matter and sediment fluxes, and hydrologic and geomorphologic processes within the watershed.

Loss and alteration of habitat

- Ensure that the width of riparian buffers is at least 30 m.
- Mitigate for timber harvest impacts by increasing habitat heterogeneity via enhancement and restoration of watershed processes.
- Create a mixture of successional trajectories of riparian vegetation to reestablish and sustain natural disturbance processes.

Altered hydrology and geomorphology

- Keep overall harvest percentages low (including through the use of buffers) to control impacts of timber harvest on hydrology and stream flow (see Bosch and Hewlett 1982, Stednick 1996, Brown et al. 2005).
- Use process-based runoff models (e.g., DHSVM[5]) to evaluate potential for timber harvest-induced changes in stream flow.

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[5] https://www.pnnl.gov/projects/distributed-hydrology-soil-vegetation-model

Release of contaminants

- Avoid fueling near streams and include contingencies to avoid and contain spills.
- Ensure that all forestry operations incorporate conservation plans that include controlling non-point source pollution, avoiding sensitive habitats, maintaining riparian corridors, and monitoring and controlling pesticide use.
- Develop a fuel transport, storage, and spill contingency plan.
- Complete staging, cleaning, maintenance, refueling, and fuel storage for wheeled and tracked machinery in staging areas placed 50 m or more away from any stream or stream-associated wetland, or in areas that are hydrologically disconnected from streams and wetlands.
- Inspect all wheeled and tracked machinery that will be operated within 50 m of any stream, waterbody, or wetland daily for fluid leaks before leaving the vehicle staging area. Repair any leaks detected in the vehicle staging area before resuming operation.

Impacts to water quality

- Ensure that riparian buffers are wide enough to limit negative impacts on streams, and that total basal area harvested is less than ~20% (e.g., Stednick 1996, Kiffney et al. 2003).
- Ensure that nearby streams are not already temperature compromised prior to timber harvest.
- Design monitoring studies to assess timber harvest activities on stream temperature and EFH habitat (e.g., Smith 2013).
- Use alternative harvesting methods, such as selective harvest or thinning rather than clear-cutting, to reduce impacts to nutrient cycling (Dahlgren 1998).
- Limit the size of clear-cut units.

Impaired connectivity

- Ensure that new, reconstructed, and existing roads:
  - ◦ Will not impair lateral and longitudinal connections between stream channels, ground water, and wetlands.
  - ◦ Will not increase sedimentation to aquatic systems.
  - ◦ Will have adequate drainage and surfacing.
  - ◦ Will not discharge drainage water into streams or onto potentially unstable land forms (e.g., concave hollows or headwalls on steep hills).
- Require stream crossings to: a) provide adequate fish passage for both adults and juveniles, b) accommodate a 100-year flood without over-topping the road, and c) pass adequate sediment and organic material, including LWD.

Increased surface erosion and mass wasting

- Avoid timber harvest activities near EFH such as streams and wetlands, and on steep or unstable slopes.
- Restrict building of crossing structures during periods where fish are vulnerable (e.g., embryo, larval, and spawning stages).
- Ensure that all timber harvest roads do not increase fine sediments in EFH.
- Apply best management practices (BMPs) for log hauling, recreational use, and seasonal closure, to minimize erosion and sediment generation.
- Require stream crossings to: a) provide adequate fish passage for both adults and juveniles, b) accommodate a 100-year flood without over-topping the road, and c) pass adequate woody material.
- Use temporary roads and stream crossings, where practicable.
- Mitigate for riparian functions altered by new road segments.
- Ensure that all logging roads have adequate drainage and surfacing, and will

not discharge drainage water into EFH or onto potentially unstable land forms.
- Design monitoring studies to assess forest harvest activities on fine sediment inputs and EFH habitat using BACI design (before-after control-impact; Smith 2013).

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6. Dam Operations and Removal

Dams are built on rivers and streams to impound or divert water for uses such as power generation, flood control, irrigation, water supply, and navigation. Dams disrupt the flow of water, nutrients, organic matter, organisms, and sediment, leading to profound changes in aquatic environments (NRC 1992, Ligon et al. 1995, Heinz Center 2002). Impacts of dams on EFH are extensive and well documented, occurring both upstream and downstream of the dam. Impacts include modification of hydrologic and geomorphologic processes, alteration of water quality, and fish migration (Ward 1976, Raymond 1979, Ward and Stanford 1979, Armitage 1984, Petts 1984a; Cushman 1985, NRC 1996, Petts 1986, Quinn and Adams 1996, Poff et al. 1997, Quinn et al. 1997, Larinier 2001, Heinz Center 2002, Pringle 2003, Petts and Gurnell 2005, Hodgson et al. 2006, Dewson et al. 2007, Svendsen et al. 2009, Elosegi et al. 2010, Fullerton et al. 2010, Poff and Zimmerman 2010, Tockner et al. 2010). Environmental impacts of dams have been linked to the decline or extirpation of several ecologically, commercially, recreationally, and culturally important fish populations in western North America (Nehlsen et al. 1991, Waples et al. 1991, Fisher 1994, Slaney et al. 1996, Yoshiyama et al. 1998, Schaller et al. 1999, Kareiva et al. 2000, Levin and Tolimeri 2001, McClure et al. 2003, Pess et al. 2008), and to degradation and loss of EFH in estuaries (Bottom et al. 2005, Fresh et al. 2005).

Dams are built because they are important to local and municipal infrastructure and economy; however, many have become obsolete and have lost economic viability (Born et al. 1998). Many others have deteriorated or been abandoned, leaving a legacy of structures that unnecessarily continue to degrade EFH, hinder recovery of endangered species, and even pose a risk to public safety in some cases (Shuman 1995). In addition, some dams were built without fish passage, leading to local extirpation above the dam (Kiffney et al. 2009). Thus, for some dams, environmental costs associated with continued operation outweigh monetary or social benefits. As this information has become more widely understood, the selective removal of dams has gained wider acceptance (Bednarek 2001, Hart et al. 2002, Poff and Hart 2002, O'Connor et al. 2015). While there are many substantial benefits that accompany dam removal (Bednarek 2001, Stanley et al. 2002, Pess et al. 2008, Roark and Podolak 2009, Ritchie and Shellberg 2010, Simons et al. 2011), it is also known that dam removal can have short-term negative impacts on freshwater (Stanley and Doyle 2003, Sethi et al. 2004, Rahel 2013) and marine EFH (Foley et al. 2015), such as increases in suspended sediment previously trapped behind the removed dam (Warrick et al. 2015).

The Dam Operations section outlines some of the adverse impacts of dams. Dam Removal outlines some of the potential adverse impacts of dam removal. Suggestions for avoidance, minimization, and mitigation of these impacts on EFH are provided in each section.

Dam Operations

Potential adverse impacts of dam operations

The following factors associated with dams, dam operations, and flow regulation can impact EFH and are described below briefly: loss and alteration of habitat, altered hydrology and geomorphology, impaired fish passage, and impacts to water quality. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Regulated flows alter stream-channel geomorphic processes and riparian interactions in EFH (Junk et al. 1989, Spence et al. 1996, Brandt 2000, Kondolf 2000, Grant et al. 2003, Petts and Gurnell 2005, Graf 2006, Dewson et al. 2007, Elosegi et al. 2010). Because of altered sediment delivery and substrate recruitment downstream of dams, EFH can become severely degraded (Kondolf 1997). Substrates can become coarser (Pohl 2004) and increasingly embedded (Sennatt et al. 2006), homogenizing instream habitat (Moyle and Mount 2007) and reducing growth and survival of invertebrates and fish (Cederholm and Reid 1987, Bjornn and Reiser 1991, DeVries 1997, Poff et al. 1997, Quinn 2005). Riparian ecosystems that contribute to the overall condition of EFH can become disconnected from instream processes (Nilsson and Berggren 2000), and both riparian and instream geomorphic processes can be hampered, leading to changes in riparian plant composition and habitat structure, including homogenization of instream habitat. For example, reduced flooding of the Snake River below Jackson Dam transformed a complex, sinuous riparian floodplain to a simple channel with little connection with the floodplain (Marston et al. 2005).

Altered hydrology and geomorphology

Flow regulation during dam operation alters hydrologic conditions in EFH, changing the frequency, duration, and magnitude of low and high flows and the timing, duration, and variability in flow regimes (Ward 1976, Petts 1984a, Junk et al. 1989, Brandt 2000, Magilligan and Nislow 2005, Graf 2006, Naik and Jay 2011). Flow regulation homogenizes flow regimes (Nislow et al. 2002, Moyle and Mount 2007), impacting physical processes such as sediment and organic matter budgets (transport, erosion, deposition; Petts 1984b, Kondolf 1997, Pess et al. 2008). Regulated flows can lead to stranding of juvenile and larval fish (Woodin 1984) and embryos, alter spawning behavior (Connor and Pflug 2004, Geist et al. 2008, Tiffan et al. 2010, Poirier et al. 2012), and possibly influence life-history strategies of anadromous fish (Connor et al. 2005, Beechie et al. 2006). Regulation can also lead to downstream displacement of fish, as large-volume releases can flush fish over dams and low-volume releases can block upstream movement back into EFH critical to certain life stages (Chun et al. 2011, Young et al. 2011).

Hydrologic connectivity is the water-mediated transfer of matter, energy, and organisms (Ziemer and Lisle 1998). Dams impair hydrologic connectivity, eliminating chemical and physical processes—such as delivery of sediment and organic matter (e.g., wood)—and altering food webs in EFH both upstream and downstream of dams (Pringle 2001, Pringle 2003, Naiman et al. 2012). Sediment and large woody debris are important to development and maintenance of EFH throughout a watershed, but cannot readily pass from upstream EFH through dams into downstream EFH. Instead, sediment and organic matter settle to the bottoms of reservoirs upstream of dams (Wood and Armitage 1997), and wood accumulates at the outlets of reservoirs on the upstream face of dams (e.g., Moulin and Piegay 2004), where neither can serve in development or maintenance of downstream EFH. Water-storage management for reservoirs can also reduce the frequency and magnitude of high flows required to scour fine sediments from spawning substrate in downstream EFH, leading to degradation of spawning habitat (Spence et al. 1996). Furthermore, seasonally fluctuating reservoir surface elevation can impact spawning behavior and success at tributary mouths, where spawning habitat can become desiccated or inundated (Barnett et al. 2013).

Relatively deep reservoirs have high hydrostatic pressures at the bottom that can force atmospheric gases into solution. If these waters are released below the dam, either by water spilling over dams or through turbines, it can cause dissolved gas supersaturation, resulting in injury or death to fish, especially adult salmon that stage during spawning migration below the dam (Beiningen and Ebel 1970, Elston et al. 1997, Beeman and Maule 2006). Furthermore, water plunging over spillways can entrain atmospheric gas regardless of how much gas was in solution before it was spilled (Weitkamp and Katz 1980).

Impaired fish passage

Dams physically obstruct fish passage. When no mechanism is provided to get past a dam, there can be no upstream passage to EFH, leading to local fish extirpations (Schmetterling 2003, Sheer and Steel 2006, Schilt 2007, Lindley and Davis 2011). Expansive areas of EFH upstream of dams have become inaccessible due to impaired fish passage at dams (Pess et al. 2008). State and federal fish and wildlife agencies now generally require fish-passage structures at dams that impede migration routes. However, the presence of such structures does not ensure successful migration to, and spawning in, upstream EFH, and poorly designed passage structures could actually play a role in reduced survival of anadromous fishes during their spawning migration (Caudill et al. 2007).

Dams also constrain downstream passage of anadromous fish (Raymond 1979, Williams et al. 2005). Reduced flows from impoundments can result in higher mortality rates due to increased exposure to predators and physiological stress (for a review of fish passage effects, see Schilt 2007). Dams and regulated flows have shifted migration timing of fish (Scheuerell et al. 2009). Downstream-moving fish can also become entrained or impinged on hydroelectric structures (Ruggles 1980, Mathur et al. 1996).

Impacts to water quality

Dams can also alter water temperature in EFH (McCullough 1999, Brandt 2000, Lessard and Hayes 2003). Natural temperature regimes play an important role in physiological and morphological adaptations among fish populations (Eliason et al. 2011), and affect growth and survival of invertebrates and fish (e.g., Crozier et al. 2014). Changes in water temperature regimes in downstream EFH caused by flow regulation can impact fish physiology, migration timing, and food webs (Spence et al. 1996, Wootton et al. 1996, Quinn et al. 1997, Crossin et al. 2008), and increased temperature in reservoirs can be lethal to fish in some cases (e.g., Mathes et al. 2010). Furthermore, increased water temperature can influence the success of native and non-native predators and competitors (Peterson and Kitchell 2001, Kuehne et al. 2012), and can exacerbate the virulence of disease and increase susceptibility to parasites in freshwater (Cairns et al. 2005, Wagner et al. 2005) and marine EFH (Miller et al. 2010).

If seasonal drawdown of impoundments occurs, it can facilitate freezing, diminishing light penetration and photosynthesis, potentially causing fish kills through anoxia (Spence et al. 1996). Furthermore, climate warming will exacerbate the negative effects dams have on reservoir temperatures.

Potential conservation measures for dam operations

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of dam operations on EFH. Not all of these suggested measures are necessarily applicable to any one project or operation that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to or during the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of dam operations on EFH.

General guidelines

- Do not construct new dam facilities if other, less-damaging approaches to water management can be used.
- Address the cumulative impacts of past, present, and foreseeable future development activities of the dam on aquatic habitats. Consider these impacts in the review process for dam construction and operation.
- Use seasonal restrictions for construction, maintenance, and operation of dams to avoid impacts to habitat during critical life-history stages. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Develop water and energy conservation guidelines for integration into dam operations and into regional and watershed-based water resource plans.
- Coordinate maintenance and operations that require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.

Loss and alteration of habitat

- Develop a sediment transport and geomorphic maintenance plan to allow for peak flows that will result in sediment pulses through the reservoir/dam system and allow for geomorphic processes determined by high-flow events. If natural sediment and wood transport is not possible, consider sediment and wood additions below the dam.

Altered hydrology and geomorphology

- Operate dams within the natural rates and timing of flow fluctuations. Mimic the natural hydrograph and allow for sediment and wood transport. 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. Install water flow monitoring equipment upstream and downstream of the facility. Monitor reservoir levels and fluctuations during critical life-history events of fish populations.
- Operate facilities to create flow conditions that provide for fish passage, pre-dam water quality, proper timing of life-history stages, and properly functioning channel conditions.
- Avoid strandings and redd (i.e., spawning nest) dewatering (Connor and Pflug 2004).
- If a dam is deemed necessary, construct

dam facilities with the lowest hydraulic head practicable for the project purpose.

Impaired fish passage

- Design and construct new facilities with efficient and functional upstream and downstream adult and juvenile fish passage to ensure safe, effective, and timely passage.
- Consider all available upstream-passage mechanisms, including natural-like bypass channels, fish ladders, fishlifts, etc. In general, volitional passage is preferable to trap-and-truck methods.
- Retrofit existing dams with efficient and functional upstream and downstream fish passage structures.
- Provide downstream passage to prevent adults and juveniles from passing through the turbines, to minimize delays, and to provide sufficient water downstream for safe passage.
- On the dam intake, use a NOAA-approved fish screen that follows the fish screen criteria in NMFS (2008).

Impacts to water quality

- Use a selective depth outlet structure so that released water more closely matches the natural water temperature regime of adjacent downstream habitat (Stanford and Hauer 1992).

Dam Removal

Potential adverse impacts of dam removal

The following factors associated with dam removal can impact EFH and are described briefly below: sedimentation, siltation and turbidity, release of contaminants, and invasive species. Suggested conservation measures related to each of these factors are provided in the following section.

Sedimentation, siltation, and turbidity

The release of accumulated sediments from reservoirs after dam removal increases transport and deposition of fine sediments, temporarily increasing turbidity and reconfiguring channel form, substrate composition, and tidal dynamics in EFH (Bednarek 2001, Bushaw-Newton et al. 2002, Hart et al. 2002, Pizzuto 2002, Doyle et al. 2003, Pess et al. 2008, Major et al. 2012, Bountry et al. 2013, Wilcox et al. 2014, East et al. 2015, Foley et al. 2015, Warrick et al. 2015). In the short term, these changes to EFH could impact site access, site fidelity, and reproductive success for fish (Pess et al. 2008), and increase mortality and decrease species diversity in downstream aquatic communities (Doeg and Koehn 1994, Stanley and Doyle 2003, Thomson et al. 2005). Increased sediment could also be expected to negatively impact riparian habitats connected to EFH. Native riparian vegetation might become covered in sediment, potentially enabling invasive vegetation to establish itself (Roni et al. 2008, Duda et al. 2011).

Release of contaminants

Due to differences in chemical and physical characteristics between flowing and stillwater (lotic and lentic) habitats, dam removal can temporarily impact aspects of water quality such as temperature, turbidity, and oxidation reduction potential. However, in most cases these impacts do not result in chronic water quality degradation (Nechvatal and Granata 2004). Accumulated sediments behind dams often contain contaminants. If dam removal mobilizes contaminants, there is potential to adversely affect aquatic organisms inhabiting EFH, including the eggs, larvae, and juvenile stages of fish and invertebrates (Heinz Center 2002). For example, removal of the Fort Edward Dam in New York released large amounts of PCBs, causing widespread, long-term contamination of the Hudson River (Chisholm 1999).

Invasive species

Dams can facilitate biological invasions (Johnson et al. 2008). However, because dams block the upstream distribution of aquatic organisms, removal of dams could lead to the introduction of a wide range of invasive aquatic organisms, from aquatic vegetation to apex predators (Stanley and Doyle 2003, Doyle et al. 2005, Rahel 2007, Kornis and Vander Zanden 2010, Woodward et al. 2011, Naiman et al. 2012, Rahel 2013).

Potential conservation measures for dam removal

The following site-specific measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of dam removal on EFH. Not all of these suggested measures are necessarily applicable to any one dam-removal project. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help avoid, minimize, and mitigate impacts of dam removal on EFH.

General guidelines

- Consider the history of the project, geomorphology of the watershed, and location in the river system, among other factors, as these will dictate the types of environmental issues dam removal will present.
- Conduct an assessment of the biotic component of the impacted area, particularly if anadromous fish restoration is one of the objectives of the dam removal. For example, the assessment may include characterization of the historic distribution and abundance of fish species, their various life-history habitat requirements, and their limiting environmental factors. The assessment should also evaluate the predicted physical and chemical conditions following dam removal to determine if additional restoration may be necessary.
- Provide downstream movement of large woody debris (LWD) past dam sites, rather than removing it from the system.
- Establish a monitoring protocol to evaluate success of the restoration for fish passage and utilization.

Sedimentation, siltation, and turbidity

- Evaluate past, existing, and future hydrology and sediment transport regimes using a watershed-scale analysis.
- Consider the relative benefits of rapid dam removal and “sluicing” the impounded sediments downstream versus removal of the dam in stages to meter the release of sediments. Plan dam-removal timing according to which approach is most ecologically sound.
- Revegetate the newly exposed stream bank with local native vegetation.
- Establish a contingency plan in the event that the stream channel needs modification following dam removal

(addition of riffle-and-pool complex, added features to create habitat complexity, meanders, etc.) to facilitate fish passage and achieve habitat function goals.

Release of contaminants

- Conduct sufficient testing to evaluate the type, extent, and level of contamination in accumulated sediment while planning and assessing alternatives for dam removal (Bednarek 2001). If the presence of contaminated sediments is extensive, mechanical or hydraulic removal might be required prior to the removal of the dam.

Invasive species

- Consider construction of artificial barriers to impede the dispersal of invasive species (Fausch et al. 2009; for comprehensive review of installations, see Rahel 2013).

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7. Mineral Mining

Potential Adverse Impacts of Mineral Mining

The following factors associated with mineral mining can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, sedimentation, siltation, and turbidity, release of contaminants, catastrophic mine failures, and abandoned sites and legacy effects of mining. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Complexity of habitat plays an important role in development and survival of freshwater fishes (Bisson et al. 1992, Pearsons et al. 1992, Schlosser 1995, Quinn and Peterson 1996). Channel alterations caused by the development and operation of mining sites can homogenize habitat composition, reduce channel–riparian hydrologic and geomorphic functions, and alter ground and surface water exchange (Bjerklie and LaPerriere 1985, Lisle et al. 1993, McIntosh et al. 1994, Gilvear et al. 2006, USFS 2012).

Riparian vegetation and large woody debris (LWD) are key components to the development and maintenance of EFH (Gregory et al. 1991, Fausch and Northcote 1992, Li et al. 1994, Naiman et al. 1998, Naiman et al. 2005). Riparian vegetation buffers EFH from solar radiation, helping to regulate water temperature (Spence et al. 1996), and can influence the supply of important food items for stream food webs (Allan et al. 2003). LWD creates important instream habitat features, including pools, bars, islands, and side channels (Bilby and Ward 1991, Abbe and Montgomery 1996), and regulates sediment and flow routing, nutrient cycling, and substrate availability for benthic production (Young 2000, Coe et al. 2009, Clinton 2011, Hodson et al. 2014). Riparian vegetation and organic debris, including LWD, are often removed during mine development (NRC 1999).

Mining can reduce the suitability of important stream habitat. For example, large quantities of gravel and other substrates are relocated into instream tailings piles during suction mining, and these pilings might be placed in locations that attract spawning fish (Harvey and Lisle 1998). The piling of gravel tailings at these new locations could be viewed as a net increase in the availability of gravel for use by spawning fish, especially in channels that are gravel-poor. However, substrates in tailings piles are likely unstable, and more susceptible to scour than those located on natural gravel beds (Harvey and Lisle 1999).

Altered hydrology and geomorphology

Mining activities can alter hydrologic processes that control water quality in EFH (Harvey and Lisle 1998). Instream disruption of substrates at placer mines may alter water exchange and chemistry between surface and groundwater (Bjerklie and LaPerriere 1985).

Diversion of freshwater for mining in upstream locations can impact hydrologic processes and water quality in downstream estuarine EFH. The influx of freshwater into estuary EFH influences abundance and survival of fish and invertebrates inhabiting estuaries (Kimmerer 2002). Freshwater diversions for mines can alter water budgets (e.g., residence times), temperature, and salinity in estuaries, all of which can alter thermal stratification and, in extreme cases, might cause hypoxic or anoxic events (Kennedy et al. 2002).

Sedimentation, siltation, and turbidity

Instream mineral mining disturbs fine sediments that are then transported and deposited in downstream EFH, impacting fish and invertebrate prey (for reviews, see Wood and Armitage 1997, Berry et al. 2003, Kemp et al. 2011). Increased fine sediments can clog interstitial spaces in spawning gravels (Bjornn and Reiser 1991), damage gill membranes of aquatic organisms, reduce benthic production, and decrease the area of available EFH (Wagener and LaPerriere 1985, Cederholm and Reid 1987, Hicks et al. 1991, Brown et al. 1998, Smith and Wegner 2001, Melton 2009). Increased sedimentation can alter distribution (Culp et al. 1986), abundance, and composition of invertebrates (Waters 1995) and impair predator avoidance of fish. Increased turbidity caused by mining can alter fish feeding behavior and physiology (Harvey and Lisle 1998). Conversely, feeding may increase (Gregory 1993), while predation by piscivores could decrease (Gregory and Levings 1998), in moderately turbid water. It is important to note that seasonal streamflow could exacerbate or buffer impacts of sedimentation caused by mines (Pentz and Kostaschuk 1999), and that the duration and timing of exposure to increased suspended sediments could significantly alter the degree of impact on fish inhabiting EFH (Newcombe and MacDonald 1991).

Release of contaminants

Mine waste has a high potential to negatively impact water quality in EFH (Moore et al. 1991, Nelson et al. 1991, West et al. 1995, Allan 2004), with subsequent effects on fish populations (Richer et al. 2021). Mine tailings are composed of heavy metals and toxic substances found in ore, as well as chemicals used during the milling process. These substances can infiltrate EFH through instream pilings and when wastewater from mines is allowed to flow into surface or groundwater systems (Nelson et al. 1991, Phillips and Lipton 1995, USEPA 1997 Appendix B, PFMC 1999). Impacts from water quality contamination that results from mining can persist for years, decades, or centuries (e.g., Bouse et al. 2010).

At high concentrations, metals in EFH can cause widespread invertebrate and fish mortality (e.g., Phillips and Lipton 1995). At lower concentrations, immediate symptoms may not be as obvious, as water soluble metals accumulate on substrates and associated biofilms and travel through the aquatic food web (Clements and Rees 1997, Farag et al. 1998). Copper mining in southern California led to metal contamination of coastal sediments (Shumilin et al. 2011) bioaccumulating in invertebrates and fish (Bonar and Matter 2011). In the Sacramento River, Saiki et al. (2001) found elevated metal concentrations (copper, cadmium, and zinc) in macroinvertebrate prey and juvenile Chinook salmon that had been exposed to mine effluent; in addition, trout that fed on invertebrates from metal-contaminated stream reaches had histopathological abnormalities, reduced feeding and growth, and increased mortality (Woodward et al. 1994, Farag et al. 1995, Woodward et al. 1995). It is important to note that impacts of toxic metals on fish vary depending on the metal, species, life stage, and exposure to other stressors (Chapman 1978, Atchison et al. 1987, Hellawell 1988, Mebane et al. 2012).

Natural processes that release contaminants into EFH have become increasingly widespread as a result of mining (e.g., Todd et al. 2007). Acid mine drainage (AMD) occurs when rock containing sulfide minerals is excavated from an open pit or an underground mine, and then reacts with water and oxygen to create sulfuric acid (West et al. 1995, Jennings et al. 2008). AMD increases the amount of metals and acidic compounds in EFH to levels that are toxic to fish, and may render streams uninhabitable by fish (Munshower et al. 1997, Finlayson et al. 2000, Todd et al. 2007). EFH affected by AMD shows reduced biodiversity, as stream communities become dominated by only a few tolerant species, and altered ecosystem processes, such as decomposition (Hogsden and Harding 2012).

Catastrophic mine failures

Catastrophic failures at mines are relatively uncommon and not well studied; however, water bodies, instream and riparian habitats, and the aquatic food web are highly vulnerable to such unpredictable events (Phillips and Lipton 1995, Lemly 2015, Mount Polley Mining Corporation 2015). For example, in August 2014, a massive tailings pond dam failure released 7.3 million m^3 of tailings, 10.6 million m^3 of water, 6.5 million m^3 of interstitial water, and 0.6 million m^3 of construction materials into downstream lake and stream habitats. Subsequent water samples indicated that water from the tailings pond was alkaline and not acid-generating. However, the channel and riparian zone of Hazeltine Creek were obliterated as a result of a massive debris flood, substrates and debris from the mine were deposited into two relatively pristine lakes, and, while not immediately evident, the influx of trace elements from the tailings pond into the environment is likely to impact the food web over time (Mount Polley Mining Corporation 2015, Byrne et al. 2018). Although relatively rare, tailings retention dam or dike failures have the potential to devastate large, expansive networks of EFH. Considering the latent impacts, contingencies for such disasters should be addressed in licensing of mining operations.

Abandoned sites and legacy effects of mining

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, chemical, and biological characteristics of EFH. Though instream mining is not as common today, past mining activities, such as hydraulic gold mining, have left a legacy of altered stream channels (USFS 2012); contaminated sediments and water continue to impact EFH near to, and downstream of, abandoned instream mine sites (Spence et al. 1996). Contamination related to mining in the Sierra Nevada has persisted for over 120 years after hydraulic mining ceased (Bouse et al. 2010). The effect of metal mining on riparian and aquatic EFH can be spatially extensive, especially in metal-rich regions, because of the ubiquity of mines (Clements et al. 2000) and high loadings of contaminated mine water. Mercury released from hydraulic gold mining in the Sierra Nevada has been found in sediments up to 250 km downstream in the San Francisco estuary (Bouse et al. 2010). Trophic food webs in EFH continue to be affected by abandoned mines (Suchanek et al. 2008); however, the degree of in-situ contamination and toxicity is possibly a function of contaminant(s) and particle size, water chemistry, water temperature, productivity, and species composition (Simpson and Batley 2007, Pinheiro et al. 2019, Silva et al. 2018, Paller et al. 2019). Particle size of mercury was hypothesized to be a key factor affecting assimilation into the ecosystem (e.g., Gray et al. 2000).

Potential Conservation Measures for Mineral Mining

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of mineral mining on EFH. Not all of these suggested measures are necessarily applicable to any one project or operation that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of mineral mining on EFH.

General guidelines

- Implement integrated environmental assessments and monitoring programs. For example, long-term sequential sampling should be implemented in water bodies connected to the mine site to determine the impacts of mine operations on EFH. Such a program could involve collection of baseline trophic food web data (i.e., water quality, invertebrates, and fish) including invertebrate and fish abundance and diversity, and metal concentrations in water, sediment, and tissue. Collect pre-development data over a time frame that accounts for temporal variability in physical and biological responses.
- Schedule all maintenance and construction activities when the fewest aquatic species and least vulnerable life stages will be present. This is especially important where listed species are present in the vicinity of, or could be affected by, the operation.
- Obtain a plan of operation from dredge miners before dredge mining begins. An operating plan provides an opportunity for dialog with the miners concerning potential EFH impacts. An operating plan might include the following:
    - ◦ Projected dates of operation.
    - ◦ Descriptions of the types of equipment that will be used.
    - ◦ Ingress/egress locations.
    - ◦ Maps or sketches showing locations where dredging will occur and locations of sensitive areas that should be avoided (spawning gravels, debris jams, etc.).
- For specific guidelines for sand and gravel extraction, see NMFS's *National Gravel Extraction Guidance* (Packer et al. 2005).

Loss and alteration of habitat

- Do not mine in water, near water sources, in riparian areas, near hyporheic zones, and in floodplains. Maximize the distance from waterways to minimize all impacts.
- Place suction mine tailings piles in instream locations that will not interfere with important fish life history events (Harvey and Lisle 1999).
- Restore on-site natural contours and plant native vegetation after use to restore habitat function. Monitor the site for an appropriate time to evaluate performance, and implement additional corrective measures if necessary.
- Do not remove or disturb instream roughness elements during mining activities. Preserve and enhance recruitment of LWD, and replace or restore that which is disturbed.
- Do not dredge in locations where the activity could undermine stream banks or widen the stream channel.

Altered hydrology and geomorphology

- Conduct hydrologic, hydraulic, and geomorphologic modeling in conjunction with sub-basin-specific riparian, fish, and invertebrate data to estimate impacts of development and operation on natural resources (including the acid-generating potential associated with the proposed activities). Modelers must clearly articulate how data were collected, clearly report inputs, outputs,and governing equations, and be able to successfully defend assumptions using vetted sensitivity analyses.

Sedimentation, siltation, and turbidity

- Do not allow mine-generated sediments to directly enter or affect EFH. Reduce the aerial extent of ground disturbance (e.g., through phasing of operations), and stabilize disturbed lands to reduce erosion and downstream impacts. Employ methods such as contouring, mulching, and construction of settling ponds to control sediment transport.
- Do not dredge in locations with fine-textured substrates (predominantly sands, fines, or silt).

Release of contaminants

- Conduct contaminant modeling in conjunction with water quality monitoring; consider hydrologic, geomorphologic, riparian, fish, and invertebrate information to estimate impacts of development and operation on natural resources, including the acid-generating potential associated with the proposed activities. Modelers clearly articulate how data were collected, clearly report inputs, outputs, and governing equations, and defend assumptions using vetted sensitivity analyses.
- Eliminate possible spillage of dirt, fuel, oil, toxic materials, and other contaminants directly or indirectly into EFH. Monitor and report turbidity in real time during operations. Prepare a HAZMAT-type spill prevention plan and maintain spill containment and water repellent/oil absorbent clean-up materials on hand.
- Treat wastewater (acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle on-site to minimize discharge or infiltration into surface and groundwater systems near EFH. Test wastewater before discharge for compliance with federal and state clean water standards.
- If mercury collects in sluice boxes or other equipment during dredging or other activities, the mercury must be transferred into a vapor-proof, sturdy, unbreakable container to be safely stored and disposed of or recycled.

Catastrophic mine failures

- Monitor environmental conditions using real-time water quality data—for example, turbidity, conductivity, or pH. Employ empirical, vetted regressions between in-situ instantaneous variables at the site (e.g., conductivity) and trace metals, and transmit to online databases to alert subscribers (operators) when metal concentrations or other "site failure" indicators become elevated.

Abandoned sites and legacy effects of mining

- Improve monitoring of development or abandoned site impacts by enabling access to contemporary and historical data (Kuipers et al. 2006).

- Reclaim areas of mine waste that contain heavy metals, acid materials, or other toxic compounds that might impact EFH.
- Monitor environmental conditions using real-time water quality data—for example, turbidity, conductivity, or pH. Laboratory-verified regressions between in-situ instantaneous variables at the site (e.g., conductivity) and trace metals could then be transmitted to online databases to alert subscribers when metal concentrations or other indicators become elevated.

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8. Oil Extraction, Shipping, and Production

Potential Adverse Impacts of Oil Extraction, Shipping, and Production

Oil extraction, shipping, and production can have several negative impacts on EFH. The following factors associated with oil extraction, shipping, and production can impact EFH and are described below (with summarizations from Johnson et al. 2008 where noted): loss and alteration of habitat, release of contaminants, discharge of debris, noise effects, and introduction of invasive species. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Negative impacts of oil extraction, shipping, and production, namely oil spills, pose a major potential threat to EFH along the nearshore (Allison et al. 2003, Huppert et al. 2003, Peterson et al. 2003, McCall and Pennings 2012) and offshore of the U.S. West Coast (Coleman and Williams 2002). Impacts of oil spills vary widely among spill sites and species (Claireaux et al. 2004, Frantzen et al. 2012, Mendelssohn et al. 2012). They can infiltrate intertidal zones, living habitats such as mussel beds (Carls et al. 2001), and upstream into freshwater habitats (Carls et al. 2003). Impacts from oil spills linger, continually affecting EFH for decades (Hayes and Michel 1999, Carls et al. 2004, Culbertson et al. 2008, Iverson and Esler 2010, Fodrie and Heck 2011, McCall and Pennings 2012).

Structures associated with fossil fuel facilities in marine EFH can serve as habitat and influence species assemblages, larval production, and trophic pathways of marine organisms (Love et al. 2000, Fabi et al. 2004, Love and York 2005, Page et al. 2007, Lowe et al. 2009, Manoukian et al. 2010, Macreadie et al. 2011). Fish congregate near oil platforms, using the large structures as habitat (Claisse et al. 2014). Thus, the removal of such structures during decommissioning is the removal of habitat (Bull and Kendall 1994, Helvey 2002, Schroeder and Love 2004, Lowe et al. 2009, Martin and Lowe 2010, Buhl-Mortensen et al. 2010). Conversely, the installation of such structures could impact shellfish beds, hard-bottomed habitats, and aquatic vegetation (Mills and Fonseca 2003), such as eelgrass and kelp; underwater trenching for pipeline and cable installation could affect marsh drainage, freshwater and sediment transport, and increase the inland encroachment of saltwater (Chabreck 1972). Inland encroachment of saltwater can lead to the loss of aquatic vegetation (Pezeshki et al. 1987), causing increased soil erosion and a net loss of organic matter. In freshwater EFH, instream pipeline crossing structures can affect water quality and channel morphology (Lévesque and Dubé 2007), and inland oil development can cause widespread habitat degradation (Jorgenson and Joyce 1994, Ramirez and Mosley 2015).

Release of contaminants

The accidental leaking or spillage of petroleum products can devastate marine (Bue et al. 1998, Dubansky et al. 2013) and freshwater organisms and EFH (Carls et al. 2003). Contaminants from oil spills can linger in EFH for decades (Irvine et al. 2006), causing numerous symptoms in fish behavior (Rooker et al. 2013) and physiology (Carls et al. 1999), including cardiac toxicity and dysfunction (Incardona et al. 2005, Incardona et al. 2012, Incardona et al. 2014), and reduced body condition and growth

(Claireaux et al. 2004). Oil contamination inhibits ecosystem functions important to EFH (Culbertson et al. 2008), affects all life stages of fish (Wertheimer et al. 2000), and impacts benthic organisms and vegetation (Jewett et al. 1999). Furthermore, processes used to clean up oil contamination could also have negative impacts on fish. For example, Milinkovitch et al. (2011) found dispersants used to clean up some oiled habitats were harmful to fish, indicating the importance of selecting the appropriate measures for clean-up in different habitats.

Discharge of debris (adapted from Johnson et al. 2008)

Marine fossil fuel facilities cause discharge of debris, including domestic wastewaters generated from the offshore facility and other trash and debris from human activities associated with the facility (Caselle et al. 2002). Debris—whether floating on the surface, suspended in the water column, covering the benthos, or along the shoreline—can have deleterious impacts on fish and shellfish within benthic and pelagic habitats in the marine environment (NEFMC 1998). Furthermore, debris from fossil fuel transportation activities can be ingested by fish (Hoagland and Kite-Powell 1997).

Noise effects

Potential noise sources associated with fossil fuel facilities include aircraft, construction, pile driving, vessel thrusters, dredging, drilling, explosives, seismic exploration, shipping vessels, sonar and acoustic devices, and general site operations. Undersea noise could interfere with fish communication and orientation (Wahlberg and Westerberg 2005). Electrical cables produce noise that could affect organisms in marine EFH (Richardson et al. 1995). Furthermore, the noise produced during installation of facilities, cables, and pipelines could impact marine organisms and EFH (Hoffmann et al. 2000, Thomsen et al. 2006, Snyder and Kaiser 2009). There remains little empirical evidence that demonstrates exactly how and to what degree operational noise will negatively impact fish and other aquatic organisms (OSPAR 2009, Gill and Bartlett 2010, Hawkins et al. 2014, Cordes et al. 2016).

Introduction of invasive species (adapted from Johnson et al. 2008)

Invasive species indroduced into marine and estuarine waters are a significant threat to marine resources (Carlton 1999). Non-native species can be released unintentionally when ships release ballast water (Niimi 2004). Hundreds of species have been introduced into U.S. waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). The transportation of nonindigenous organisms to new environments can have severe impacts on habitat, food webs, and ecosystems (Omori et al. 1994, Keller and Perrings 2011, Pajuelo et al. 2016, Geraldi et al. 2020). Oil platforms can also serve as vectors for invasive species (Friedlander et al. 2014).

Potential Conservation Measures for Oil Extraction, Shipping, and Production

The following measures can be undertaken by the action agency on a site-specific basis to avoid, minimize, and mitigate impacts of oil extraction, shipping, and production on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process and then communicated to the appropriate agency. The options represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of oil extraction, shipping, and production on EFH.

Loss and alteration of habitat

- Remove residual oil from sediments if oil will persist in sediment and continue to impact recovery of benthic organisms and vegetation (Iverson and Esler 2010).
- Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process.
- Do not locate projects where they will harm sensitive marine and estuarine resources and habitats.
- Characterize pre-construction habitat and associated biological community with consideration for temporal variability, and monitor post-installation change to the community in response to habitat alteration.
- Prior to construction, identify adaptive management thresholds and response actions to be implemented in the event adverse effects to freshwater and marine species occur as a result of loss or alteration of habitat. Consider cumulative effects from other developments within the species range.
- Use modern construction materials and technologies, proper siting protocols, and standardized operating procedures to reduce the risk of environmental damage and degradation.
- Monitor project components installed on the benthos of aquatic habitat—including lakes, streams, wetlands, and the seafloor—for indications of scour, deposition, or other changes to sediment characteristics.

Release of contaminants

- Utilize systems that detect spills and leaks as rapidly as technologically possible so that action can be taken to avoid or reduce the effect to EFH.
- Provide compensatory mitigation when spills occur.
- Plan a comprehensive response to oil spills and stage response equipment.
- Develop a spill clean-up plan and protocols, and make clean-up equipment available on-site for quick response times.

Noise effects

- Time construction and operation to avoid impacts to sensitive life stages and species.
- Prescribe acoustic monitoring for the operational phase, and require that acoustic outputs remain below NMFS acoustic thresholds.
- Do not conduct in-water blasting. If necessary, conduct such activities only when sensitive species are not present in EFH within proximity to the construction activity.

- Pile driving noise: see conservation measures in PFMC (2019), Section 17.1: Pile Driving.
- Vessel noise: see conservation measures in PFMC (2019), Section 11.2: Operation and Maintenance of Vessels.
- Exclude vessels or limit specific vessel activities, such as high-intensity, low-frequency sonar, to known sensitive EFH if evidence indicates that these activities could have an effect on aquatic organisms.

Introduction of invasive species

- Implement invasive species awareness and training efforts that include the use of invasive species identification guides and reporting forms for encounters with priority invasive species.
- Examine and, if necessary, treat all vehicles entering the project area for invasive species.

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9. Energy-Related Activities

Global demands on energy resources have increased rapidly, and the movement to reduce the human carbon footprint has driven the development of alternative renewable energy sources, such as waves, tidal and oceanic currents, offshore wind, and different forms of fossil fuels (Langhamer et al. 2010, Spaulding et al. 2010, Frid et al. 2012, Moriarty and Honnery 2012, Davies et al. 2014). Located within EFH, marine renewable energy facilities and associated electric cables and pipes are expected to impact EFH and associated organisms in both marine and freshwater environments (Petersen and Malm 2006, Gallaway et al. 2007, Weilgart 2007, Inger et al. 2009, Punt et al. 2009, Snyder and Kaiser 2009, Kirby 2010, Langhamer 2012, Reubens et al. 2013b; Leeny et al. 2014, Ramirez and Mosley 2015). It is thought that the development and mere presence of such structures could have several effects on physical and biological processes in EFH (for a comprehensive review, see Boehlert and Gill 2010). However, because the technology is still developing, empirical information on impacts to EFH along the U.S. West Coast, and globally, is limited (Boehlert et al. 2008, McClure et al. 2010, Miller and Schaefer 2010, Ward et al. 2010, Polagye et al. 2011, Shields et al. 2011, Shumchenia et al. 2012, Witt et al. 2012, Broadhurst et al. 2014, Copping et al. 2014, Gill et al. 2014, Shields and Payne 2014, Lindeboom et al. 2015).

This chapter is divided into four sections that outline some of the adverse impacts of energy-related activities on EFH, including factors associated with Wave and Tidal Energy Facilities, Cables and Pipelines, Offshore Wind Facilities, and Liquefied Natural Gas. Suggestions for avoidance, minimization, and mitigation of these possible effects on EFH are provided in each section.

Wave and Tidal Energy Facilities

Potential adverse impacts of wave and tidal energy facilities

The following factors associated with wave and tidal energy facilities can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology, sedimentation, siltation, and turbidity, release of contaminants, entrainment and impingement, noise effects, and alteration of electromagnetic fields. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Sedimentary habitat dominates the Pacific Northwest ocean seafloor and is teeming with life, providing nursery and foraging habitat (Henkel et al. 2014). Wave and tidal energy facilities will introduce artificial habitat into the ocean and estuaries, affecting EFH and potentially compounding impacts to often previously compromised EFH (Gill 2005). Wave and tidal energy structures sited in soft-bottom habitat may act like artificial reefs on the seafloor and in the water column, altering predation pressure and natural species composition and providing a vector for invasive species by increasing the area of reef-type habitat in native pelagic EFH (Boehlert and Gill 2010, Henkel et al. 2014). Bottom structures (e.g., devices, anchors, moorings, cables) may alter water flow and cause scour, deposition, or other sedimentary grain size changes up to an estimated 20 meters from installations, affecting the prey base for EFH-dependent fish in response to sediment changes (Henkel et al. 2014, Frid et al. 2012). Bottom structures installed on the seafloor may be damaged by snagged fishing gear, resulting in additional disturbance or damage to marine habitat from repair of damaged facilities. Biofouled project equipment may lead to attraction of large predators (Frid et al. 2012), altering species composition and predator–prey relationships in the vicinity. Structures floating in pelagic waters may attract adult or juvenile fish seeking shelter, refuge from predators, food, or the opportunity to increase encounter rate with other conspecifics (Kramer et al. 2015). Facilities located near sensitive EFH could negatively impact various life stages of fish and organisms (Witt et al. 2012), and operation of turbine arrays could impede movements of migrating fish (Hammar et al. 2013).

Altered hydrology

Hydrologic functionality in marine habitats is important to EFH functionality and marine organisms (Goodwin and Williams 1992, Findlay et al. 2002, Burrows 2012). Wave and tidal facilities utilize marine and estuarine hydrologic processes such as swells, waves, tides, and currents to generate power (Frid et al. 2012). Tidal energy facilities could alter water circulation patterns and tidal regimes (Yang et al. 2014), affecting water flow and depth and affecting habitat accessibility, temperature regime, water quality (NEFMC 1998), and impacting marine organisms (Boehlert et al. 2008, Frid et al. 2012, Broadhurst et al. 2014). Estuarine tidal energy structures could change spatial water flow and sediment deposition patterns, potentially altering habitat suitability as fish spawning or nursery areas (Frid et al. 2012). Wave energy facilities could alter wave structure and water flow, features of marine EFH (Frid et al. 2012, Witt et al. 2012) that could be important to marine vegetation (Mork 1996, Burrows 2012), the transport of larvae, and structuring of fish assemblages (Layman 2000, Jordaan et al. 2011, Frid et al. 2012).

Sedimentation, siltation, and turbidity

Construction, decommissioning, and cable burial at wave and tidal facilities could disturb sedimentary habitat and cause increased sedimentation (Frid et al. 2012, Henkel et al. 2014). The impact of increased suspended sediments on aquatic organisms depends on the magnitude of change and the duration of exposure (Newcombe and Jensen 1996). Increased sedimentation can impact feeding ability (Langhamer et al. 2010), injure gills (Lake and Hinch 1999), and lead to increased mortality in aquatic organisms (Wilber and Clarke 2001). Shallow waters, rocky reefs and rises, marshes, wetlands, and estuaries may be particularly vulnerable to increased sedimentation because lower water volumes could decrease dilution and dispersal of suspended sediments (Gowen 1978).

Increased sedimentation could also lead to increased turbidity. Turbidity reduces light availability, which can impact habitat features and aquatic organisms. Light availability influences depth distribution, density, and productivity of eelgrass and other types of submerged aquatic vegetation that provide both habitat structure and energy for nearshore and estuarine EFH (Dennison and Alberte 1982, Dennison and Alberte 1985, Dennison and Alberte 1986, Thom et al. 2003, Zimmerman 2006). Increased turbidity from wave and tidal facilities could affect the development of phytoplankton blooms, affecting organisms at higher trophic levels (Frid et al. 2012, Witt et al. 2012). Even slight reductions in light availability can result in lower rates of photosynthesis for submerged aquatic vegetation (Dennison 1987) such as eelgrass and phytoplankton (Cloern 1987), resulting in less forage material for benthic invertebrates and fish.

Release of contaminants

Chemical spills are a possibility during project activities (Boehlert and Gill 2010), including from vessel support or devices themselves (Henkel et al. 2014). Testing of nascent technologies for research or demonstration of technical feasibility may necessitate higher-frequency installation and decommissioning cycles, increasing risks associated with construction activities. Other contamination may result from leaching of anti-fouling paints and heavy metal concentrations when heat exchangers are used, which can have toxic effects on aquatic ecosystems (Boehlert and Gill 2010, Henkel et al. 2014). Recent studies link the potential for chemical pollution from marine renewable energy facilities to adverse effects on a variety of marine species (Shields and Payne 2014, Kramer et al. 2010).

Entrainment and impingement

Tidal and wave energy facilities could impinge or entrain fish (Frid et al. 2012, Witt et al. 2012). Impacts of turbines on migrating fish has been highlighted as a major area of concern (Henderson and Bird 2010), and moving parts of facilities could cause collisions or blade strikes, harming organisms (Boehlert and Gill 2010, Henkel et al. 2014). Furthermore, mooring lines designed to secure floating wave devices may present entanglement risks for marine mammals, sea turtles, and other animals if the lines are slack or capable of making loops, and lines may accumulate marine debris that could act as a web, increasing the risk (Henkel et al. 2014). Collision risk may be highest for baleen whales or young animals with less experience navigating through the water (Henkel et al. 2014). However, empirical information regarding marine species interactions with wave and tidal facilities is sparse.

Noise effects

Construction, operation, and decommissioning of wave and tidal energy facilities will generate considerable noise at levels potentially damaging to marine life (Frid et al. 2012). Several fish and marine mammal species could be affected by noise generated by wave energy facilities (Haikonen et al. 2013). Noise can affect fish and marine mammal behavior, communication, and, in extreme cases, cause direct tissue damage, resulting in immediate or delayed mortality (Hastings and Popper 2005, Thomsen et al. 2006, Popper and Hastings 2009, Frid et al. 2012, Henkel et al. 2014, Popper et al. 2014). Behavioral changes can result in increased susceptibility to predation or disruption of feeding, reproduction, or migration (Popper et al. 2014). Many fish species have swim bladders or other gas-filled structures that can detect sound pressure and are more susceptible to physical damage (e.g., barotrauma) from loud, sudden sounds. For example, in the case of underwater explosions, fish with swim bladders are susceptible to barotrauma 100 times farther away from the explosion than non-swim-bladder fish (Popper et al. 2014). These species are most likely to show behavioral changes from sound (Popper et al. 2014), possibly including altered migration and schooling, which can impact foraging, predator avoidance, or reproductive success. The Clupeiformes (e.g., Pacific herring, American shad, Pacific sardine, northern anchovy), gadids (e.g., Pacific cod) and juvenile salmonids (e.g., Chinook salmon) have been shown to respond to sound (Knudsen et al. 1997, Thomsen et al. 2006). Sounds produced at frequencies similar to vocalizations of marine mammals or their prey may impair communication, navigation, feeding, and avoidance of predators (Henkel et al. 2014). Conditions at wave energy sites in the ocean may be characterized by high ambient noise produced by existing natural (e.g., surf) and anthropogenic (e.g., shipping traffic) sources; thus, new energy facility noise generation should be assessed in the context of cumulative effects of the entire system (Frid et al. 2012). Operational facility noise may or may not be audible above ambient conditions, so the acoustic signature of facilities should be characterized through post-installation study (Henkel et al. 2014, Frid et al. 2012). Both tidal and wave energy facilities have the potential for adverse impacts by creating a source of anthropogenic noise (Frid et al. 2012). Operational and construction noise can be potentially damaging to marine life, but more research is needed (Frid et al. 2012) to determine the hearing sensitivity of marine species in EFH and to fine-tune thresholds at which negative impacts could be expected to occur.

Alteration of electromagnetic fields

The Earth's magnetic field is naturally present throughout all parts of the ocean at all times, and is relied upon by some marine species for essential life functions (Lohmann et al. 2008a, Gill et al. 2014). Electrical transmission cables from wave energy facilities produce electromagnetic fields (EMF) that could affect organisms living in EFH (reviewed by Gill et al. 2012). Other project components including interarray cables, subsea transformers, or devices themselves may also produce EMF; however, the strength of project-related EMF signatures relative to natural EMF is not well understood. Wave facilities, in particular, are expected to contain a relatively high concentration of electrical transmission cables (Witt et al. 2012), which could interfere with behavior of electro- and magnetosensitive fish and marine mammals (Gill et al. 2005). Some elasmobranchs (sharks, skates, and rays) use electroreception to locate prey, and use magnetic fields to orient themselves for migration and habitat use (Normandeau et al. 2011, Frid et al. 2012). Magnetic fields guide orientation and navigation of some marine animals (e.g., isopods, lobsters, rays) as well as orientation, navigation, and homing of long-distance ocean migrants like sea turtles, salmonids, scombrids (tunas and mackerels), and whales (Boles and Lohmann 2003, Lohmann et al. 2008a, Lohmann et al. 2008b, Normandeau et al. 2011). Recent studies on juvenile Chinook salmon and other salmonid species have demonstrated the role of magnetic fields in their migratory behavior in the ocean (Lohmann et al. 2008b, Putman et al. 2013, Putman et al. 2014), raising concern that artificial magnetic fields can disrupt this migratory behavior. However, there is little empirical evidence that demonstrates how electromagnetic fields from wave and tidal facilities will negatively impact fish and other aquatic organisms.

Potential conservation measures for wave and tidal energy facilities

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of wave and tidal energy facilities on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of wave and tidal energy facilities on EFH.

General guidelines

- Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic and riparian habitats in the review process for wave and tidal facility construction and operations.
- Do not locate projects in areas that may result in adverse effects to sensitive freshwater, marine, and estuarine resources and habitats.

Loss and alteration of habitat

- Characterize pre-construction habitat and associated biological community with consideration for temporal variability, and monitor post-installation change to the community in response to habitat alteration.
- If feasible, monitor during construction activities to help identify and remediate impacts to EFH.
- Prior to construction, identify adaptive management thresholds and response actions to be implemented in the event adverse effects to marine species occur as a result of loss or alteration of habitat.
- Consider cumulative effects from other developments within the species range.

Altered hydrology

- Monitor project components installed on the seafloor for indications of scour, deposition, or other changes to sediment characteristics.
- Monitor water quality parameters after installation of shallow-water or estuarine project components.

Sedimentation, siltation, and turbidity

- Conduct pre-construction contaminant surveys of the sediment in excavation or scour areas.
- Site facilities on the coarsest substrate possible to reduce siltation and turbidity.

Release of contaminants

- Do not permit construction of barrage-type tidal energy facilities due to their potential for large impacts to migratory fishery resources and the ecosystem.
- Include impacts associated with the decommissioning and/or dismantling of wave or tidal energy facilities as part of the environmental analyses. Contingency for removal of structures should be required as part of any permits or licenses.
- For all projects, require pre-construction assessments for analysis of potential impacts to fishery resources. Assessments should include comprehensive monitoring of the timing, duration, and utilization of the area by migratory, diadromous, and resident fish stock species. Compare assessments to potential impacts from the project, and develop contingency planning using avoidance measures and/or adaptive management.
- Time construction of facilities to avoid impacts to sensitive life stages and species. Recommended seasonal work windows are generally tailored to specific project areas as appropriate to regional or watershed-level environmental conditions and species requirements.
- Develop a comprehensive oil spill response plan that includes staging of spill-response equipment.

Entrainment and impingement

- Engineer sluices, water intakes, and turbines to reduce fish entrainment. Use rotary turbines when applicable.
- Apply NOAA Fisheries screening criteria to minimize or avoid entrainment.
- Identify any moving parts and determine if animal exclusion devices can be engineered to minimize impingement.
- Require that mooring lines be designed to prevent looping and be maintained free of debris to reduce entanglement risk.

Noise effects

- Require that noise impacts be monitored and minimized.
- Pile driving noise: see conservation measures in PFMC (2019), Section 17.1: Pile Driving.
- Vessel noise: see conservation measures in PFMC (2019), Section 11.2: Operation and Maintenance of Vessels.
- Implement technologies that minimize the levels of underwater sound.

Alteration of electromagnetic fields

- Conduct studies that measure pre-construction on-site ambient EMFs and post-installation EMFs generated from wave and tidal energy facilities, and identify how they may impact aquatic organisms and EFH.
- Require pre-construction analysis of anticipated EMFs generated by proposed project facilities based on best available science from energized cables and components elsewhere.

Cables and Pipelines

Potential adverse impacts of cables and pipelines

The following factors associated with cables and pipelines can impact marine, estuarine, and freshwater EFH and are described briefly below: loss and alteration of habitat, sedimentation, siltation, and turbidity, release of contaminants, impacts to organisms, noise effects, and alteration of electromagnetic fields. Suggested conservation measures related to each of these factors are provided in the following sections.

Loss and alteration of habitat

Cables and pipelines installed unburied in marine EFH can serve as habitat, and influence species assemblages and larval production of fish (Love and York 2005, Love et al. 2005, Buhl-Mortensen et al. 2010). Thus, the removal of such structures is the removal of habitat, impacting EFH and marine aquatic organisms (Bull and Kendall 1994, Schroeder and Love 2004, Lowe et al. 2009). Unburied cables and pipelines laid on the seafloor pose additional hazards to bottom fishing, which may snag and damage the cable or pipeline, resulting in additional disturbance or damage to marine habitat from repair of damaged facilities. Unburied cables can scour the seafloor, altering habitats to varying degrees depending on substrate type. Conversely, the installation of pipelines can impact shellfish beds, hard-bottomed habitats, and aquatic vegetation (Gowen 1978), and underwater trenching in rivers and estuaries for pipeline and cable installation could affect marsh drainage and freshwater and sediment transport, and increase the inland encroachment of saltwater (Chabreck 1972). Inland encroachment of saltwater can lead to the loss of aquatic vegetation (Pezeshki et al. 1987), causing increased soil erosion and a net loss of organic matter (Craig et al. 1979). In freshwater EFH, instream pipeline crossing structures can affect water quality, channel morphology (Lévesque and Dubé 2007), and fish passage.

Sedimentation, siltation, and turbidity

Installation, maintenance, and removal of cables and pipelines within or adjacent to waterbodies can release suspended sediments into the water column. The relative severity of impacts from increased suspended sediment on aquatic organisms depends on both abiotic factors, especially concentration and duration of exposure (Newcombe and Jensen 1996), and biotic factors, such as trophic level and life stage of the affected organism. Increased sedimentation can injure gills (Lake and Hinch 1999), leading to reduced growth and increased mortality of aquatic organisms (Wilber and Clarke 2001). Long-term effects of suspended sediment also include reduced light penetration, with lowered photosynthesis rates and primary production (Gowen 1978). Slight reductions in light availability can also result in lower rates of photosynthesis for phytoplankton, a key basal resource (Cloern 1987) ultimately resulting in less energy available for benthic invertebrates and fish living in EFH. Light availability influences depth distribution, density, and productivity of eelgrass, an important structural feature in nearshore and estuarine EFH (Dennison and Alberte 1982, Dennison and Alberte 1985, Dennison and Alberte 1986, Zimmerman 2006).

The installation of pipelines in freshwater EFH can also increase sedimentation and turbidity (Reid and Anderson 1999), thereby altering habitat conditions and associated aquatic food webs. Fine sediment loading above natural background levels contributes to: embedding of substrates, which can negatively affect salmonids by reducing availability of spawning and rearing habitat, and the ability of fish to obtain food, because salmonids are visual foragers (Hall and Lanz 1969, Burns 1970, Tripp and Poulin 1992, Waters 1995, Suttle et al. 2004). Riparian clearing can also increase streams' susceptibility to erosion, sedimentation, and temperature changes, as well as changes in organic matter dynamics via the loss of detrital inputs. These changes will likely negatively affect fish populations, including cold-water fish like salmonids, via changes in habitat quality, water temperature, and prey availability.

Impacts to organisms

Unburied cables and pipelines have the potential to alter species abundance and composition in marine EFH because they can serve as artificial substrates that attract and concentrate species that otherwise might not be present (Bohnsack et al. 1994, Pickering and Whitmarsh 1997, Bortone 1998, OSPAR 2009). Subsea pipelines that are placed on the substrate also have the potential to create physical barriers to benthic invertebrates during migration and movement. For example, the migration of American lobster (*Homarus americanus*) between inshore and offshore habitats can be adversely affected if pipelines are not buried to sufficient depths (Fuller 2003).

Release of contaminants

Contaminants can be released into the environment, either during pipeline installation (Gowen 1978)or if pipelines are broken or ruptured by unintentional activities (e.g., shipping accidents, catastrophic failures). The accidental leaking or spillage of petroleum products can devastate marine (Bue et al. 1998, Dubansky et al. 2013) and freshwater organisms and EFH (Carls et al. 2003). Oil contamination causes numerous effects on fish physiology, including cardiac toxicity and dysfunction (Incardona et al. 2005, 2012) and reduced body condition and growth (Claireaux et al. 2004). Furthermore, processes used to clean up oil contamination could also have negative impacts on fish. For example, Milinkovitch et al. (2011) found that in some habitats, oil that was dispersed was harmful to fish, indicating the importance of selecting the appropriate measures for cleanup in different habitats.

During construction, horizontal directional drilling (HDD) may be used to string a pipeline or cable under a waterbody, shoreline, or sensitive wetland. During HDD operations, “frac-outs” may occur, in which environmental damage is caused by drilling fluids leaking from the drill hole into habitat such as fish-bearing streams.

Alteration of electromagnetic fields

The Earth’s magnetic field is naturally present throughout all parts of the ocean at all times, and is relied upon by some marine species for essential life functions (Lohmann et al. 2008a). Electrical transmission cables from marine energy facilities produce electromagnetic fields (EMFs) that could affect electro- and magnetosensitive organisms living in EFH (Gill et al. 2005, Öhman et al. 2007, Fisher and Slater 2010, Gill et al. 2012, Witt et al. 2012, Gill et al. 2014). Wave facilities, in particular, are expected to contain a relatively high concentration of electrical transmission cables (Witt et al. 2012), but the issues caused by cable EMFs are similar for wave, wind, or tidal projects (Gill et al. 2014). Where cables converge with each other or with natural geomagnetic lines, the EMF becomes more complex, with some signals being additive and others canceling each other out (Gill et al. 2014). EMFs could interfere with fish and mammal behaviors (e.g., migration) or physiology (e.g., swimming), and impacts on fish could correlate with distance from undersea cables (Gill and Bartlett 2010, Gill et al. 2005). Some elasmobranchs (sharks, skates, and rays) use magnetic fields to orient themselves for migration and habitat use (Normandeau et al. 2011, Frid et al. 2012), and magnetic fields guide navigation and orientation of some marine animals like isopods, lobsters, and rays—as well as orientation, navigation, and homing of long-distance ocean migrants like sea turtles, salmonids, scombrids (tunas and mackerels), and possibly whales (Boles and Lohmann 2003, Lohmann et al. 2008a, 2008b, Normandeau et al. 2011). Recent studies on juvenile Chinook salmon and other salmonid species have demonstrated the role of magnetic fields in their migratory behavior in the ocean (Lohmann et al. 2008b, Putman et al. 2013, Putman et al. 2014), raising concern that artificial magnetic fields can disrupt this migratory behavior. However, there remains little empirical evidence that demonstrates exactly how and to what degree electromagnetic fields from marine energy facility cables will negatively impact fish and other aquatic organisms (Woodruff et al. 2011, Lindeboom et al. 2015). Cable burial of 1–1.5 meters does not dampen B-field emission, but does create a physical barrier between epibenthic organisms and the cable skin, where signals are strongest (Gill et al. 2014). Cable shielding can contain electric fields (E-fields) and could theoretically contain magnetic fields (B-fields), but design and cost limitations make it infeasible to heighten precautions while there is insufficient evidence to require redesign of EMF-emitting cables (Gill et al. 2012). This emphasizes the need to advance the study of E- and B-fields and how fish respond to natural and altered signals to determine whether such requirements are warranted (Gill et al. 2012).

Noise effects

Noise produced during installation of electrical cables associated with marine energy facilities and pipelines associated with LNG facilities could impact marine organisms and EFH (e.g., Wyatt 2008). Noise produced during construction of natural gas pipelines could originate from in-water blasting and could affect anadromous or marine species. Noise can affect fish and marine mammal behavior, communication, and, in extreme cases, cause direct tissue damage, resulting in immediate or delayed mortality (Hastings and Popper 2005, Thomsen et al. 2006, Popper and Hastings 2009, Frid et al. 2012, Henkel et al. 2014, Popper et al. 2014). Behavioral changes can result in increased susceptibility to predation or disruption of feeding, reproduction, or migration (Popper et al. 2014). Many fish species have swim bladders or other gas-filled structures that can detect sound pressure and are more susceptible to physical damage (e.g., barotrauma) from loud, sudden sounds. For example, in the case of underwater explosions, fish with swim bladders are susceptible to barotrauma 100× farther away from the explosion than non-swim-bladder fish (Popper et al. 2014). These species are most likely to show behavioral changes from sound (Popper et al. 2014), possibly including altered migration and schooling, which can impact foraging, predator avoidance, or reproductive success. The Clupeiformes (e.g., Pacific herring, American shad, Pacific sardine, northern anchovy), gaddids (e.g., Pacific cod), and juvenile salmonids (e.g., Chinook salmon) have all been shown to respond to sound (Knudsen et al. 1997, Thomsen et al. 2006). Sounds produced at frequencies similar to vocalizations of marine mammals or their prey may mask communication and affect the animal's ability to communicate, navigate, feed, or avoid predation (Henkel et al. 2014). While construction may impose acoustic risks, there remains little empirical evidence that demonstrates exactly how and to what degree operational noise from marine energy facility cables will negatively impact fish and other aquatic organisms (OSPAR 2009, Gill and Bartlett 2010).

Potential conservation measures for cables and pipelines

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of cables and pipelines on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of cables and pipelines on EFH.

General guidelines

- Plan access routes and staging areas for equipment to avoid passage through sensitive resources such as Habitat Areas of Particular Concern.
- Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for cable and pipeline construction and operations.

Loss and alteration of habitat

- Align cable and pipeline crossings along the least environmentally damaging route. Avoid sensitive habitats such as hard-bottom (e.g., rocky reefs), SAV, oyster reefs, emergent marsh, and mud flats.
- Use existing rights-of-way whenever possible to lessen overall encroachment and disturbance of wetlands.
- Use horizontal directional drilling (HDD) where cables or pipelines would cross sensitive habitats, such as intertidal mudflats and vegetated intertidal zones, to avoid surface disturbances.
- Avoid the use of open trenching for installation in freshwater and shoreline habitats.
- Immediately backfill trenches to reduce the impact duration.
- During the permitting phase, require evaluation of impacts to EFH that may occur during the decommissioning phase, including impacts during the demolition phase and impacts resulting from short- and long-term habitat loss.

- Prescribe fish passage guidance to ensure fish access to suitable habitat and minimize loss of EFH during migration.

Sedimentation, siltation, and turbidity

- Use silt curtains or other types of sediment control to protect sensitive freshwater habitats and resources.
- Avoid construction of permanent access channels in freshwater habitats, since they disrupt natural drainage patterns and destroy wetlands through excavation, filling, and bank erosion.
- Minimize riparian clearing and restore necessary disturbance areas immediately following completion of pipeline construction to minimize potential erosion in streams.
- Avoid conducting activities that increase turbidity during periods of the year when eelgrass is growing rapidly and is most sensitive to reductions in light (generally starting in July in the Pacific Northwest; Phillips 1984).

Impacts to organisms

- Avoid burying pipelines and submerged cables in areas where scouring or wave activity will eventually expose them, as this can result in impacts to EFH.
- Conduct construction during times of year that will have the least impact on sensitive habitats and species. Appropriate work windows can be established based on preconstruction biological sampling spanning multiple seasons and years. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

Release of contaminants

- Ensure that oil and gas pipeline systems include leak detection capabilities to minimize potential impacts from spills.
- Stream-crossing plans involving HDD should include risk assessment for frac-out based on geotechnical analysis, and contingency planning to address frac-out if it occurs (construction stoppage, cleanup, and remediation). Employ measures to avoid/minimize impacts to sensitive fishery habitats from potential frac-outs, including:
  - Use only nonpolluting, water-based lubricants.
  - Monitor drill stem pressures to identify potential frac-outs.
  - If frac-outs are suspected, cease drilling operations immediately.
  - Implement aboveground monitoring to identify potential frac-outs.
  - Develop spill clean-up plan and protocols, and on-site availability of clean-up equipment to quickly respond to frac-outs.

Alteration of electromagnetic fields

- Measure natural on-site EMFs prior to construction, for comparison to post-installation monitoring.
- Conduct studies that identify how EMFs generated from pipes and cables impact aquatic organisms and EFH. Cable orientation relative to the geomagnetic field can increase the intensity of the local magnetic field (Normandeau et al. 2011) and should be studied in situ for each project.

Noise effects

- Conduct studies that identify how noise generated from pipes and cables impacts aquatic organisms and EFH.
- Prescribe acoustic monitoring for the operational phase of marine energy installations, and require that acoustic outputs remain below NMFS acoustic thresholds.
- Do not conduct in-water blasting. If necessary, conduct such activities only when sensitive species are not present in EFH within proximity to the construction activity.

Offshore Wind Facilities

Potential adverse impacts of offshore wind facilities

The following factors associated with offshore wind facilities can impact EFH and are described briefly below: loss and alteration of habitat, sedimentation, siltation, and turbidity, impacts to organisms, noise effects, and alteration of electromagnetic fields. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Offshore wind facilities introduce artificial habitat into the ocean, potentially compounding impacts to previously compromised EFH (Gill 2005). This novel habitat could act as stepping stones for colonization, which may support the spread of existing and introduced species in the area because it increases the area of reef-type habitat in native pelagic EFH (Boehlert and Gill 2010, Wilson et al. 2010). Such shifts in EFH could also have implications for commercial fisheries if aggregations of vulnerable life stages are redistributed because of wind facilities (Reubens et al. 2014). The addition of novel habitats created by facilities located near sensitive EFH could impact abundance and distribution of aquatic organisms (Witt et al. 2012). Turbines sited in shallower nearshore habitats increase shade in eelgrass meadows and kelp beds, and anchors could alter sea-bottom topography, impacting echinoderms and other benthic organisms (Schläppy et al. 2014) and many other species reliant on EFH.

Sedimentation, siltation, and turbidity

Installation and decommissioning of large anchor systems or other seafloor components of offshore wind facilities could cause increased sedimentation (Frid et al. 2012). The impacts of increased suspended sediments on aquatic organisms depend on the magnitude of increase in concentration and the duration of exposure (Newcombe and Jensen 1996). Increased sedimentation can impact feeding ability (Langhamer et al. 2010), injure gills (Lake and Hinch 1999), and lead to reduced growth and increased mortality in aquatic organisms (Wilber and Clarke 2001). Increased sedimentation could also lead to increased turbidity. However, reduction of fine sediments related to a wind energy facility could also have positive short-term effects on fish densities (van Deurs et al. 2012).

Impacts to organisms

Offshore wind facilities have the potential to alter species abundance and composition in marine EFH (Wilhelmsson et al. 2006, Wilhelmsson and Malm 2008, Andersson and Öhman 2010, Stenberg et al. 2015), and such shifts could alter predation and impact food web structure (Bergström et al. 2013, Russell et al. 2014). Floating wind turbines may require ballast or other water intakes that present fish entrainment or impingement potential if not properly designed to avoid these risks. Mooring lines designed to secure floating wind devices may present entanglement risks for marine mammals, sea turtles, and other animals if the lines are slack or capable of making loops, or lines may accumulate marine debris that could act as a web, increasing the risk (Henkel et al. 2014). Collisions between marine life and wind turbine structures could occur; the risk may be highest for baleen whales or young animals with less experience navigating through the water (Henkel et al. 2014). Facility components can serve as artificial reefs, providing hard substrate to which organisms may attach (Bailey et al. 2014), or acting as artificial substrates that attract and concentrate species that otherwise might not be present (Bohnsack et al. 1994, Pickering and Whitmarsh 1997, Bortone 1998, OSPAR 2009). Conversely, facility noise or structures may invoke an avoidance response by marine mammals or other marine species, potentially leading to long-term impacts linked to changes in energetic costs, survival, or fecundity (Bailey et al. 2014). Impacts can vary widely among different habitats (Vandendriessche et al. 2015). Offshore wind facilities could have numerous other impacts on marine fish that would be difficult to evaluate if no baseline data were available (Wilson et al. 2010). Other impacts could include alteration to population dynamics (Wilson et al. 2010), site fidelity (Reubens et al. 2013a), noise effects (Frid et al. 2012), and contaminants introduced to EFH during operations (Boehlert and Gill 2010).

Alteration of electromagnetic fields

Electrical transmission cables, inter-array cables suspended in the water column, subsea transformers, or devices themselves may produce electromagnetic fields (EMFs); however, the strength of project-related EMF signatures relative to natural EMF is not well understood. Cable orientation relative to the geomagnetic field can increase the intensity of the local magnetic field (Normandeau et al. 2011) and should be measured for each proposed project site prior to construction. EMFs produced by marine energy facility cables or devices could affect electro- and magnetosensitive organisms living in EFH (Gill et al. 2005, Öhman et al. 2007, Snyder and Kaiser 2009, Fisher and Slater 2010, Gill et al. 2012, Witt et al. 2012, Gill et al. 2014). EMFs could interfere with fish behaviors (e.g., migration) or physiology (e.g., swimming), and impacts on fish could correlate with distance from the source of emission (Gill and Bartlett 2010). Some elasmobranchs use electroreception to detect bioelectric fields emitted by prey, conspecifics, and predators (Gill et al. 2014), and use magnetic fields to orient themselves for migration and habitat use (Normandeau et al. 2011, Frid et al. 2012). Some fish (e.g. lampreys, sturgeon) are electrosensitive and may be repulsed by strong E-fields (Gill et al. 2014). Magnetic fields guide navigation and orientation of some marine animals like isopods, lobsters, and rays, as well as orientation, navigation, and homing of long-distance ocean migrants like sea turtles, salmonids, scombrids (tunas and mackerels), and whales (Boles and Lohmann 2003, Lohmann et al. 2008a, 2008b, Normandeau et al. 2011). Recent studies on juvenile Chinook salmon and other salmonid species have demonstrated the role of magnetic fields in their migratory behavior in the ocean (Lohmann et al. 2008b, Putman et al. 2013, Putman et al. 2014), raising concern that artificial magnetic fields can disrupt this migratory behavior. However, there remains little empirical evidence that demonstrates exactly how, and to what degree, electromagnetic fields from marine energy facility cables will negatively impact fish and other aquatic organisms (Woodruff et al. 2011, Lindeboom et al. 2015).

Noise effects

Noise from the construction and operation of offshore wind farms could disrupt normal behavior within a large area (Popper et al. 2014) for marine species including mammals, sea turtles, and fish (Wahlberg and Westerberg 2005, Madsen et al. 2006), and could impact EFH (Thomsen et al. 2006, Snyder and Kaiser 2009). The area of potential effect can be vast because sound propagates long distances underwater, and potentially affected species may be highly mobile or migratory (Bailey et al. 2014). Sound perceived by fish and marine mammals can lead to effects on hearing, fitness, injury, and even survival (Popper et al. 2014, Henkel et al. 2014). Underwater noise measured at offshore wind facilities off Denmark and Sweden showed that turbine noise was only detectable over ambient levels at frequencies below 315–500 Hz, and the zone of audibility for mammals may extend 6.4 km, depending on transmission loss (Tougaard et al. 2009). However, most studies of marine species' response to installed wind farms have been conducted in relatively shallow (e.g., <50 m) waters at offshore wind facilities in Europe, whereas emerging floating-foundation technologies designed for deeper waters (300–700 m; Bailey et al. 2014) will be more likely for U.S. West Coast project proposals. Marine species such as the blue whale or fin whale migrating through deeper waters may be susceptible to other impacts from facility-produced sound, such as masking of communication within their call frequencies (Bailey et al. 2014). Sounds produced at frequencies similar to vocalizations of marine mammals or their prey may mask communication and affect navigation, feeding, and predator avoidance (Henkel et al. 2014). There remains little empirical evidence that demonstrates exactly how and to what degree operational noise will negatively impact fish, mammals, and other aquatic organisms (OSPAR 2009, Gill and Bartlett 2010, Bailey et al. 2014).

Potential conservation measures for offshore wind facilities

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of offshore wind facilities on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of offshore wind facilities on EFH.

General guidelines

- Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for offshore wind energy facility construction and operations.

Loss and alteration of habitat

- Avoid placing cables associated with offshore wind facilities near HAPC and sensitive benthic habitats, such as SAV.
- Monitor fish attraction to anchors, mooring lines, and facility components on the seafloor and in the water column, and identify any negative community change effects that occur as a result of habitat conversion.
- Design mooring and anchoring systems to the minimum necessary for device stability, in order to minimize scour and avoid unnecessary alteration and conversion of benthic habitat.
- Plan construction procedures to occur as quickly and efficiently as possible, to minimize the duration of disruption on the seafloor.

Sedimentation, siltation, and turbidity

- Use the minimum practicable scour protection for turbines and associated structures and cables, in order to avoid alteration/conversion of benthic habitat.
- Bury cables to an adequate depth, in order to minimize the need for maintenance activities and to reduce conflicts with other ocean uses.

Impacts to organisms

- Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area.
- Time construction of facilities to avoid impacts on sensitive life stages and species. Construction in the Pacific Ocean may be technically constrained to the summer season, but may be tailored as necessary based on recommended seasonal work windows specific to regional environmental conditions and sensitive species life histories.
- Make contingency plans and response equipment available at the offshore wind facility to respond to spills associated with maintenance activities.

Alteration of electromagnetic fields

- Measure natural EMF for each proposed project site prior to construction.
- Conduct studies that identify how EMFs generated from offshore wind facilities impact aquatic organisms and EFH.

Noise effects

- Define the area of potential effect, which may vary by project location and affected species.
- Conduct studies that document pre-construction ambient sound of the project area in various sea states. Determine appropriate thresholds above ambient conditions at which marine species could be negatively affected.
- Conduct studies to characterize noise generated from offshore wind facilities and identify how it may impact aquatic organisms and EFH.
- Require a slowly progressing "soft start" for construction activities expected to be audible above background noise, to allow marine animals to vacate the area.

Liquefied Natural Gas

Potential adverse impacts of liquefied natural gas

The following factors associated with transport and processing (i.e., gasification or liquefaction) of liquefied natural gas (LNG) can impact EFH and were summarized below based on Johnson et al. (2008): loss and alteration of habitat, altered hydrology, sedimentation, siltation, and turbidity, release of contaminants, invasive organisms, entrainment and impingement, noise effects, impacts to water quality, and discharge of debris. Suggested conservation measures related to each of these factors are provided in the following sections.

Loss and alteration of habitat

Structures associated with LNG in marine EFH can serve as habitat, and influence species assemblages and larval production of marine organisms (Love et al. 1999, Fabi et al. 2004, Manoukian et al. 2010). New construction of pilings in estuaries results in fill of subtidal habitat and impacts the vertical structure in the water column. Installation of rip-rap or sheet-piling for berth areas will simplify deep-water estuarine habitats, inhibiting the productive capacity for fish and wildlife. Such structures could impact shellfish beds, hard-bottomed habitats, and aquatic vegetation (Gowen 1978, Mills and Fonseca 2003), and underwater trenching for pipeline and cable installation could affect marsh drainage, freshwater, and sediment transport, and increase the inland encroachment of saltwater (Chabreck 1972). Inland encroachment of saltwater can lead to the loss of aquatic vegetation (Pezeshki et al. 1987), causing increased soil erosion and a net loss of organic matter (Craig et al. 1979).

Dredging of estuarine bottom material may be necessary to create space for LNG slip areas, docking facilities, turning basins, access channels, etc. The extent of dredging may vary by project, but maintenance dredging will likely be necessary and will result in repeated and lasting loss and alteration of habitat (Nightingale and Simenstad 2001). Dredging will negatively impact communities and habitats by direct removal, disturbance, and restructuring of the benthic substrata (Armstrong et al. 1981, Newell et al. 1998) and possibly native eelgrass (*Zostera marina*) meadows (Erftemeijer and Lewis 2006) and kelp forests. Eelgrass meadows, and other submerged aquatic vegetation, provide critical cover and energy resources for a number of fish and wildlife species (Kentula and DeWitt 2003, Thom et al. 2003). Macroinvertebrate and fish/shellfish species complexity is typically greater within eelgrass stands than in locations where eelgrass is not present (Hosack et al. 2006).

Facility installation may alter existing habitat in ways that affect physical habitat, the estuarine community composition, and predator–prey relationships. Construction of pilings provides perch opportunities for piscivorous birds that increase predation risk to species like juvenile salmonids. Artificial lighting from over-water structures may affect fish predation, disorient migrating fish (e.g., juvenile salmonids), affect photosynthesis of aquatic vegetation, disrupt foraging behavior, or influence wildlife that predate on fish in estuarine EFH. Dredging may significantly alter the prey base relied upon by demersal fish, including starry flounder, English sole, sand sole, staghorn sculpins, and sturgeon (Nightingale and Simenstad 2001).

Altered hydrology

LNG tankers can alter hydrologic regimes through the discharge of brine from onboard desalination operations, altering salinities in coastal and estuarine EFH (Dodson et al. 1972, Leggett and O'Boyle 1976, Schlenk and Lavado 2011). Dredging estuarine systems to convert shallower habitats to deep-water channels to accommodate large tankers may alter water flow and composition (e.g., salinity, turbidity; Johnston 1981, Nightingale and Simenstad 2001, Van Maren et al. 2015). Effects on marine and estuarine organisms from saline intrusion associated with increased dredging would only be detectable through monitoring (Miller et al. 1990, Newell et al. 1998). Construction of new LNG terminal facilities or natural gas pipelines may interfere with tidal processes or floodplain connectivity. Filling wetlands or clearing vegetation on floodplains could alter hydrology. Waterbody crossings may necessitate dewatering or water diversion.

Sedimentation, siltation, and turbidity

Dredging activities associated with construction and maintenance of the slip, berth, and turning basin will result in initial and intermittent disturbance (for maintenance) to the estuarine water column by increasing turbidity and increasing the load of suspended sediments (Van Maren et al. 2015). The primary ecological impacts associated with dredging, siltation, turbidity, and unnatural loadings of suspended sediment in estuaries include: a) reduced survival and growth of phytoplankton and zooplankton (Irwin and Claffey 1966, Cloern 1987); b) altered feeding capacity and subsequent reduction in planktivorous organisms (Bash et al. 2001, Horppila et al. 2004, Carter et al. 2009); c) direct disturbance and entrainment of bottom fish and benthic epifaunal and infaunal invertebrate communities; d) smothering and burial of benthos; and e) decreased survival and growth of submerged aquatic vegetation and microbenthic algae. The impacts of increased suspended sediments on aquatic organisms depend on the magnitude of increase in concentration and the duration of exposure (Newcombe and Jensen 1996). Increased sedimentation can impact feeding ability (Langhamer et al. 2010), injure gills (Lake and Hinch 1999), and lead to increased mortality in aquatic organisms (Wilber and Clarke 2001). Increased turbidity could alter algal blooms, affecting higher trophic organisms (Frid et al. 2012, Witt et al. 2012). Shallow waters, rocky reefs and rises, marshes, wetlands, and estuaries may be particularly vulnerable to increased sedimentation and turbidity because lower water volumes could decrease dilution and dispersal of suspended sediments (Gowen 1978).

Release of contaminants

There is limited information and experience regarding impacts of LNG spills or leaks; however, because of the toxic nature of natural gas, acute impacts to nearby resources and habitats should be anticipated. Contaminants can be released into the environment, whether during pipeline installation (Gowen 1978) or if pipelines are broken or ruptured by unintentional activities, such as shipping accidents and catastrophic failures. The accidental leaking or spillage of petroleum products can devastate marine (Bue et al. 1998, Dubansky et al. 2013) and freshwater organisms and EFH (Carls et al. 2003). Furthermore, biocides are often used at LNG structures to prevent pipeline and engine fouling from marine organisms. The release of biocides into EFH can contaminate, bioaccumulate, and cause death in nontarget fishes and organisms (Bao et al. 2011, Guardiola et al. 2012). Hydrostatic testing of installed pipelines would necessitate diversion of water and subsequent discharge back to the source waterbody, and discharge could contain contaminants. Accidental release of natural gas liquids or a cloud of toxic gas from an LNG facility would pose threats to human safety and other living organisms in the vicinity.

Invasive organisms

Introduction of invasive species into marine and estuarine waters may pose a significant threat to living marine resources (Carlton 2001). Non-native species can be released unintentionally when ships release ballast water (Niimi 2004). Hundreds of species have been introduced into U.S. waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). LNG tankers entering U.S. waters are generally loaded with cargo and do not need to release large amounts of ballast water. However, even small amounts of released ballast water have the potential to contain invasive species, and vessels can transport invasive species attached to ship hulls. Once introduced, invasive species are expected to flourish in newly disturbed slip areas. Throughout the world, aquatic invasive species are found most prominently in locations with low velocity or no current where transient ships dock (Ruiz et al. 1997). In addition, as vessels are unloaded and ballast is taken on in U.S. waters, the water may contain species that are potentially invasive to other locations. The transportation of nonindigenous organisms to new environments can have severe impacts on habitat (Omori et al. 1994, Keller and Perrings 2011).

Entrainment and impingement

Intake structures for traditional power plants can result in impingement and entrainment of marine organisms (Enright 1977, Helvey 1985, Callaghan 2004). Depending on the geographic location and the water depth of the intake pipe, phytoplankton, zooplankton, and fish eggs and larvae could be entrained in LNG systems. Juvenile fish can also be impinged on screens of water intake structures (Hanson et al. 1977). Increased ship operations associated with LNG facilities could increase the potential for impingement and entrainment of aquatic organisms (Ashe et al. 2013). Gravity or pumped water diversions increase risks for entrainment or impingement of game fish, food fish, and fish species protected under ESA (Nightingale and Simenstad 2001). LNG facilities may require water intake for ballast and cooling water, terminal fire systems, re-deluge fire pumps, reverse osmosis, hydrostatic testing, concrete mixing, road construction, and soil maintenance.

Noise effects

Potential noise sources associated with LNG facilities include aircraft, construction, pile driving, vessel thrusters, dredging, drilling, explosives, seismic exploration, shipping vessels, sonar and acoustic devices, and general site operations. For a comprehensive review see Wyatt (2008).

Undersea noise could interfere with fish communication and orientation (Wahlberg and Westerberg 2005). Furthermore, the noise produced during installation of facilities, cables, and pipelines could impact marine organisms and EFH (Thomsen et al. 2006, Snyder and Kaiser 2009). Noise can affect fish behavior, communication, and, in extreme cases, cause direct tissue damage, resulting in immediate or delayed mortality (Hastings and Popper 2005, Thomsen et al. 2006, Popper and Hastings 2009, Frid et al. 2012, Popper et al. 2014). Behavioral changes can result in increased susceptibility to predation or disruption of feeding, reproduction, or migration (Popper et al. 2014). Many fish species have swim bladders or other gas-filled structures that can detect sound pressure and are more susceptible to physical damage from loud, sudden sounds. In-water blasting, if required, may injure fish and wildlife due to percussion shock waves produced by the energy associated with the explosion. This percussion can cause direct injury and stressors, including bursting of the swim bladder, hemorrhaging, damage to sensory organs, and triggering of displacement behavior in fish species (Nightingale and Simenstad 2001). For example, in the case of underwater explosions, fish with swim bladders are susceptible to barotrauma 100× farther away from the explosion than non-swim bladder fish (Popper et al. 2014). These species are most likely to show behavioral changes from sound (Popper et al. 2014), possibly including altered migration and schooling, which can impact foraging, predator avoidance, or reproductive success. The Clupeiformes (e.g., Pacific herring, American shad, Pacific sardine, northern anchovy), gaddids (e.g., Pacific cod), and juvenile salmonids (e.g., Chinook salmon) have been shown to respond to sound (Thomsen et al. 2006, Knudsen et al. 1997). Sounds produced at frequencies similar to vocalizations of marine mammals or their prey may affect communication, navigation, feeding, or avoidance of predators (Henkel et al. 2014). Harbor porpoises, a species found in the nearshore and in bays, may be particularly sensitive to even low levels of exposure to human-produced sounds (Henkel et al. 2014). There remains little empirical evidence that demonstrates exactly how and to what degree operational noise will negatively impact fish and other aquatic organisms (OSPAR 2009, Gill and Bartlett 2010).

Impacts to water quality

Natural gas is condensed to a liquid by cooling it to –260°F, producing liquefied natural gas that can be stored and transported by ships to and from terminals in the United States (USDOE 2005). Regasification occurs at receiving terminals and satellite facilities around the United States, where LNG is transferred to warming systems that use ambient temperature from air or seawater to vaporize the cryogenic liquid (USDOE 2005). The operation of LNG facilities produces thermal effluent, and altered temperatures can adversely affect marine organisms (Isreal et al. 2011). Ships loading at LNG facilities may discharge heated engine-cooling water, creating a plume of warm water that may stress fish. Dredging activities that elevate turbidity also contribute to higher water temperatures and limited reductions of concentrations of dissolved oxygen in the water column (USACE 1983, Nightingale and Simenstad 2001). Upland and riparian clearing for construction of pipelines and facilities can result in shade loss adjacent to streams that can increase water temperatures.

Discharge of debris

LNG facilities can result in the discharge of debris, including domestic wastewater generated from the offshore facility and other trash and debris from human activities associated with the facility (PFMC 1999). Debris, either floating on the surface, suspended in the water column, covering the benthos, or along the shoreline, can have deleterious impacts on fish and shellfish within benthic and pelagic habitats in the marine environment (NEFMC 1998). Furthermore, debris from natural gas transportation activities can be ingested by fish (Hoagland and Kite-Powell 1997).

Potential conservation measures for liquefied natural gas

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of LNG on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of liquefied natural gas on EFH.

General guidelines

- Address cumulative impacts of past, present, and foreseeable future development projects on aquatic habitats by considering them in the project review process of LNG facility construction and operation. Based on predicted impacts to EFH, a determination can be made regarding the most suitable location and operational procedures for LNG facilities. Ideally, such an analysis would be done at the regional or national level based on natural gas usage and need. However, such analysis is not the case for all activities.
- Require analysis of potential adverse effects to all EFH listed species including native, pelagic, salmonid, and non-salmonid (e.g., eulachon) ESA-listed species potentially present. Impacts on all life stages present (e.g., rockfish juveniles) must be considered.

Loss and alteration of habitat

- Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area.
- Offsite mitigation, if proposed, should be located in habitat similar to that altered by the project, with similar species assemblages.
- Provide detailed monitoring plans should be developed for mitigation activities to evaluate native condition, alteration from project activities, and successful recovery of ecological

function and processes.

- Monitor stream crossing restoration to ensure the trench or otherwise disturbed area does not scour or result in diversion of flow.
- Provide a thorough analysis of lighting needs during project construction and operation, and assess the potential biological effects of such lighting on EFH species. Develop measures to minimize potential effects (e.g., alter light intensity, color, or direction).
- Perform dredging or other construction activities during the appropriate in-water work window to mitigate impacts to less than significant levels.

Altered hydrology

- Require applicant to ensure natural gas pipelines are sufficiently deep along the entirety of the route so as not to interfere with restoration activities (e.g., placement of large woody debris or reestablishment of channel function, tidal processes, or floodplain connectivity).

Impacts to water quality

- Locate facilities that use surface waters for regasification and engine-cooling purposes away from areas of high biological productivity (e.g., estuaries).
- Regulate discharge temperatures (both heated and cooled effluent) such that they do not appreciably alter the temperature regimes of the receiving waters. Implement strategies to diffuse the heated effluent.
- Use regasification and liquefaction systems that neither rely on surface waters nor affect water temperature in the surrounding waters. If a water-sourced system is necessary, use a closed-loop rather than an open-loop system.

Sedimentation, siltation, and turbidity

- Schedule dredging and excavation activities when the fewest species and least-vulnerable life stages are present. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Do not conduct activities that increase turbidity during periods of the year when eelgrass is growing rapidly and is most sensitive to reductions in light (generally starting in July in the Pacific Northwest; Phillips 1984).

Release of contaminants

- Do not use biocides (e.g., aluminum, copper, chlorine compounds) to prevent fouling, where possible. The least damaging antifouling alternatives should be implemented.
- Provide real-time monitoring and leak detection systems at natural gas production and transportation facilities that preclude gas from entering the environment.
- Ensure that gas production and transportation facilities have developed and implemented adequate gas spill response plans. Assist government agencies responsible for gas spills (e.g., U.S. Coast Guard, state and local resource agencies) in developing response plans and protocols, including identification of sensitive marine habitats and development and implementation of appropriate gas spill response measures.

- Require a plan for notification of unintentional spills that alerts state and federal fish and wildlife agencies.
- Require that hydrostatic test water be analyzed for relevant water-quality parameters prior to being discharged back to the source waterbody.

Discharge of debris

- Implement operational monitoring plans to analyze impacts resulting from intake and discharge structures, and link them to a plan for adaptive management.

Entrainment and impingement

- Design intakes that do not impinge or entrain aquatic organisms. Use vaporization systems that do not rely on surface waters as a heat source (e.g., ambient air systems). If a water- sourced system must be used, use closed-loop systems that minimize the volume of water utilized for regasification. Do not use open-loop systems.
- Install fish-screening systems at all ballast and cooling water intakes and all surface water points of diversion. Screen intakes must comply with NMFS screening guidance.[6]
- Acquire written verification of screen inspection and approval by state and federal fish screen experts prior to the withdrawal of any water.
- Require site-specific waterbody crossing plans with fish passage plans for review and approval prior to any construction activity.

Noise effects

- Conduct construction and maintenance activities during periods when activity noisewon't impact organisms inhabiting EFH (e.g., van Staveren et al. 2010).
- When possible, avoid potentially damaging noise effects of activities when ESA-managed species are most abundant, especially sensitive life stages (see PFMC 2019).
- Install hydrophones to document pre-, during, and post-construction and operational noise levels.

Introduction of invasive species

- Develop and adhere to ballast water management guidelines as a first line of defense to prevent introduction of invasive species.
- Monitor newly disturbed areas (e.g., vessel slips) for colonization by invasive species.
- Develop a plan for elimination or control of invasive species if detected. Prescribe changes to project operations that may be implemented to prevent further introduction.

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10. Agriculture and Grazing

Potential Adverse Impacts of Agriculture and Grazing

The following factors associated with agriculture and grazing can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology, sedimentation, siltation, and turbidity, release of contaminants, and impacts to water quality. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Functionality of EFH depends, in part, on bank stability, channel complexity, and condition of riparian vegetation (Zierholdz et al. 2001, USEPA 2003, Vondracek et al. 2005, Palmer et al. 2009). Land development is associated with habitat simplification (e.g., loss of multithreaded channels, floodplains) and reduction in riparian zone and wetland habitat; as vegetation is removed, soils are disturbed and erosion increases, negatively impacting benthic organisms and fishes (Chapman and Knudsen 1980, Kauffman and Krueger 1984, Platts 1991, Clary 1999, USGS 1999, Pess et al. 2002, Scrimgeour and Kendall 2003, Stone et al. 2005, Lohse et al. 2008, Roni et al. 2008, Lindley et al. 2009). Livestock grazing intensity and impacts vary over time and space, habitat and vegetation type, and season (George et al. 2002); seasonal increases in grazing pressure could exacerbate grazing impacts on EFH during periods that are already stressful for aquatic organisms (i.e., during periods of low flows and warm water temperatures; Parsons et al. 2003).

Reductions in flows caused by water withdrawals, such as those used for agriculture, can lead to increased solar heating, increase fish embryo mortality as spawning grounds are exposed (Deitch et al. 2009), reduce food resources (McKay and King 2006), and disrupt larval and juvenile fish recruitment into estuaries (Deegan and Buchsbaum 2005).

Altered hydrology

Freshwater is diverted from EFH to agricultural lands for irrigation of crops and livestock (Adams and Cho 1998, Cuffney et al. 2000, Levy 2003, Markham 2006), impacting hydrologic functionality of EFH (Johnson 1992, Reid 1993, Tabacchi et al. 1998, Deitch et al. 2009). Upstream water use can decrease river flows (Caldwell et al. 2012), alter the transport of sediments (Fajen and Layzer 1993) and organic matter, reduce water depths, alter water chemistry, and affect water temperatures (McCullough 1999). Altered hydrologic functionality can affect survival of embryonic and larval life stages of fish (Cederholm and Reid 1987, DeVries 1997, Quinn 2005, Lohse et al. 2008, Deitch et al. 2009), and can lead to reduction of invertebrate populations (McKay and King 2006) that support fish production (Deitch et al. 2009). Livestock grazing also impacts watershed hydrology through a variety of mechanisms, such as reducing vegetation cover or composition, creating new flowpaths by making trails, and compacting soils (e.g., Trimble and Mendel 1995).

The volume and timing of freshwater delivery to estuary EFH is also impacted by upstream water use resulting from agricultural practices, affecting water residence time, temperature, salinity, water quality, and stratification of the water column (Kimmerer 2002, Flemer and Champ 2006).

Such degradation of estuary EFH can reduce the survival of estuarine-dependent species that have adapted to more dynamic freshwater influxes (Nichols et al. 1986).

Sedimentation, siltation, and turbidity

Agricultural practices such as grazing and tilling can disturb streamside soil and vegetation, reducing organic matter, exposing sensitive soils, affecting water infiltration, and reducing vegetative biomass (Platts 1991, Johnson 1992, Zimmerman et al. 2003, Wooster and DeBano 2006), all of which can increase soil erosion and sedimentation in EFH (Kauffman and Krueger 1984, Wood and Armitage 1997, Hook 2002, Markham 2006, Yuan et al. 2009). Increased sedimentation can inhibit aquatic vegetation (USEPA 2003), interfere with feeding by filter feeders (MacKenzie 2007), clog and harm fish gills (Bilby et al. 1989, Waldichuk 1993), cover fish spawning areas (Cederholm and Reid 1987, Chapman 1988, Smith and Wegner 2001), and alter food supply for invertebrates and fish living in EFH (Newcombe and Jensen 1996, Suttle et al. 2004).

Release of contaminants

The agriculture industry is a major source of contamination and pollution in EFH (Kauffman and Krueger 1984, Platts 1991, Heady and Child 1994, Witman 1996, Saiki et al. 2001, Adams 2002, USEPA 2003, Macneale et al. 2010, USEPA 2013). Contaminants typically introduced to EFH include pesticides (Scholz et al. 2012), herbicides (Nordone et al. 1998, Katagi 2010), and insecticides (Weston et al. 2005) in the form of steroid hormones (Kolodziej and Sedlak 2007), endocrine disruptors (Bertram et al. 2015), and metals (Manning and Burau 1995, Wu 2004, Kiaune and Singhasemanon 2011). With respect to fish, for example, livestock can receive a number of supplements including steroids that affect reproductive pheromones and behavior (Kolodziej and Seldak 2007), endocrine disruptors that affect reproduction and physiology (Brodeur et al. 1997, Johnson et al. 2002, Pait and Nelson 2002, Thurberg and Gould 2005, Baker et al. 2009, Peck et al. 2011), and metals that affect sense of smell and behavior (Kiaune and Singhasemanon 2011).

Runoff from agriculture, particularly livestock manure, typically contains elevated levels of pathogens, including bacteria, viruses, and protozoa (USEPA 2003). Nutrient enrichment of rivers, streams, lakes, wetlands, and coastal waters from agriculture contributes to algal blooms, which are sometimes toxic (Miller et al. 2010, Paerl et al. 2011). These algal blooms can also be associated with reductions in dissolved oxygen (DO) that can be lethal to aquatic organisms (e.g., Camargo and Alonso 2006).

Impacts to water quality

Agricultural practices can influence water quality in EFH, impacting survival of invertebrates and fish (Nehlsen et al. 1991, Levy 2003, Zhu et al. 2012). Loss of riparian vegetation resulting from land conversion for agricultural and other uses can increase solar radiation and water temperatures, reducing suitability of conditions in otherwise important EFH (Tabacchi et al. 1998, Kiffney et al. 2003, Kishi et al. 2004, Moring 2005, Lawrence et al. 2014). Water diversions for agricultural purposes can lead to altered water temperatures, in part, impacting survival of fish (e.g., the die-off of 30,000 Chinook salmon during 2002 in the Klamath River; Levy 2003). Altered temperature regimes also affect fish distribution and habitat use, growth rate, migration patterns, embryonic development, trophic interactions, and susceptibility to parasites and pathogens (USEPA 2003, Quinn 2005).

Agricultural practices can increase nutrient loads and DO in EFH (Reed 2003, Zhu et al. 2012). Nutrients (i.e., nitrogen and phosphorous) from animal waste and fertilizers collect in agricultural lands and flow into EFH (Howarth et al. 2002, Markham 2006, USEPA 2013), leading to increased eutrophication, decreased DO, and significant impacts to fish and other aquatic organisms (Deegan and Buchsbaum 2005). Temperature and DO are important factors affecting the development of embryos, larvae, and juvenile fish (Chapman 1988, Hicks et al. 1991, Quinn 2005). Reduced DO can alter species composition and productivity (Castro et al. 2003) and contributes to the formation of dead zones, areas where DO is too low to support most marine life (Diaz and Rosenberg 2008, Brown and Power 2011, Steinberg et al. 2011). Eutrophication resulting from agricultural and grazing activities can also reduce and alter important vegetation features in marine EFH, such as eelgrass (Short et al. 1993, MacKenzie 2005), and can stimulate the spread of invasive aquatic vegetation, providing increased habitat for invasive predators such as largemouth bass (Mount et al. 2012).

Potential Conservation Measures for Agriculture and Grazing

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of agriculture and grazing on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help land managers avoid, minimize, and mitigate impacts of agriculture and grazing on EFH.

General guidelines

- Promote and incentivize acquisition of agricultural lands, when available, to prevent urban, rural, and upland development, which leads to permanent loss of aquatic habitats.
- Include private landowner, and public and private land manager, input when developing and implementing BMPs (Thompson et al. 2006).
- Collect control and treatment data in the vicinity of agricultural restoration sites prior to restoration activities to evaluate effectiveness of restoration efforts (Cooperman et al. 2007).
- Incentivize protection and restoration of rangelands using practices such as rotational grazing systems or livestock distribution controls, exclusion of livestock from sensitive riparian and aquatic areas, dry residual matter monitoring, the use of off-stream attractants such as water sources and salt or nutrient licks, livestock-specific erosion controls, reestablishment and protection of vegetation to promote growth of desirable native species, and/or extensive brush management correction.
- Incentivize conservation programs, especially those in the Food, Conservation, and Energy Act of 2008 (i.e., the Farm Bill).
- Incentivize the Conservation of Private Grazing Land Program (CPGL), and the Conservation Reserve Enhancement Program (CREP), voluntary programs that help owners and managers of private grazing land address natural resource concerns while enhancing the economic and social stability of grazing land enterprises and the rural

communities that depend on them. Technical assistance is provided by the Natural Resource Conservation Service.

Loss and alteration of habitat

- Roads for agricultural lands must be sited in locations to avoid sensitive areas such as streams, wetlands, and steep slopes. Decommission and relocate all roads that impact vulnerable and sensitive areas.
- In actively grazed areas, reconstruct riparian buffers and implement monitoring, management, and grazing regimes. In degraded grazed areas in or near streams, wetlands, and the riparian zone, implement mitigation to reconstruct riparian buffers with the goal of restoring riparian–aquatic functionality.
- Construct, manage and mitigate riparian and stream corridors to improve terrestrial invertebrate production (Saunders and Fausch 2007), streamside shading, large woody debris and leaf litter inputs, and sediment and nutrient routing control (Lowrance et al. 2002). The width of the buffers is dependent upon site characteristics; various methods can be implemented: riparian forest planting, alley cropping, filter strips, field borders, etc. (Fischer and Fischenich 2000).
- Do not plant crops in areas with steep slopes and erodible soils, and do not disturb or drain wetlands and marshes.
- Design restoration projects that provide durable structures used to increase cover, improve geomorphologic functionality, and reduce erosion (e.g., timber and log check dams; Allan 2004).
- Implement rotational grazing, livestock exclusion, manure storage, and off-stream watering and feeding sites to reduce impacts of grazing on riparian and stream habitat and benthic communities (Platts 1991, Lyons et al. 2000, McInnis and McIver 2001, Scrimgeour and Kendall 2003, Yates et al. 2007).
- Implement no-till crop management to reduce impacts of crop management on riparian and stream habitat (Yates et al. 2006).

Altered hydrology

- Redesign and operate water diversion systems to ensure that flow conditions provide for passage and proper timing of life-history stages of aquatic organisms.
- Monitor diversion facility operations to assess impacts on water temperatures, dissolved oxygen, and other applicable parameters, and use adaptive management to minimize impacts.

Sedimentation, siltation, and turbidity

- Ensure stream grazing buffer width is at least 6 m (Hook 2002, Yuan et al. 2009) to retain banks and decrease sedimentation in EFH, and ensure that buffers cover enough length of stream so that restoration efforts are effective (Wooster and DeBano 2006).
- Monitor the duration of increased suspended sediments to evaluate potential impacts on invertebrates and fishes (Vondracek et al. 2003).
- Utilize spatially explicit evaluations of land cover to understand erosion potential (Wissmar et al. 2004).
- Reduce erosion and run-off by using practices such as contour plowing and terracing, no-till agriculture, conservation tillage, crop sequencing, cover and green manure cropping and crop residue, and by maximizing use of riparian management zones. Some approaches include filter strips, field borders, grassed waterways, terraces with safe outlet structures, contour strip cropping, diversion channels, sediment retention basins, and restoration of riparian vegetation.

- Utilize upland grazing management that minimizes surface erosion and disruption of hydrologic processes. Eliminate livestock access into riparian zones and stream reaches.
- Establish proper streambank alteration move triggers and endpoint indicators, in combination with the other management measures intended to reduce the amount of time livestock spend in riparian areas, to reduce the amount of fine sediment introduced into streams.
- Include BMPs for agricultural road construction plans, including erosion control, avoidance of side casting of road materials into streams, and native-only vegetation in stabilization plantings. Design road systems to direct water to infiltration areas rather than directly to streams.
- Protect and restore soil quality using practices that improve native soil characteristics such as permeability, water retention, nutrient uptake, organic matter content, and biological activity. BMP examples include cover cropping, crop sequencing, sediment and infiltration basins, contour farming, conservation tillage, crop residue management, grazing management, and the use of low-compaction farming equipment.

Release of contaminants

- Install fencing and expand riparian vegetation buffers to reduce discharge of animal waste into EFH (Kolodziej and Sedlak 2007).
- Minimize water withdrawals for irrigation and promote water conservation measures, such as more efficient irrigation systems (e.g., convert sprinkler irrigation systems to drip systems in orchards). Use alternative water sources such as rooftop rain collection or reclaimed municipal (or agricultural) wastewater, where available. Reuse drainage water on sequentially more salt-tolerant crops, or recapture and blend with freshwater until the necessary salinity is achieved (CDFG and NMFS 2002).
- Develop and use seasonal restrictions to avoid impacts to habitat during critical life-history stages for aquatic organisms. Seasonal work windows are specific to regional or watershed-level environmental conditions and species life-history requirements.

Impacts to water quality

- For comprehensive review of stream water quality BMPs related to agricultural impacts, see Agouridis et al. (2005).
- Incorporate and incentivize water-quality monitoring as an element of landowner assistance programs for water quality. Assist with evaluation of monitoring data, and assist landowners with adjustments to agricultural practices as needed.
- Ensure efficient use and appropriate application of pesticides on agricultural land, and that such chemicals do not come into contact with EFH—neither directly nor indirectly. Monitor nearby water bodies for contamination and incentivize measures to prevent the flow of pesticides into adjacent water bodies. BMPs include use of integrated pest management, planting of insectary cover crops or borders to increase beneficial insect populations, frequent calibration of spray equipment, monitoring of wind speeds with weather stations or anemometers rather than visual means, incentivized use of least-toxic pesticides, irrigation management, soil monitoring for moisture and nutrient levels, monitoring plant nutrient levels, and

careful timing of nutrient applications. Select pesticides considering their persistence, toxicity, runoff potential, and leaching potential.

- Eliminate the use of chemical treatments within the riparian zone. Reduce pesticide use by evaluating pest problems and understanding past pest control measures. Select pesticides considering their persistence, toxicity, runoff potential, and leaching potential.
- Do not apply manure or other fertilizer to land unless appropriate management measures are in place to eliminate sediment and nutrient input to EFH.
- Do not site or expand animal facilities adjacent to EFH, or in areas with high leaching potential to surface or groundwater. Use BMPs to minimize discharges from animal facilities (for both wastewater and process water).
- Do not site animal facilities (e.g., feedlots, corrals, horse boarding facilities) near EFH or adjacent habitats such as the riparian zone, or near areas with potential for leaching or runoff. Relocate existing facilities or management areas to appropriate locations. At new locations, ensure that adequate nutrient and wastewater collection facilities are in place and serviceable.
- Investigate biofiltration systems, such as those used for urban runoff, for their utility in improving water quality in EFH located near systems degraded by agriculture and grazing practices.

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11. Shoreline and Bank Stabilization

Potential Adverse Impacts of Shoreline and Bank Stabilization

Where water meets land (banks and shorelines) provides critical EFH that performs a variety of ecological functions. Anthropogenic modification of these habitats can have several negative impacts on EFH, including impairing migration, refugia, and conditions for rearing and spawning. The following factors associated with shoreline and bank stabilization can impact EFH, including: altered hydrology and geomorphology, loss and degradation of habitat (e.g., changes in microclimate), and release of contaminants. Suggested conservation measures related to each of these factors are provided in the following section.

By design, streambank stabilization projects prevent lateral channel migration, effectively forcing streams into a simplified linear configuration that, without the ability to move laterally, instead erode and deepen vertically (Dunn and Leopold 1978, Randle 2006). The resulting "incised" channel fails to create and maintain aquatic and riparian habitat through lateral migration, and can instead impair groundwater/stream flow connectivity and repress floodplain and riparian habitat function. The resulting simplified stream reach typically produces limited macroinvertebrate prey (Lennox and Rasmussen 2016) and presents poor functional habitat for rearing juvenile salmonids (Lau et al. 2006). Also, because bank stabilization structures are typically designed to withstand high streamflow caused by large storm events, the structures, and by extension the impacts to instream habitat, can be considered everlasting, harming future fish generations in perpetuity. Lastly, streambank stabilization impacts not only extend temporally; altered geomorphic and hydraulic processes can propagate spatially both upstream and downstream of bank stabilization structures, dependent upon site- and structure-specific characteristics (Florsheim et al. 2008).

Altered hydrology and geomorphology

Shoreline and bank stabilization can alter hydrology and geomorphology in nearshore EFH (for more comprehensive reviews, see Williams and Thom 2001, Nordstrom 2014). Protection of eroding coastal cliffs can suppress the supply of sand to beaches (Stamski 2005). Reduced erosion impairs landward migration of shorelines, leading to confinement of beaches (Dugan et al. 2011, Noujas et al. 2014) and changes in bottom form and substrate that can reduce habitat suitability for aquatic plants, invertebrates, and fish (Williams and Thom 2001). Jetties and other protective or stabilizing structures redirect wave energy, leading to coarsening of substrates, reduced sediment storage, transport and deposition of organic debris, and altered temperature, salinity, and water surface elevation in nearshore EFH (Williams and Thom 2001, Rice 2006, Dugan et al. 2011, Heerhartz et al. 2014).

Armoring structures (e.g., dikes, seawalls, bulkheads) are constructed in the nearshore to control flooding and erosion (Scavia et al. 2002, Hanak and Moreno 2012); however, in many cases, they actually increase erosion (Stamski 2005). Shoreline armoring can also reduce habitat complexity and abundance and alter hydrology, influencing littoral drift and larval and sediment transport (Williams and Thom 2001, Johnson et al. 2009, Bulleri and Chapman 2010).

Structures can have compounding impacts on hydrologic processes in EFH. Dikes, levees, ditches, and other water-control structures can eliminate the movement of materials into and out of marshes, preventing water, sediment, organic matter, and nutrient exchange (Williams and Thom 2001, Heerhartz et al. 2014, Nordstrom 2014). Blockage of freshwater exchange can result in a lowered water table, increasing saltwater intrusion into marshes and creating migration barriers for some aquatic species. Hydrogen sulfide, which is toxic to some organisms, may be produced in deeper channels where anoxic conditions prevail, and acidic conditions, often associated with anoxia, could result in release of bioavailable heavy metals bound to sediments.

Loss and alteration of habitat

Shoreline protection and bank stabilization can lead to the loss and alteration of nearshore EFH. Habitat heterogeneity or complexity and other environmental conditions, such as water quality and temperature, are important factors influencing species composition and ecosystem productivity (accrual of biomass) of nearshore EFH (Tonnes 2008, Scapini 2014); shoreline structures can impede processes that maintain these important attributes (Rice 2006, Nordstrom 2014). Artificial structures inconsistent with the character of natural EFH can reduce both production of important refuge such as eelgrass and other submerged aquatic vegetation (Shafer 1999, Ely and Viani 2008) and accumulation of organic matter (Tonnes 2008, Heerhartz et al. 2014). Loss of such structure can impact colonization, abundance, and density of intertidal organisms (Bulleri and Chapman 2010, Heerhartz et al. 2016) and organic and nutrient dynamics, with likely consequences for higher trophic levels. Armoring of the shoreline can reduce shallow-water and intertidal habitat, lead to coarsening of substrates, and reduce organic debris, altering macroinvertebrate assemblages and reducing important prey sources for fish (Sobocinski et al. 2010). In Puget Sound, Washington, epibenthic invertebrate densities were over ten times greater on unarmored shorelines, and species richness was twice that of armored locations (Morley et al. 2012). Changes in habitat characteristics of shorelines can reduce habitat suitability for a variety of organisms, including small pelagic fish (e.g., herring, surf smelt, sand lance; Quinn et al. 2012), English sole (Toft et al. 2007), and juvenile salmon in freshwater (Jorgensen et al. 2013). In addition, anthropogenic shoreline modification can impact microclimate (e.g., temperature, moisture, light) that can affect aquatic species. An artificially modified beach (armoring) had significantly higher daily mean light intensity and air and substrate temperature, and lower humidity, relative to a nearby natural beach—potentially contributing to a 50% reduction in viable surf smelt embryos on the armored beach (Rice 2006).

Habitat alterations associated with shoreline protection and bank stabilization structures can alter community assemblages, abundances, and trophic structure (Froeschke et al. 2005, Wen et al. 2010, Gidley et al. 2012, Munsch et al. 2014). Breakwaters and jetties can bury and remove resident biota and alter cover, prey sources, and presence of predators, thereby impacting EFH (Williams and Thom 2001). Although there were no changes in abundance or richness relative to natural reefs, trophic generalists replaced reef-obligate fish following construction of concrete breakwaters (Wen et al. 2010), and the proportion of younger fish increased at artificial structures over natural reefs in nearshore habitats of the North Sea (Wehkamp and Fischer 2013). While there is some evidence that artificial structures support fish assemblages comparable to those of natural reefs (Fowler and Booth 2013), more research is needed to investigate how aquatic organisms respond to modification of coastal shorelines (Wehkamp and Fischer 2013).

Release of contaminants

The use of chemicals (creosote, chromated copper arsenate, and copper zinc arsenate) in wood products used for shoreline and bank stabilization can increase the amount of chemicals and contaminants in coastal EFH (Ownby et al. 2002). Chemicals are used to protect the wood from fungus, insects, and marine boring animals, but are released over time via leaching following contact with water (rain or snow) or when physical activities on the structure cause wood fibers to dislodge. Chemicals released from these structures can bioaccumulate in the food web (USEPA 2005, Sandahl et al. 2007, Macneale et al. 2010) and impair physiology, behavior, growth, survival, and reproduction of invertebrates and fish (Dethloff et al. 2001, Meador et al. 2010, Feist et al. 2011, Scholz et al. 2011).

Potential Conservation Measures for Shoreline and Bank Stabilization

The following measures can be undertaken by the action agency on a site-specific basis to avoid, minimize, and mitigate impacts of shoreline and bank stabilization on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The options represent a short menu of actions that could help developers avoid, minimize, and mitigate for impacts of shoreline and bank stabilization on EFH.

General guidelines

- Use vegetation methods or “soft” approaches (beach nourishment, vegetative plantings, placement of large woody debris) instead of “hard” modifications. Hard modification should be a last resort after ruling out the efficacy of tree revetments, stream flow deflectors, and vegetative riprap, among other soft approaches. Soft, “natural,” “ecosystem-based,” or “living shoreline” coastal protection has potential to be more ecologically sound than coastal armoring (Piazza et al. 2005, Shepard et al. 2011, Hanak and Moreno 2012). Living shorelines provide the service of hard structures while also promoting ecological restoration (Swann 2008, Gedan et al. 2011). Artificial reefs are naturally forming ecological structures used as submerged breakwaters to stabilize and minimize adverse impacts to the shoreline (Piazza et al. 2005).
- Predetermine the cumulative effects of existing and proposed shoreline and bank modification projects on EFH. Assessments must include prey species (Heerhartz et al. 2016).
- Use manmade structures in combination with ecosystem-based methods (e.g., oyster domes) to promote both shoreline protection and ecological benefits (Gedan et al. 2011).
- Use seasonal restrictions on construction or maintenance to avoid impacts during critical life-history stages of fish (e.g., spawning, egg and larval development periods). Seasonal work windows

are generally specific to regional or watershed-level environmental conditions and species requirements.
- Use tidal windows. Do work during low tide.

Altered hydrology and geomorphology

- Do not install new water-control structures in tidal marshes and freshwater streams. If the installation of new structures in this EFH cannot be avoided, ensure that they are designed to allow optimal fish passage and natural water circulation.
- Develop design criteria based on site-specific geomorphology, hydrology, and sediment dynamics appropriate for the stream channel for any stabilization, protection, and restoration projects.
- Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties, especially when "hard" shoreline stabilization is deemed necessary.
- Monitor water-control structures for potential alteration of water temperature, dissolved oxygen concentration, and other water-quality variables.
- If all other alternatives have been exhausted and armoring a riverbed must occur, construct a low-flow channel to facilitate fish passage and help maintain water temperature in reaches where armoring occurs.

Loss and alteration of habitat

- Mitigate for any losses in stream EFH by installing habitat-forming structures such as anchored rootwads, deflector logs, boulders, or rock weirs, and by replanting native vegetation.
- Use an adaptive management plan with ecological indicators to oversee monitoring and ensure mitigation objectives are met. Take corrective action as needed.
- Preserve and enhance EFH by providing new gravel for spawning areas (beach nourishment), removing anthropogenic barriers to fish passage, and using weirs, grade-control structures, and low-flow channels to provide suitable fish habitat.
- Revegetate sites to resemble the natural ecosystem community and maintain an appropriate riparian buffer zone.
- Do not dike or drain tidal marshlands, estuaries, or any other EFH waterbodies.
- Do not cause losses in the area of coastal wetlands, or of riparian vegetation and habitat.

Release of contaminants

- Do not use protection or stabilization materials treated with chemicals.

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12. Marine and Freshwater Transportation

Demand for marine and freshwater transport and associated facilities and infrastructure has increased in recent decades (UNCTAD 2013), and many factors associated with these activities impact aquatic organisms and EFH. Construction and operation of ports and marinas can fragment, contaminate, and increase noise, sedimentation, and turbidity in EFH (Miller et al. 1983, Thom et al. 1997, Penttila 2000). Vessel activities—such as wake generation, anchor and propeller scour, vessel groundings, invasive species, and contamination (Wilbur and Pentony 1999, Uhrin and Holmquist 2003, Eriksson et al. 2004)—impact benthic, shoreline, and pelagic organisms that inhabit EFH (Yousef 1974, Karaki and vanHoften 1975, Barr 1993). Navigational dredging (see Chapter 14) creates turbidity, altering light penetration (Kenworthy and Fonseca 1996) and water circulation (Deegan and Buchsbaum 2005), and disrupts benthic communities (Watling et al. 2001, Bolam and Rees 2003).

This chapter is divided into three sections that outline some of the adverse impacts of marine and freshwater transportation on EFH, including factors associated with Ports and Marinas, Vessel Operation and Maintenance, and Navigational Dredging and Disposal. Suggestions for avoidance, minimization, and mitigation of these possible effects on EFH are provided after each section.

Ports and Marinas

Potential adverse impacts of ports and marinas

Construction, expansion, operation and maintenance of ports and marinas can have several negative impacts on EFH, described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, sedimentation, siltation, and turbidity, release of contaminants, impacts to organisms, and noise effects. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Port and marina facilities are typically located in areas containing highly productive intertidal and subtidal EFH, including saltmarsh wetlands and marshes that contain submerged aquatic vegetation (SAV). Piers, docks, floating breakwaters, barges, rafts, booms, and mooring buoys shade these habitats and fragment important migratory corridors and rearing and spawning habitat (Burdick and Short 1999, Shafer et al. 2008). Floats, rafts, and barges can ground at low tides, scouring substrate, and piles, anchors, and mooring buoys can alter substrate adjacent to structures (Penttila and Doty 1990, Page et al. 2006). Shoreline armoring reduces heterogeneity of EFH, altering the composition and distribution of aquatic organisms (Williams and Thom 2001, Toft et al. 2007, Morley et al. 2012, Jorgensen et al. 2013).

Vessels that moor in ports and marinas can smother or crush shellfish, scour vegetation, and disturb substrates, which can fragment critical habitats (Betcher and Williams 1996). Anchors connected to surface buoys often scour the bottom and form depressions in the substrate (Walker et al. 1989).

Altered hydrology and geomorphology

Transportation-related structures (e.g., pilings, breakwaters, armored shorelines) alter current patterns and water movement, causing scour (Miller et al. 1983), altering sediment deposition (Iannuzzi et al. 1996), and impacting invertebrate and fish communities (Clynick 2006). Pilings alter water velocities, causing increased scour around the base of piles, and floating piers and docks alter wave energy, current patterns, and longshore sediment transport, especially in areas that experience strong current velocities (Kelty and Bliven 2003). Alteration of hydrologic functionality can inhibit natural processes that create EFH and replenish substrate for plant propagation, fish and shellfish settlement and rearing, and forage fish spawning (Thom et al. 1998, Penttila 2000).

Sedimentation, siltation, and turbidity

Port or marina construction can cause increased sedimentation, siltation, and turbidity in marine EFH, impacting aquatic flora and fauna (Erftemeijer and Lewis 2006, Fettweis et al 2011, Erftemeijer et al. 2013). Jetties and groins alter substrate composition and bathymetry (Johannessen 2010), and may reduce or alter sediment transport. This can lead to increased shoreline erosion, alteration of currents, and interference with distribution of larval fish and invertebrates (Williams and Thom 2001). Sediments near ports and marinas are often contaminated, and resuspension of these sediments renders them bioavailable to organisms inhabiting EFH (Roberts 2012).

Release of contaminants

Chemicals used during port and marina maintenance activities can contaminate EFH, thereby affecting plants, invertebrates, and fish (Weis et al. 1991, Pentony 1999, Wilbur and Amaral et al. 2005, Schiff et al. 2007). Arsenic (paint and preservative), zinc (corrosion anodes), mercury (float switches), lead (batteries), nickel, and cadmium (brake linings) contaminate EFH in the vicinity of ports and marinas (USEPA 2001). Organic compounds such as sewage, trash, fish waste, pet waste, fertilizers, and food wastes degrade water quality and alter dissolved oxygen concentrations (USEPA 2001). Changes in water quality can impact important SAV, such as seagrass (Costa et al. 1992, Burdick and Short 1999). Creosote-treated wood (NOAA 2009) causes phototoxicity, disturbs hormone regulation (van Brummelen et al. 1998), and is immunotoxic (Möller et al. 2014) to aquatic organisms. Wood treated with alternative chemicals, such as ammoniacal copper zinc arsenate and chromated copper arsenate, also leaches contaminants into EFH, but residence time is shorter than creosote (Poston 2001). Port and marina structures impede water circulation, sometimes concentrating contaminants and nutrients (Moreno et al. 2009).

EFH in ports and marinas is often dredged and filled, resuspending contaminated sediments (Edinger and Martin 2010). The ecological effects of these sediment-associated contaminants vary by life stage and species (Besser et al. 2007, Vardy et al. 2014). Contaminants are not always lethal, but can have sublethal effects on fish physiology and behavior that could lead to lower rates of growth and reproduction and increase susceptibility to predation (Poston 2001, Johnson et al. 2007, Spearow et al. 2011, McIntyre et al. 2012, Sovová et al. 2014).

Impacts to organisms

Structures associated with ports and marinas shade the water surface, reducing the amount of sunlight available to adjacent pelagic and benthic habitats and directly affecting growth, distribution, and behavior of aquatic organisms (Iannuzzi et al. 1996, Kenworthy and Fonseca 1996, Able et al. 1998, Burdick and Short 1999, Shafer 1999, Haas et al. 2002, Zimmerman 2006, Tabor et al. 2011, Ono and Simenstad 2014). These structures can also serve as habitat for non-native species, which can spill over to invade adjacent benthic habitats (e.g., Simkanin et al. 2012).

Noise effects

Noise pollution in ports and marinas results from high amounts of vessel activity and construction (Hildebrand 2004, Jasny et al. 2005). The magnitude of vessel noise correlates with size of vessel, so ports that accommodate large shipping containers may experience increased impacts from noise pollution (Jasny et al. 2005). Pile driving is a major source of noise pollution in ports and marinas, but several factors, including the size and material of the piling, the firmness of the substrate, and the type of pile-driving hammer used, affect the type and intensity of noise (Feist et al. 1996).

Impacts to fish vary by species and life stage and depend on frequency and magnitude of noises (Hildebrand 2004, Popper and Hastings 2009, Halvorsen et al. 2011, Halvorsen et al. 2012), which differ among and within activities (Feist et al. 1996) and among different environments (Rogers and Cox 1988). Smaller fish species can be more sensitive to underwater noise than larger ones (Yelverton et al. 1975), but all life stages can be negatively impacted (Popper 1993). Noise can also impact marine invertebrates physically (André et al. 2011) and behaviorally (Wale et al. 2013).

Potential conservation measures for ports and marinas

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of ports and marinas on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help land managers avoid, minimize, and mitigate impacts of ports and marinas on EFH.

General guidelines

- Identify the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for port and marina construction and operations.
- Design and implement mitigation for losses in EFH caused by new development or expansion of ports and marinas.
- Incentivize state and local authorities to assist port authorities and marinas in developing management plans that avoid and minimize impacts to EFH. Incorporate operational controls that practice BMPs to reduce impacts to EFH. Design job descriptions and work instructions to protect EFH within and around ports and marinas.
- Incentivize marina operator participation in the NOAA/EPA Coastal Nonpoint Pollution Control Program and the Clean Marina initiative.
- Identify environmental impacts and provide marina operators with the means to clearly and efficiently identify potential environmental impacts. Assist operators with implementing environmental practices, evaluating BMPs and technologies such as evaluation and monitoring technologies, reducing impacts of pump out facilities, improving stormwater management, and developing and implementing environmental management guidelines.

- Incentivize alternative ports, such as satellite ports and offshore terminals, to reduce impacts of inshore ports.

Loss and alteration of habitat

- Conduct site suitability analyses for new or proposed expansion of port and marina facilities. Analyses should predict alterations to current and circulation patterns, water quality, bathymetric and topographic features, fish utilization, species distributions, and substrates.
- Minimize the footprint of new facilities (see PFMC 2019).

Altered hydrology and geomorphology

- Do not locate new port and marina facilities in areas that have reduced tidal exchange or shallow-water habitats (e.g., enclosed bays, salt ponds, tidal creeks).
- Retain and preserve marine riparian buffers to maintain intertidal microclimate, flood and stormwater storage capacity, and nutrient cycling.
- Design proposed ports and marinas to facilitate acceptable levels of water circulation and maintain migratory corridors for organisms.
- Do not construct or permit structures that impede tidal exchange and that may interfere with the movement of marine organisms (e.g., solid breakwaters).
- Require low-wake vessel technology and appropriate vessel routes in facility design and permitting. Vessel speeds must minimize wake damage to shorelines, and no-wake zones should be considered in highly sensitive areas, such as fish spawning habitat and SAV beds.

Sedimentation, siltation, and turbidity

- Use hydrodynamics models to estimate sediment transport and turbidity prior to construction in ports and marinas to enable long-term monitoring of the effects of such developments.
- Site new or expanded port and marina facilities in deep-water areas to avoid the need for dredging. Avoid areas that are subject to rapid shoaling or erosion, as they will require frequent maintenance dredging, which impacts EFH.
- Ensure that floating structures, including barges, mooring buoys, and docks, are located in adequate water depths to avoid propeller scour and grounding of vessels and floating structures. When floating docks cannot be located in adequate depth to avoid contact on the bottom at low tides, install float stops (structural supports to prevent the float from resting on the bottom). Float stops should be designed to provide a minimum of 2 feet of clearance between the float and substrate, to prevent hydraulic disturbances to the bottom. Greater clearances may be necessary in higher-energy environments that experience strong wave action.
- Use anchoring techniques and mooring designs that avoid scouring from anchor chains (e.g., helical anchors, subsurface float moorings). Avoid areas prone to high current and wind velocity, which can cause losses to EFH.
- Use vibratory hammers when removing old piles to reduce suspended sediments, silt, and contaminants into the water column; these may be preferable over direct pull or the use of a clamshell dredge.

Release of contaminants

- Develop site-specific solutions to nonpoint-source pollution by considering the frequency of marina operations and potential pollution sources. Management practices should be tailored to the specific issues of each marina.

- Do not use wood treated with preservatives, such as ACZA and CCA. If CCA-treated wood must be used, the wood can be presoaked for several weeks, or the wood can be coated with a plastic sheath to reduce or eliminate leaching.
- Use concrete and steel pilings. However, concrete pilings and docks generally increase the overall size of the overwater structure and may not be preferable in areas containing SAV.
- Ensure that marina and port facility operations have contaminant spill response plans and equipment in place and are clearly marked and easily accessed. Oil-spill response equipment may include oil booms, absorbent pads, and oil dispersant chemicals.
- Use dispersants that remove oils from the environment, rather than those that simply move them from the surface to the ocean bottom.
- Install automatic shut-off nozzles at fuel dispensing sites and require the use of fuel/air separators on air vents or tank stems to reduce the amount of fuel or oil spilled at stations.
- Incentivize the use of oil-absorbing materials in the bilge areas of all boats with inboard engines.
- Place containment berms around machinery.
- Incentivize and promote the use of pump-out facilities and restrooms at marinas and ports to reduce the release of sewage into surface waters. Ensure that these facilities are maintained and operational, and provide these services at convenient times, locations, and reasonable cost.
- Designate protected areas for maintenance activities (sanding, painting, engine repairs, abrasive blasting).
- Ensure that facilities provide for appropriate storage, disposal, transfer, containment, and disposal facilities for harmful liquid material, such as solvents, antifreeze, and paints, and a containment filtering and treatment system for vessel wash-down wastewater.
- Require proper disposal of solid debris and polluting materials.
- Provide lidded garbage containers to reduce litter in the marine environment.
- Prohibit disposal of fish waste or other nutrient-laden material in marina or port basins by providing containers.
- Develop biofiltration systems for runoff in parking lots and from other impervious surfaces.
- Minimize the amount of impervious surfaces surrounding the port or marina facility, and maintain a buffer zone between the coastal zone and upland facilities.
- Implement runoff-control strategies to decrease the amount of contaminants entering marine waters from upland sources. Use alternative surface materials such as crushed gravel, decrease the slope of surfaces toward the water's edge, and install filtering systems or settling ponds to accomplish this.

Impacts to organisms

- Tall narrow piers and docks produce more diffuse shadows, which have been shown to reduce shading impacts to SAV, such as seagrasses (Burdick and Short 1999, Shafer 1999).
- Shading caused by structures can be ameliorated through the use of adequate spacing of the pilings, and light-reflecting materials (Thom and Shreffler 1996).
- Do not develop ports and marinas in or near areas that support high abundances and diversities of organisms (e.g., SAV beds, intertidal mudflats, emergent wetlands, fish spawning areas).

- Conduct pre- and post-project biological surveys over multiple growing seasons to assess impacts on submerged and emergent aquatic vegetation communities.
- Site floating docks, which limit light transmittance more than elevated structures, only in non-vegetated, deeper, protected areas.
- Orient night lighting to avoid illumination of the surrounding waters.
- Implement seasonal restrictions to avoid construction-related impacts on organisms during critical life-history stages.

Noise effects

(For additional details on noise effects see PFMC 2019.)

- Use technologies designed to reduce the adverse effects of underwater sound pressure waves (air bubble curtains and metal or fabric pile sleeves).
- Conduct pile driving only during low tides in intertidal and shallow subtidal areas.
- Use vibratory hammers while pile driving to the greatest depth possible, and only use impact hammers for proofing.

Vessel Operation and Maintenance

Potential adverse impacts of vessel operation and maintenance

The following factors associated with vessel operation and maintenance can impact EFH and are described briefly below: loss and alteration of habitat, sedimentation, siltation, and turbidity, release of contaminants, invasive organisms, noise effects, release of debris, and abandoned and derelict vessels. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Vessel operation and maintenance can have negative impacts on EFH (Klein 1997, Uhrin and Holmquist 2003). The severity of these effects depends on type and size of vessel and associated activity, which dictates wave energy and surge produced by the vessel, but also depends on shoreline slope, substrate, shoreline vegetation, and other characteristics of aquatic habitat (e.g., water depth, bottom topography; Karaki and van Hoften 1975, Barr 1993). Regardless of vessel size, altered wake and wave action can hamper growth, production, and distribution of SAV important to aquatic organisms (Doyle 2001), potentially impacting biodiversity (Wilcox and Murphy 1985) and habitat suitability for fish and shellfish (Eriksson et al. 2004).

Sedimentation, siltation, and turbidity

Vessel activity can increase suspension of sediment and silt, leading to increased turbidity in EFH; however, effects depend on the magnitude and frequency of wave energy and surge produced by the vessel, sediment particle size, and water depth (Karaki and van Hoften 1975, Barr 1993). Reduced water clarity and light penetration can fragment important vegetation beds (i.e., eelgrass), and resettlement of sediment and silt can smother aquatic vegetation and benthic organisms (Barr 1993, Klein 1997, Eriksson et al. 2004).

The resuspension of sediments resulting from vehicle activity can affect habitat suitability, spatial distribution, and abundance of fish and shellfish in EFH (Nightingale and Simenstad 2001a, Uhrin and Holmquist 2003, Eriksson et al. 2004). Embryo and larval stages of marine and estuarine fish are generally highly sensitive to increased levels of suspended sediment (Wilber and Clarke 2001). Juvenile fish may be susceptible to gill injury when suspended sediment levels are high, and sedimentation and turbidity impacts may be more pronounced in areas that contain shallow-water habitat with fine substrates (Klein 1997).

Release of contaminants

Industrial shipping and recreational boating can introduce toxic metals—such as arsenic, cadmium, copper, lead, and mercury—into EFH, impacting aquatic organisms (Woodward et al. 1994, Wilbur and Pentony 1999, Spearow et al. 2011, McIntyre et al. 2012, Sovová et al. 2014). Metals enter the water through various vessel maintenance activities such as washing, scraping, and the application of antifouling agents (Milliken and Lee 1990, Hofer 1998, Amaral et al. 2005). Herbicides are also used in some antifouling paints, and can impact plant and animal community structure (Readman et al. 1993).

Fuel and oil spills from vessels can harm aquatic organisms inhabiting EFH (Neff 1985). Properly maintained vessels may not leak large amounts of fuel and oil, but small, repeated releases of oil are common (contributing nearly 85% of the total input of oil into aquatic habitats; ASMFC 2004). Effects of low-level chronic exposure by fish to fuels and oil include increased embryo mortality, reduced growth, and altered migratory patterns (Heintz et al. 2000, Wertheimer et al. 2000). Exhaust from two-cycle engines contains hydrocarbon compounds (Moore and Stolpe 1995) that may remain suspended in the water column, concentrate on the surface, or settle to the bottom (Milliken and Lee 1990).

Gray water and sewage discharge from boats can impact water quality in EFH by increasing nutrient loading, bacteria, and toxic substances, including emerging contaminants such as synthetic hormones (Thom and Shreffler 1996, Klein 1997). The Clean Water Act of 1972 makes it illegal to discharge untreated wastes into coastal waters, and the Federal Water Pollution Control Act requires recreational boats to be equipped with marine sanitation devices (MSDs); however, it is legal to discharge treated wastes, and illegal discharges of untreated waste may be common (Milliken and Lee 1990, Amaral et al. 2005). Furthermore, impacts from vessel waste discharges may be more pronounced in small, poorly flushed waterways where pollutant concentrations can reach unusually high levels (Klein 1997).

Invasive organisms

Invasive species are often introduced to EFH by industrial and recreational vessels (Omori et al. 1994, Hofer 1998, Wilbur and Pentony 1999, Pertola et al. 2006). Invasive species can impact EFH by reducing habitat suitability for fish (Deegan and Buchsbaum 2005), benthic communities (Grosholtz et al. 2009), and aquatic vegetation (Santos et al. 2011), and can impact trophic processes (Sanderson et al. 2009, Carey et al. 2011, Grason and Miner 2012) and genetic composition (Palumbi 2003), and can increase pathogens (Minchinton and Bertness 2003, Deegan and Buchsbaum 2005, Rahel and Olden 2008).

Noise effects

The noise generated by vessel operations concentrates in ports, marinas, and heavily used shipping lanes or routes, and may impact fish spawning, migration, and recruitment behaviors (Stocker 2002, Hildebrand 2004, Codarin et al. 2009).

Exposure to continuous noise may also impair hearing in aquatic organisms (Jasny et al. 1999, Scholik and Yan 2002). Small craft with high-speed engines and propellers (e.g., recreational boats with outboard engines) typically produce higher-frequency noise than do larger vessels that generate substantial low-frequency noise; however, overall sound levels are higher for larger vessels, and increase with vessel speed (Kipple and Gabriele 2004).

Release of debris

The introduction of marine debris from vessels, whether floating on the surface, suspended in the water column, covering the benthos, or along the shoreline, can have numerous negative impacts (e.g., entanglement and ingestion) on organisms that inhabit EFH (Cottingham 1988, Milliken and Lee 1990, Derraik 2002, Cozar et al. 2014, Clarke-Murray et al. 2015).

Abandoned and derelict vessels

Existing federal laws and regulations do not provide clear authority or funding to any single agency for the removal of grounded or abandoned vessels that harm natural resources but are not otherwise obstructing or threatening to obstruct navigation or threatening a pollution discharge (Smith, Helton, et al. 2003). In many cases, vessels are abandoned and are left to continually damage the marine environment because a responsible party cannot be identified or a funding source for removal cannot be secured (Zelo and Helton 2005).

Abandoned or derelict vessels can physically damage or smother benthic EFH, create changes in wave energy and sedimentation patterns, and scatter debris across sensitive habitats (Precht et al. 2001). The potential footprint of a grounded vessel can be larger than the vessel itself as the vessel moves and breaks apart (Zelo and Helton 2005).

Physical impacts of a grounded vessel on EFH can be increased in shallower water because waves and currents cause increased shifting and destruction of the vessel, and the vessel may impede navigation, which would require removal and potential release of unknown materials into EFH. Abandoned or derelict vessels can release oil or other chemicals that impact EFH (Smith, Helton, et al. 2003). Abandoned and neglected floating vessels also add shade, inhibiting seagrass beds (Zelo and Helton 2005), and anchor chains can scour substrates (Sunda 1994, Negri et al. 2002, Smith, Negri, et al. 2003).

Potential conservation measures for vessel operation and maintenance

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of vessel operation and maintenance on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of vessel operation and maintenance on EFH.

General guidelines

- Incentivize marina operator participation in the NOAA/EPA Coastal Nonpoint Pollution Control Program and the Clean Marina initiative.

Loss and alteration of habitat

- Conduct site suitability analyses for new or proposed expansions of vessel docking facilities. Analyses should predict alterations to current and circulation patterns, water quality, bathymetric and topographic features, fish utilization, species distributions, and substrates.

Sedimentation, siltation, and turbidity

- Limit vessel speed near shorelines to reduce waves that erode the shore. Designate all sensitive EFH areas (e.g., eelgrass beds) as no-wake zones.

Release of contaminants

- Ensure that commercial ships and port facilities have acceptable contaminant spill response plans/equipment in place.
- Use dispersants that remove oils from the environment rather than dispersants that simply move them from the surface to the ocean bottom.
- Establish no-discharge zones to prevent sewage from entering EFH.
- Use appropriate methods for containment of wastewater, surface water collection, and recycling to avoid the discharge of pollution during the maintenance and operation of vessels.
- Promote education and signage on all vessels to encourage proper disposal of solid debris at sea.
- Encourage the use of innovative cargo securing and stowing designs that may reduce solid debris in the marine environment from the transportation of commercial cargo.

Invasive organisms

- Follow ballast water requirements and regulations for Western Region states:
    - *Washington*: Ballast Water Management, 77.120 RCW.
    - *Oregon*: Oregon Revised Statutes governing ballast water regulations, ORS 783.620-992.
    - *California*: Ballast Water Regulations for Vessels Arriving at California Ports or Places after Departing from Ports or Places within the Pacific Coast Region, Title 2, Division 3, Chapter 1, Article 4.6, Sections 2280–2284.
- Inspect all vessels for hull fouling invasive species prior to introducing the vessels into new waterbodies.
- Conduct vessel hull cleaning on land, and capture all runoff from such operations to ensure it does not enter waterbodies.
- Encourage natural resource managers to provide outreach materials on the potential impacts resulting from releases of invasive species into the natural environment.
- Develop appropriate early detection and rapid response eradication methods for invasive organisms consistent with federal guidelines as specified by the National Invasive Species Management Plan.
- Provide and display educational materials on the potential impacts resulting from the release of invasive species into the natural environment to increase public awareness and engender broad cooperation among user groups and stakeholders.

Noise effects

- Incentivize ship designs that include technologies capable of reducing noise generated and transmitted to the water column, such as the use of muffling devices already required for land-based machinery that may help reduce the impacts of vessel noise.
- Assess the effects of proposed and existing vessel traffic and associated underwater noise for potential impacts to sensitive areas.
- Exclude vessels or limit high-intensity use and low-frequency sonar in known sensitive marine areas.

Release of debris

- Promote the use of biodegradable materials when possible, especially in areas with tourism.
- Provide resources to the public on the impact of marine debris, and guidance on how to reduce or eliminate the problem.

Abandoned and derelict vessels

- Consider the potential for collateral impacts when planning a salvage operation to avoid fuel spillage.
- Use appropriate equipment and techniques to salvage and remove grounded vessels, and follow all necessary state and federal laws and regulations. Avoid propulsion systems of salvage tugs that can cause propeller wash and scour the bottom. Instead, moor the tugs and use a ground tackle system to provide maneuvering and pull.
- Minimize additional seafloor damage when a derelict vessel has to be dragged across the seafloor to deep water by following the same ingress path. Alternatively, identify the least sensitive, operationally feasible, towpath. Dismantling derelict vessels in place when stranded close to shore may cause less environmental impact than dredging or dragging a vessel across an extensive shallow habitat.
- Implement non-emergency salvage operations while including environmental considerations to minimize potential impacts on natural resources. Environmental considerations include periods when few sensitive species are present, avoidance of critical reproductive periods, and weather patterns that influence the trajectory of potential releases during operations.
- Choose a scuttling site for a derelict vessel in a deep-water location in federal or Exclusive Economic Zone (EEZ) waters that do not contain significant sensitive resources or geological hazards. Ensure that all proposed disposal of vessels in the open ocean adheres to state and federal guidance and regulations, including Section 102(a) of the Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act), and under 40 CFR 229.3 of the U.S. EPA regulations.

Navigational Dredging and Disposal

Potential adverse impacts of navigational dredging and disposal

The following factors associated with navigational dredging and disposal can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, sedimentation, siltation, and turbidity, release of contaminants, impacts to organisms, and noise effects (see Chapter 14). Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Dredging causes loss and alteration of important marine and freshwater EFH (Newell et al. 1998, Nightingale and Simenstad 2001b, Drabble 2012a). Historically, dredged material was used to fill wetland, salt marshes, and tidal flats for development. Filling wetlands eliminates their ecological functionalities: reducing flooding, filtering nutrients, and providing critical rearing habitat for a variety of aquatic and terrestrial species (Taylor 2012). Thus, dredging and filling wetlands causes severe impacts to EFH that are not easily mitigated (Nightingale and Simenstad 2001b, Taylor 2012).

Dredging can reduce aquatic community biodiversity (Thrush and Dayton 2002) and eliminate important food sources (Bilkovic 2011), impacting the food web for years (Gilkinson et al. 2005, Mearns et al. 2012). Recovery rates in dredged areas vary temporally, spatially, and by organism (Kennish 1997) based on differences in morphology, physiology, and behavior of organisms (Gilkinson et al. 2005), size of substrate (Reish 1961, McCauley et al. 1977, Oliver et al. 1977, Thrush et al. 1995, Currie and Parry 1996, Tuck et al. 1998, Watling et al. 2001, Gilkinson et al. 2005, Fischer et al. 2012), and currents (Oliver et al. 1977).

Dredging can eliminate vegetated habitat features that provide critical rearing and spawning habitat for a variety of fish species (Thayer et al. 1984, Deegan and Buchsbaum 2005). Eelgrass beds are particularly vulnerable to dredging because they are difficult to map, and recolonization could be limited if the bottom sediments become destabilized or composition is altered (Thayer et al. 1984). However, even after bottom sediments stabilize, channel deepening could change nutrient availability, water velocities, and reduce light needed for recolonization of eelgrass and other macrophytes (Barr 1993, Kenworthy and Fonseca 1996).

Altered hydrology and geomorphology

Dredging has impacts on hydrology and geomorphology in freshwater (Kondolf 1994, Poole et al. 2006, Bellmore et al. 2012) and marine EFH (Meire et al. 2005). Deepening of habitats impacts water circulation, currents, and flow velocity, all of which impact geomorphological processes (Lisle et al. 1993, Nightingale and Simenstad 2001b, Pereyra et al. 2014). Navigational dredging and disposal activities may have correspondingly similar impacts on EFH. Dredging may modify water circulation by changing the direction or velocity of water flow or depth of the water body traditionally used by invertebrates and fish for shelter, forage, or reproductive purposes. Specifically, navigational dredging converts shallow subtidal or intertidal habitats into deeper-water environments through the disturbance and removal of sediments (Deegan and Buchsbaum 2005).

Sedimentation, siltation and turbidity

Navigational dredging increases sedimentation, siltation, and turbidity, impacting aquatic flora and fauna inhabiting EFH (Wilber and Clarke 2001, Sabol et al. 2005). For fish, increased fine sediment can reduce reproductive success (Suedel et al. 2008), fill interstitial spaces in spawning gravels (Bjornn and Reiser 1991), damage or clog gill membranes (Lake and Hinch 1999), reduce food sources, and decrease area of suitable fish habitat (Cederholm and Reid 1987, Hicks et al. 1991, Smith and Wegner 2001). Increased sediment can also alter distribution (Culp et al. 1986), abundance, and composition of invertebrates (Waters 1995), contributing to reduced feeding (Bricelj and Malouf 1984), condition, survival, reproduction (Cake 1983), and development rate of higher trophic levels (Mullholland 1984).

Turbidity, which is partly influenced by suspended sediment loads, reduces light availability, thereby altering visibility and habitat conditions and impacting aquatic food webs via changes in primary and secondary productivity. Many fish are visual predators; therefore, visibility is important for foraging (Able et al. 1998) and avoiding predators (Helfman 1981, Tabor et al. 2011). Increased turbidity can impair how fish perceive predators (Sigler 1988, Birtwell and Korstrom 2002). Conversely, fish feeding rates may increase (Gregory 1993) while predation by piscivores is reduced in moderately turbid water (Gregory and Levings 1998). It is important to note that the duration and timing of exposure to increased suspended sediments could significantly alter the degree of impact on plants, invertebrates, and fish inhabiting EFH (Newcombe and MacDonald 1991).

Light availability influences depth distribution, density, and productivity of SAV, which provides important structural features and food resources in nearshore EFH (Dennison and Alberte 1982, Dennison and Alberte 1985, Dennison and Alberte 1986, Schiel et al. 2006, Zimmerman 2006). Large sediment plumes caused by dredging (Suedel et al. 2008) can reduce light penetration, causing reduced growth and survival of eelgrass (Kenworthy and Fonseca 1996, Schiel et al. 2006, Mumford 2007, Moore et al. 2012). Slight reductions in light availability can also result in lower rates of photosynthesis for phytoplankton (Cloern 1987), ultimately resulting in less energy available for benthic invertebrates and fish living in EFH.

Release of contaminants

Sediments act as a contaminant sink and source in EFH. When resuspended, particulate-bound contaminants may be remobilized into the water column where they impact EFH, including invertebrate and fish populations (Kennish 1997, Brown et al. 1998, Kennish 2002, Islam and Tanaka 2004, Sovová et al. 2014). Sediments in estuaries downstream from agricultural or urban/suburban residential areas may also contain herbicides and pesticides (NMFS 1997). The effects of these compounds range from sublethal (e.g., reduced growth or feeding) to lethal depending on type of contaminant, route of exposure, ambient conditions, species, life stage, and body size (Poston 2001, Brinkmann et al. 2013). For example, PAHs have been reported to cause cancer, reproductive anomalies, immune dysfunction, impaired growth and development, and other impairments in fish when present in high concentrations for sufficiently long periods of time (Poston 2001, Johnson et al. 2008, Spearow et al. 2011, Collier et al. 2014).

Current standards are based on toxicity to benthic invertebrates, so while they may protect against impacts to the fish prey base, they are not necessarily protective of fish (e.g., Meador et al. 2002). This is especially true for contaminants such as polycyclic aromatic hydrocarbons (PAHs), which are metabolized to mutagenic and carcinogenic intermediates in fish, but to a much lesser extent in invertebrates (see Varanasi 1989.

Impacts to organisms

Dredging entrainment can have significant effects on fish populations (McGraw and Armstrong 1990, Boysen and Hoover 2009, Drabble 2012a,b). Dredging entrainment is the uptake and trapping of aquatic organisms by the dredge suction (Reine and Clarke 1998). Depending on the operation, every life stage of invertebrate and fish may be at risk of being injured or killed by dredge entrainment (Buell 1992). In many cases, important food sources for important EFH species can be significantly reduced or eliminated (Van der Veer et al. 1985, Newell et al. 1998, Boysen and Hoover 2009). Furthermore, by removing or displacing native species and severely disturbing EFH, dredging may provide opportunities for colonization by invasive species (Vitousek et al. 1997, Minchinton and Bertness 2003, Strecker and Olden 2014).

Entrainment rates for invertebrates vary based on machinery, habitat, season, and size of organism (Armstrong et al. 1982, Larson 1989). Where vulnerable, impacts on invertebrates can be significant and may extend at least 100 m from the dredging site (McCauley et al. 1977).

Noise effects

Dredging equipment and dredging-related activities generate underwater sound pressure waves that may adversely affect EFH. Sources of these underwater sounds originate from vessel propellers, pumps, generators, and from dredge buckets and dragheads coming in contact with the substrate (Dickerson et al. 2001, Clarke et al. 2002). Sound recordings during dredging operations documented increases above background noise levels as far as 1.2 km from the source, and peak sound pressures of 175 decibels (Reine et al. 2014). Injuries associated directly with noise produced by dredging are poorly studied, but effects of similar noises include avoidance of area, increased stress, and temporary shifts in hearing thresholds (Hastings and Popper 2005). Shifts in hearing thresholds may result from exposure to low levels of sound for a relatively long period of time or exposure to high levels of sound for shorter periods (Scholik and Yan 2002, Liu et al. 2013). Threshold shifts can impact a fish's ability to carry out its life functions, such as locating food or mates.

Potential conservation measures for navigational dredging and disposal

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of navigational dredging and disposal on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help land managers avoid, minimize, and mitigate impacts of navigational dredging and disposal on EFH.

General guidelines

- Do not dredge in or near sensitive EFH such as spawning grounds, eelgrass beds, or habitats that support important prey sources for fish.
- Perform dredging only during periods that have the least impact on fish and food webs. Establish areal extent and timing guidelines in cooperation with local, state, tribal, and federal fish biologists. Make every effort to dredge only to the authorized depth using deeper, single-day events rather than shallower, multiple-day events.
- Use only hydraulic dredges and allow no overflow.
- When using a mechanical dredge, increase cycle time and reduce bucket deployment.
- Conduct pre-dredging site sampling and analyses to predict cumulative effects of existing and proposed dredging operations on EFH and organisms. Include all impacts to EFH as part of the permitting process, mitigate for all adverse effects, and monitor mitigation effectiveness.
- Use alternative dredge material disposal options (e.g., upland disposal), and recycle dredged material for beneficial use opportunities.

Loss and alteration of habitat

- Do not place pipelines and accessory equipment used in conjunction with dredging operations close to sensitive EFH and Habitat Areas of Particular Concern (HAPC)—e.g., kelp beds, eelgrass beds, estuarine/salt marshes, etc.

- Do not directly remove or bury habitat features. In cases where features are removed or buried, the operator must mitigate these losses to EFH.

Altered hydrology and geomorphology

- Avoid new dredging projects. Activities that would likely require dredging (such as placement of piers, docks, marinas, etc.) should instead be sited in deeper-water areas or designed to alleviate the need for maintenance dredging. New projects should only be permitted for water-dependent purposes, and only when no feasible alternatives are possible.

Sedimentation, siltation, and turbidity

- Use equipment that generates the least amount of sedimentation, siltation, and turbidity (e.g., environmental buckets instead of excavators).
- Use BMPs, such as the establishing riparian area buffers, to help reduce and control sediment input.
- Make every effort to avoid dredging very fine sediments, such as silt. In general, the finest substrate dredged should be sand (>80% sand).
- Implement light monitoring at treatment (within adjacent EFH) and control sites (area outside of dredging influence) during dredging.
- Incorporate adequate control measures to minimize turbidity where the dredging equipment used is expected to create significant turbidity, especially where effects may be long-lasting (>1 day).
- Explore collaborative approaches between material management planners, pollution control agencies, and others involved in watershed planning to identify point and nonpoint sources of sediment and sediment pollution associated with dredging.

Release of contaminants

- Monitor sediment contamination levels during dredging and report all effects, preferably in real-time. If contamination is acute, reevaluate dredging methodology and require methods that do not release contaminants.
- Using best available science, develop procedures for disposal of dredged material that protect EFH and organisms from contaminants.

Impacts to organisms

- Avoid dredging in or near EFH areas of particular concern.
- Design and implement dredging suction mechanisms that minimize or eliminate entrainment or impingement of fish and their prey sources.

Noise effects

- Clearly report predicted noise levels that will occur during dredging activities.
- Sample and monitor noise levels in real time during dredging activities. If noise levels surpass accepted thresholds for aquatic organisms, cease operations and implement alternative methodology.
- Incentivize development of peer-reviewed studies that identify how noise generated from dredging impacts aquatic organisms and EFH.

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13. Coastal Development

Population growth has led to increased development along the U.S. West Coast (Griggs et al. 2005, NOAA 2013a). The health of coastal EFH is vitally important to the maintenance and persistence of a wide array of freshwater and marine flora and fauna (Hughes et al. 2009). The way in which humans develop the coastal landscape has several compounding negative impacts on EFH (Simenstad 1983, Thom 1987, Osborn et al. 2006, Airoldi et al. 2008, Boström et al. 2011, Taylor 2012). Increasingly, coastal EFH is filled in (Crain et al. 2009), structures are built to stabilize and protect property (Scavia et al. 2002, Bulleri and Chapman 2010, Nordstrom 2014), and sea-level rise and increased storm intensity could increase the demand for additional coastal protection structures (Shepard et al. 2011). The filling-in of EFH has led to the decline of highly productive and valuable coastal habitat (Crain et al. 2009). Structures such as bulkheads, seawalls, revetments, and groins impact functionality of coastal EFH (Downing 1983, Dugan et al. 2011), inhibiting shoreward migration of marsh wetlands and aquatic vegetation (Orth et al. 2006), both of which naturally protect coasts. Manmade shoreline structures also lead to coastal sediment budget deficits, subsidence of land (Shellenbarger et al. 2013), and increased beach erosion. These factors can exacerbate degradation of coastal geomorphological processes already compromised by inland development activities, such as damming of rivers (Kana 1988, Kondolf 1997, CDBW 2002, Greene 2002, Borde et al. 2003). Because of the high ecological costs of coastal development, costly mitigation activities, such as beach nourishment, increase. Such mitigation is a costly short-term solution, and can further impact coastal processes, residing organisms, and habitats (Peterson and Bishop 2005, Speybroeck et al. 2006, Munsch et al. 2015). Finally, the increase in coastal development often corresponds with an increase in land-based debris that litters sensitive, compromised coastal EFH and can harm residing organisms (Laist 1987, Cozar et al. 2014).

This chapter is divided into four sections that outline some of the adverse impacts of coastal development on EFH, including factors associated with Beach Nourishment, Shoreline and Bank Stabilization, Aquatic Fill, and Marine Debris. Suggestions for avoidance, minimization, and mitigation of these impacts on EFH are provided in each section.

Beach Nourishment

Potential adverse impacts of beach nourishment

The following factors associated with beach nourishment can impact EFH and are described briefly below: altered hydrology and geomorphology, sedimentation, siltation, and turbidity, and impacts to organisms. Suggested conservation measures related to each of these factors are provided in the following section.

Altered hydrology and geomorphology

Coastal EFH is created and maintained by waves, tides, currents, weather, and changes in sea level that influence erosion and accretion of coastal sediment. Sediment is transported by these forces from rivers and eroding beaches and deposited in distinct littoral "cells" along the coast (Kondolf 1997, Patsch and Griggs 2007). Sediment budgets in these littoral cells influence the structure of coastal EFH (Inman and Jenkins 1999, Hapke et al. 2006, Young and Ashford 2006).

The impacts of beach nourishment on hydrology and geomorphology in EFH vary among different coastal environments (Nelson 1993); however, many authors have found that artificial accretion resulting from beach nourishment inhibits coastal hydrologic and geomorphologic processes that form and maintain EFH (Flick 1993, Wiegel 1994, Greene 2002, Hapke et al. 2006, Speybroeck et al. 2006, Munsch et al. 2015). Furthermore, many studies indicated that use of different grain size and shape during beach nourishment can alter the distribution of sediment, reduce porosity of the beach surface, and alter hydrological patterns along the coast (Pilkey and Dixon 1996, Greene 2002, Jackson et al. 2010, Román-Sierra et al. 2014).

Sedimentation, siltation, and turbidity

Beach nourishment temporarily increases suspended sediments and turbidity in neashore EFH (Greene 2002, Warrick 2013, Manning et al. 2014). The impacts of increased suspended sediments on aquatic organisms are influenced by abiotic factors, especially concentration and duration of exposure (Newcombe and Jensen 1996), as well as biotic factors such as trophic level and life stage. Increased sedimentation can reduce feeding ability (Breitburg 1988, Benfield and Minello 1996), injure gills (Lake and Hinch 1999), and lead to increased mortality of aquatic organisms (Wilber and Clarke 2001).

Turbidity, which is partly influenced by suspended sediment loads, reduces light availability, thereby altering habitat conditions and associated aquatic food webs. Light availability influences depth distribution, density, and productivity of eelgrass, an important structural feature in nearshore EFH (Dennison and Alberte 1982, 1985, 1986, Zimmerman 2006). Slight reductions in light availability can also result in lower rates of photosynthesis for phytoplankton, a key basal resource (Cloern 1987), ultimately resulting in less energy available for benthic invertebrates and fish living in EFH.

Impacts to organisms

Aquatic organisms can be directly affected during the process of beach nourishment. Peterson and Manning (2001) found that fining and increased sorting of sediments, and turbidity that resulted from beach nourishment, corresponded with reduced size and abundance of benthic macrofauna. Benthic invertebrates were buried during beach nourishment (Greene 2002), altering invertebrate biodiversity and composition, and possibly impacting recruitment of different life stages of organisms from adjacent areas (Peterson et al. 2000, Greene 2002, Manning et al. 2014).

The size, shape, and type of sediment used in beach nourishment can impact the trophic structure of coastal EFH (Manning et al. 2014, Vanden Eede et al. 2014, Munsch et al. 2015). For example, some nourishment sediments reduce the suitability of substrates for burrowing organisms (Nordstrom 2005, Colosio et al. 2007, Viola et al. 2014). Shell fragments do not transport or deposit the same way that sediment does. If beach nourishment sediment contains a high proportion of shells brought into certain cells from other beach areas, the shell fragments may dissolve and form a cemented shell layer (Speybroeck et al. 2006), prohibiting access to burrowing habitats and leading to changes in invertebrate and fish composition (Greene 2002). Sediment grain-size mismatch is also common in beach nourishment (Greene 2002). For example, beaches with larger substrates can be buried by fine sediments that would otherwise not occur (Jackson et al. 2010), reducing habitat for algae, an important food source for epibenthic organisms (Cheney et al. 1994) that in turn provide forage material for fish and other organisms (Peterson et al. 2000). Similarly, a shift from finer sediment to coarser substrate may result in decreased abundance of benthic macrofauna and a structural shift in benthic communities that could impact higher trophic levels (Speybroeck et al. 2006, Vanden Eede et al. 2014).

Sand placed during beach nourishment can move offshore and impact surrounding marine habitats, including rocky reef HAPC and associated habitats. For instance, surfgrasses—which display late successional traits, recover very slowly from disturbance, and require facilitation from algae before settling (Turner 1985)—exhibited a statistically significant decline in shoot count at burial depths of 0.8 feet (Craig et al. 2008). Removal of surfgrass from a rocky reef community can have profound impacts to community structure (Turner 1985), and reductions in surfgrass could negatively affect recruitment patterns (Galst and Anderson 2008). In addition, coralline algae habitat, which harbors important prey for many species of fish and invertebrates and is important habitat for abalone recruitment, may be impacted by burial depths of as little as 3–4 cm (Huff and Jarett 2007).

Despite decades of monitoring, there is still much uncertainty regarding the ecological impacts of beach nourishment. In a review of 46 beach nourishment monitoring studies, Peterson and Bishop (2005) identified serious deficiencies in design, analysis, and interpretation of results, and made specific recommendations for improving future monitoring efforts to enhance the understanding of the environmental impacts of beach nourishment.

Potential conservation measures for beach nourishment

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of beach nourishment on EFH. Not all of these suggested measures are necessarily applicable to any one beach nourishment project or activity. More specific or different measures based on the best and most current scientific information may be developed prior to or during the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help avoid, minimize, and mitigate for impacts of beach nourishment on EFH.

General guidelines

- Consider alternatives that would avoid or minimize impacts to EFH (e.g., reduce the footprint or volume of beach nourishment to the minimum required, explore sand retention alternatives).
- Complete nourishment in one season (e.g., one winter season).
- Use upland beach material sources, if compatible, to avoid impacts associated with offshore sand mining.
- Include efforts to preserve and enhance EFH by providing substrates that can be utilized by reproducing aquatic organisms, removing barriers to natural fish passage, and using weirs, grade control structures, and low-flow channels to provide the proper depth and velocity for fish.
- Restoration efforts must have specific ecological goals that can be measured and monitored to evaluate efficacy of restoration efforts.
- Preserve, enhance, or create beach dune and native dune vegetation in order to provide natural beach habitat and reduce the need for nourishment.

- Address the cumulative impacts of past, present and foreseeable future development activities on aquatic habitats by considering them in the review process for beach nourishment projects.

Altered hydrology and geomorphology

- Develop design criteria based on site-specific geomorphological, hydrological, and sediment-transport processes appropriate for the system (e.g., stream channel, embayment, littoral cell) for any stabilization, protection, and restoration projects.

Sedimentation, siltation, and turbidity

- Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels at the beach and/or borrow sites.
- Dispose of dredged spoils properly (USACE 2014).

Impacts to organisms

- Do not harvest sand in areas containing sensitive marine benthic habitats (e.g., spawning and feeding sites, hard bottom, cobble/gravel substrate, shellfish beds).
- Do not conduct beach nourishment in areas containing sensitive marine benthic habitats adjacent to the beach (e.g., submerged aquatic vegetation, kelp, spawning and feeding sites, hard bottom, and cobble/gravel substrate).
- Conduct beach nourishment during the winter, when productivity for benthic infauna is at a minimum; this may minimize impacts for some beach sites.
- Verify that nourishment activities are not coinciding with kelp recruitment.
- Implement seasonal restrictions to avoid impacts to habitat during species-critical life-history stages (e.g., spawning season, egg and larval development periods).
- Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Identify life-history traits, such as reproductive strategy and dispersal capabilities, to determine potential for species recovery from beach nourishment and other impacts (Peterson et al. 2000, Speybroeck et al. 2006).
- Assess source material for compatibility with that of material to be placed on beach (e.g., grain size and shape, color). Slope of nourished beach should mimic the natural beach profile.
- Use an adaptive management plan with ecological indicators to oversee an appropriate monitoring plan and ensure mitigation objectives are met. Take corrective action and implement compensatory mitigation as needed.

Shoreline and Bank Stabilization

Potential adverse impacts of shoreline and bank stabilization

The following factors associated with shoreline protection and bank stabilization can impact EFH and are described below briefly: loss and alteration of habitat, altered hydrology and geomorphology, and release of contaminants. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Shoreline protection and bank stabilization can lead to the loss and alteration of coastal littoral EFH. Habitat heterogeneity or complexity and other environmental conditions, such as water quality and temperature, are important factors influencing biological diversity and productivity of coastal EFH (Romanuk et al. 2003, McLachlan and Brown 2006, Rossell and Dinnel 2006, Tonnes 2008, Scapini 2014); shoreline structures can impede processes that maintain these important attributes (Sobocinski 2003, Rice 2006, Nordstrom 2014). Artificial structures inconsistent with the character of natural EFH can reduce production of important refuge such as eelgrass and kelp and other submerged aquatic vegetation (Shafer 1999, Cohen et al. 2002, Ely and Viani 2008). Loss of such structure can impact colonization, abundance, and density of intertidal organisms (Bulleri and Chapman 2010), and organic and nutrient dynamics, with likely consequences for higher trophic levels. Armoring of the shoreline can reduce shallow-water and intertidal habitat, leading to coarsening of substrates, reducing organic debris, altering macroinvertebrate assemblages, and reducing important prey sources for fish (Sobocinski et al. 2010). In Puget Sound, Washington, epibenthic invertebrate densities were more than ten times greater on unarmored shorelines, and species richness doubled that of armored locations (Morley et al. 2012). Changes in habitat characteristics of shorelines can reduce habitat suitability for juvenile and spawning fish, such as English sole (Toft et al. 2007) and surf smelt (Quinn et al. 2012).

Habitat alterations associated with shoreline protection and bank stabilization structures can alter community assemblages, abundances, and trophic structure (Froeschke et al. 2005, Wen et al. 2010, Munsch et al. 2014). Breakwaters in Australia supported higher fish abundances and greater species richness (Fowler and Booth 2013). In northern Taiwan, trophic generalists replaced reef-obligate fish (Wen et al. 2010), and the proportion of younger fish increased at artificial structures over natural reefs (Wehkamp and Fischer 2013). Breakwaters and jetties can bury and remove resident biota and alter cover, prey sources, and presence of predators, thereby impacting EFH. Artificial structures can also facilitate the establishment and spread of invasive organisms (see Chapter 16).

Altered hydrology and geomorphology

Shoreline protection and bank stabilization can alter hydrology and geomorphology in coastal EFH (for a more comprehensive review, see Nordstrom 2014). Protection of eroding coastal cliffs can suppress the supply of sand to beaches (Stamski 2005). Reduced erosion impairs landward migration of shorelines, leading to confinement of beaches (Dugan et al. 2011, Noujas et al. 2014) and changes in bottom form and substrate that can reduce habitat suitability for aquatic plants, invertebrates, and fish. Jetties and other protective or stabilizing structures redirect wave energy, leading to coarsening of substrates; reduced sediment storage, transport, and deposition; reduced organic debris; and altered temperature, salinity, and water surface elevation in coastal EFH (Dugan et al. 2011).

Structures can have compounding impacts on hydrologic processes in EFH. Dikes, levees, ditches, and other water-control structures can eliminate or regulate (i.e., tidegates) freshwater influx into and out of marshes, preventing water, sediment, organic matter, and nutrient exchange (Nordstrom 2014).

Release of contaminants

The use of chemicals (creosote, chromated copper arsenate, and copper zinc arsenate) in wood products used for shoreline protection and bank stabilization can increase the amount of chemicals and contaminants in coastal EFH (Ownby et al. 2002). These chemicals introduce toxic substances that can bioaccumulate in the food web (USEPA 2005, Sandahl et al. 2007, Macneale et al. 2010) and impair physiology, behavior, growth, survival, and reproduction of invertebrates and fish (Dethloff et al. 2001, Meador et al. 2010, Feist et al. 2011, Scholz et al. 2011). For more information on the release of contaminants in association with artificial structures, see Chapter 16.

Potential conservation measures for shoreline and bank stabilization

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of shoreline and bank stabilization on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information and project-specific considerations may be developed prior to or during the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate for impacts of shoreline and bank stabilization on EFH.

General guidelines

- Use soft approaches (e.g., beach nourishment, vegetative plantings, and placement of LWD) in lieu of hard shoreline stabilization and modifications (e.g., concrete bulkheads and seawalls, concrete or rock revetments).
- Use manmade structures in combination with ecosystem-based methods (e.g., oyster domes) to promote both shoreline protection and ecological benefits (Gedan et al. 2011).
- Use an adaptive management plan with ecological indicators to oversee an appropriate monitoring plan and ensure mitigation objectives are met. Take corrective action and implement compensatory mitigation as needed.

Loss and alteration of habitat

- 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.
- Do not dike or drain tidal marshlands or estuaries.
- Do not develop structures that lead to or cause the loss of coastal wetlands.
- Preserve and enhance fishery habitat to offset impacts of structures (e.g., new gravel for spawning or nursery habitats).

Altered hydrology and geomorphology

- Do not install structures in tidal marshes and freshwater streams flowing into coastal waters. If installation of new structures cannot be avoided, ensure they are designed to allow optimal fish passage and natural water circulation.
- Ensure hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when hard shoreline stabilization is deemed necessary.

Release of contaminants

- Do not use materials that are treated with potentially harmful chemicals.

Aquatic Fill

Potential adverse impacts of aquatic fill

The following factors associated with aquatic fill can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, release of contaminants, and impacts to organisms. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Coastal EFH can sustain high levels of productivity and supports multiple life stages and species of fish and their prey; however, the placement of aquatic fill results in loss and alteration of EFH (Borde et al. 2003, Crain et al. 2009). Estuaries, tidal wetlands, and salt marshes are often developed for urban, agriculture, and shellfish aquaculture purposes (PNCERS 2003, Airoldi et al. 2008, Shellenbarger et al. 2013), potentially resulting in expansive losses and alterations of habitat in coastal EFH (Kennish 2001, Crain et al. 2009, Gedan et al. 2009). For example, coastal development has resulted in a net loss of 200,000 hectares of salt marsh in the San Francisco Estuary (Atwater et al. 1979), and over 90% of the Coos Bay salt marsh was drained and filled to develop and create the city of Coos Bay, Oregon (Hoffnagle and Olson 1974, Seliskar and Gallagher 1983).

Coastal EFH is permanently eliminated when areas such as estuaries, tidal wetlands, and salt marshes are filled in for development (Watzin and Gosselink 1992, Airoldi et al. 2008). Loss and alteration of coastal EFH can have adverse effects on factors that influence habitat suitability in adjacent EFH, such as water quality (e.g., hypoxia and anoxia; Orth et al. 2006). Furthermore, salt marshes and other natural coastal systems could help buffer coastal areas from climate-driven events that impact EFH (Shepard et al. 2011).

Altered hydrology and geomorphology

By design, draining and filling of estuaries and marshes alters coastal hydrologic and geomorphologic processes. Placement of aquatic fill interferes with normal tidal flooding and drainage, mollifying overland water flow, decreasing sediment supply to the marsh surface, and arresting vertical accretion (Kennish 2001). The placement of fill within estuaries could threaten EFH by impeding tidal and freshwater inputs and nutrient transport (Crain et al. 2009), and by exacerbating land-based contamination of sediment (Valiela et al. 2004). Loss of hydrologic and geomorphologic functioning in coastal EFH caused by aquatic fill could also exacerbate the impacts of climate change on the coast (Ravit et al. 2015).

Release of contaminants

Placing fill within EFH can resuspend sediments into the water column that may have been contaminated by historical or ongoing activities (Scholz et al. 2012), exposing aquatic organisms to elevated concentrations of potentially harmful compounds (Duarte 2002, Edinger and Martin 2010). Salt marshes, in particular, are depositional by nature (Nixon 1980), and Leendertse et al. (1996) found that salt marshes are sinks for metal contamination. Metal contamination can have deleterious impacts on physiology and behavior of fish (Dethloff et al. 2001, Baldwin et al. 2011, McIntyre et al. 2012, Sovová et al. 2014), and filling of coastal EFH could exacerbate land-based contamination (Valiela et al. 2004, Verhoeven et al. 2006).

Impacts to organisms

Direct impacts to aquatic organisms caused by aquatic fill can have deleterious impacts on the food web. Sessile or semi-mobile aquatic organisms can be eliminated via entrainment or smothering (Larson and Moehl 1990, McGraw and Armstrong 1990, Barr 1993, Newall et al. 1998), decreasing the amount of detritus, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993).

While many coastal and estuarine species are tolerant of a range of salinities, salinity regimes can become a significant stressor when altered due to the filling-in of coastal EFH (Crain et al. 2009). Changes in salinity can cause immediate mortality or sublethal stress, leading to shifts in community and ecosystem structure. Salmonids and other anadromous fishes are particularly sensitive to anthropogenic changes to the salinity regime because they often use estuaries as an intermediate environment during osmoregulation (Quinn 2005).

Potential conservation measures for aquatic fill

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of aquatic fill on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information and project-specific considerations may be developed prior to or during the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help avoid, minimize, and mitigate for impacts of aquatic fill on EFH.

General guidelines

- Do not place aquatic or other types of fill in riparian habitats, freshwater habitats, estuaries, and bays.
- Plan filling activities to avoid special aquatic sites such as native eelgrass beds. This may include the placement of pipes and anchoring of barges and other vessels associated with the project.
- Address cumulative impacts of past, present, and foreseeable future fill operations on aquatic habitats by considering them in the review process.

Loss and alteration of habitat

- Require the use of multiple-season biological sampling data (both pre- and post-construction), when appropriate, to assess the potential and resultant impacts on certain habitat and aquatic organisms.
- Avoid or minimize loss or alteration of EFH habitat and implement compensatory mitigation as needed. For instance, seek funding for restoration or conservation of critical coastal EFH that may be affected by planned activities.

Altered hydrology and geomorphology

- Utilize BMPs to limit and control the amount and extent of turbidity and sedimentation. Standard BMPs may include constructing silt fences, coffer dams, and operational modification (e.g., hydraulic dredge rather than mechanical dredge).
- Identify sources of sedimentation within the watershed that may exacerbate repetitious maintenance activities. Implement appropriate management techniques to control these sources.

Release of contaminants

- Do not use materials that are treated with toxic materials; instead, use natural, untreated materials.

Impacts to organisms

- Schedule fill activities when the fewest species and least-vulnerable life stages are present. Appropriate work windows can be established based on the multiple-season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Require the use of multiple-season biological sampling data (both pre- and post-construction), when appropriate, to assess the potential and resultant impacts on certain habitat and aquatic organisms.

Marine Debris

Potential adverse impacts of marine debris

The following factors associated with marine debris can impact EFH and are described briefly below: impacts to organisms and invasive organisms. Suggested conservation measures related to these factors are provided in the following section.

Impacts to organisms

Land-based marine debris includes raw or partially treated sewage, litter, plastics, hazardous materials (e.g., PAHs, paint, solvents), and discarded trash. Urban litter from stormwater overflows into coastal EFH and wastewater contains numerous toxins, including viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes, all of which can pose physical and biological threats to EFH (Boesch et al. 1997). See also Chapter 4 and Chapter 17.

Size and type of debris can determine the impacts to EFH and aquatic communities. Impact pathways associated with marine debris include ingestion, entanglement, smothering/covering, and alteration of the benthic invertebrate community (Katsanevakis et al. 2007, Gregory 2009, Kuhn et al. 2015). Marine debris can also become snagged on and/or damage sensitive habitats, such as reefs (Carvalho-Souza et al. 2018). Entanglement and ingestion of marine debris, including derelict fishing nets, pots, and other gear, impact multiple organisms worldwide (Derraik 2002, Moore 2008, Doyle et al. 2012). Affected organisms inhabiting coastal EFH include filter-feeders, fish, turtles, seabirds, and marine mammals (Laist 1987).

Plastic pollution, ubiquitous throughout the marine environment, represents one of the most difficult current environmental challenges (UNEP 2011, Eriksen et al. 2014, Botterell et al. 2018). Smaller items, such as bottle caps, lighters, and plastic pieces, may be ingested or result in entanglement (NOAA 2013b). Large plastics tend to concentrate along coastal areas (Milliken and Lee 1990). However, a majority of plastic particles found on the ocean surface are less than 1 cm in diameter, enabling ingestion or entanglement by a wide range of organisms (Arthur et al. 2009, Cozar et al. 2014). Plastics also contain many toxins (Hammer et al. 2012), and when ingested can cause a wide range of deleterious effects through various physical and biochemical pathways, including internal wounds, endocrine system disruption, impairments to growth, gastrointestinal obstruction, potential starvation, and bioaccumulation in the food web (Gregory 2009, Rochman et al. 2013, 2014, Cozar et al. 2014, Talley et al. 2020, Provencher et al. 2017). Studies have indicated that certain species, including filter feeding Clupeiformes such as those managed under the Coastal Pelagic Species FMP, are likely more susceptible to plastic ingestion due to their gill structures and feeding behavior (Moore et al. 2001, Collard et al. 2017). Marine plastic pollution is a widespread problem that is likely having a cascading effect throughout the ecosystem, affecting multiple trophic levels (UNEP 2014, Tanaka and Takada 2016, Collard et al. 2017, Botterell et al. 2018, Markic et al. 2019, Talley et al. 2020).

Invasive organisms

Marine debris is the accumulation of persistent synthetic materials into the global oceans and seas (Derraik 2002, Gregory 2009). Marine debris, especially plastic (Hammer et al. 2012), can be hazardous to coastal organisms and EFH. The majority of plastic in the marine environment originates on land and is transported to coastal EFH through rivers, wastewater, wind, and public beaches (Ryan et al. 2009). Marine debris can also originate from the sea, transported by ocean currents from commercial fishing operations (derelict fishing nets and gear), freight and shipping, resource extraction facilities, recreational boating, and military vessels (Fanshawe and Everand 2002), and can also be derived from distant continents (NOAA 2013b).

Invasive species can be transported to coastal EFH by marine debris (Barnes 2002). Larger debris, such as plastic tarps and wood signs or panels, may contain invasive species (NOAA 2013b). Plastics are nonbiodegradable, can travel large distances, are widely distributed throughout the world's oceans, and provide hard surfaces for opportunistic colonizers (Thiel and Gutow 2005, Gregory 2009). Plastic marine debris can support vast microbial communities that can attach themselves at the point source, or in the open ocean (Zettler et al. 2013). Because pelagic plastics can be colonized by a variety of organisms (Gregory 2009), they can facilitate the transport and expansion of non-native species, including aggressive invasives, via increased rafting opportunities (Barnes 2002, Derraik 2002, Gregory 2009). Floating marine debris is transported to coastal EFH, enabling infiltration by these invasive organisms into coastal EFH (Gregory 2009). The potential for invasion by species from distant environments through the transport of marine debris was recently observed off the U.S. West Coast. Over 90 invasive species were observed in marine debris transported as a result of a major earthquake and tsunami that occurred in Japan (NOAA 2013b).

Potential conservation measures for marine debris

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of marine debris on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information and project-specific considerations may be developed prior to or during the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help avoid, minimize, and mitigate for impacts of marine debris on EFH.

General guidelines

- 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.
- Install barriers to catch floating debris in harbors, ports, and nearshore developments (Gregory 2009).
- Promote the use of biodegradable materials, when possible, especially in areas with tourism (Guo et al. 2009).
- Provide resources to the public on the impact of marine debris, and guidance on how to reduce or eliminate the problem.
- For projects that may discharge marine debris, implement compensatory mitigation as appropriate. Options that specifically address marine debris (e.g., preventive measures, removal efforts) warrant special consideration.

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14. Dredging

Potential Adverse Impacts of Dredging

The following factors associated with dredging can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, sedimentation, siltation, and turbidity, release of contaminants, entrainment, and noise effects. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Dredging causes loss and alteration of important marine and freshwater EFH (Newell et al. 1998, Nightingale and Simenstad 2001, Thrush and Dayton 2002, Drabble 2012a). Historically, dredged material was used to fill wetland, salt marshes, and tidal flats for development. However, filling wetlands reduces or eliminates their ecological functionality of reducing flooding, filtering nutrients, and providing critical rearing habitat for a variety of aquatic species (Taylor 2012). Thus, dredging and filling of wetlands causes severe impacts to EFH that are not easily mitigated (Nightingale and Simenstad 2001, Taylor 2012, Reine et al. 2013).

Dredging can reduce aquatic biodiversity (Thrush and Dayton 2002) and eliminate important food sources (Bilkovic 2011), impacting the food web for years (Gilkinson et al. 2005, Mearns et al. 2012). Recovery rates in dredged areas vary temporally, spatially, and by organism (Kennish 1997) based on differences in life stage, physiology, and behavior of organisms (Gilkinson et al. 2005); size of substrate (Reish 1961, McCauley et al. 1977, Oliver et al. 1977, Thrush et al. 1995, Currie and Parry 1996, Tuck et al. 1998, Watling et al. 2001, Gilkinson et al. 2005, Fischer et al. 2012); and currents (Oliver et al. 1977).

Dredging can eliminate vegetated habitat features, such as eelgrass beds, that provide critical rearing habitat for a variety of fish species (Deegan and Buchsbaum 2005). Eelgrass beds are particularly vulnerable to dredging because they are difficult to map, and recolonization could be limited if the bottom sediments become destabilized or composition is altered (Thayer et al. 1984). However, even after bottom sediments stabilize, channel deepening could reduce light needed for recolonization of eelgrass and other aquatic macrophytes (Kenworthy and Fonseca 1996).

Altered hydrology and geomorphology

Dredging has impacts on hydrology and geomorphology in freshwater (Kondolf 1994, Poole et al. 2006, Bellmore et al. 2012) and marine EFH (Meire et al. 2005). Specifically, dredging can impact water circulation, currents, and flow velocity, all of which impact geomorphological processes that form EFH (Lisle et al. 1993, Nightingale and Simenstad 2001, Pereyra et al. 2014).

Sedimentation, siltation, and turbidity

Excessive transport or deposition of fine sediment can impact organisms inhabiting EFH. For fish, increased fine sediment can reduce reproductive success (Suedel et al. 2008), fill interstitial spaces in spawning gravels (Bjornn and Reiser 1991), and damage or clog gill membranes (Lake and Hinch 1999), ultimately reducing EFH (Cederholm and Reid 1987, Hicks et al. 1991, Smith and Wegner 2001). Increased sediment can also alter distribution (Culp et al. 1986), abundance, and composition of invertebrates (Waters 1995), and can lead to reduced feeding (Bricelj and Malouf 1984), respiration (Grant and Thorpe 1991), condition, survival, reproduction (Cake 1983), and development rate of higher trophic levels (Mullholland 1984).

Turbidity, which is partly influenced by suspended sediment loads, reduces light availability, thereby altering visibility and habitat conditions, impacting aquatic food webs in EFH. Many fish are visual predators, and visibility is thus important for foraging (Able et al. 1998) and avoiding predators (Helfman 1981, Tabor et al. 2011). Increased turbidity can impair predator avoidance of fish (Sigler et al. 1988). Conversely, feeding on invertebrates and other prey may increase (Gregory 1993), while predation by piscivores could decrease (Gregory and Levings 1998) in moderately turbid water. It is important to note that the duration and timing of exposure to increased suspended sediments could significantly alter the degree of impact on fish inhabiting EFH (Newcombe and MacDonald 1991).

Light availability influences depth distribution, density, and productivity of eelgrass and other aquatic macrophytes, an important structural feature in nearshore EFH (Dennison and Alberte 1982, Dennison and Alberte 1985, Dennison and Alberte 1986, Zimmerman 2006). Large sediment plumes caused by dredging (Suedel et al. 2008) can reduce light penetration, causing reduced growth and survival of eelgrass (Kenworthy and Fonseca 1996, Schiel et al. 2006, Mumford 2007, Moore et al. 2012). Slight reductions in light availability can also result in lower rates of photosynthesis for phytoplankton (Cloern 1987), ultimately resulting in less energy supporting food webs comprising EFH.

Release of contaminants

Sediments act as a sink for contaminants in the aquatic environments. When resuspended, particulate-bound contaminants may be remobilized into the water column where they impact EFH and exhibit toxicological effects on invertebrate and fish species. Benthic habitats adjacent to industrial and urban centers can be contaminated with heavy metals, organochlorine compounds, polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, and other substances known to have negative effects on aquatic organisms (Kennish 1997, Brown et al. 1998, Kennish 2002, Islam and Tanaka 2004). Sediments in estuaries downstream from agricultural or urban/suburban residential areas may also contain herbicides and pesticides (NMFS 1997). The effects of these compounds can range from sublethal (e.g., reduced growth or feeding) to lethal depending on type of contaminant, route of exposure, ambient conditions, species, life stage, and body size (Poston 2001, Brinkmann et al. 2013). For example, PAHs have been reported to cause cancer, reproductive anomalies, immune dysfunction, impaired growth and development, and other impairments in fish when present in sufficiently high concentrations over long periods of time (Poston 2001, Johnson et al. 2008, Meador 2008, Spearow et al. 2011, Collier et al. 2014).

Current standards are based on toxicity to benthic invertebrates, so while they may protect against impacts to the fish prey base, they are not necessarily protective of fish (e.g., see Johnson et al. 2002 and Meador et al. 2002).

This is especially true for contaminants such as polycyclic aromatic hydrocarbons (PAHs), which are metabolized to mutagenic and carcinogenic intermediates in fish, but to a much lesser extent in invertebrates (see Varanasi 1989 or Meador 2008).

Entrainment

Dredging entrainment can have significant effects on fish populations (McGraw and Armstrong 1990, Boysen and Hoover 2009, Drabble 2012a,b). Dredging entrainment is the uptake and trapping of aquatic organisms by the dredge suction (Reine and Clarke 1998) or clamshell. Depending on the operation, each life stage of fish may be at risk of injury or death by dredge entrainment (Buell 1992). In many cases, important food sources can also be significantly reduced or eliminated by entrainment (Van der Veer et al. 1985, Newell et al. 1998, Boysen and Hoover 2009). Furthermore, by removing or displacing native species and severely disturbing EFH, dredging may provide opportunities for colonization of invasive species (Vitousek et al. 1997, Minchinton and Bertness 2003, Strecker and Olden 2014).

Entrainment rates for invertebrates vary based on machinery, habitat, season, and size of organism (Armstrong et al. 1982, Larson 1989). Where vulnerable, impacts on invertebrates can be significant and may extend at least 100 m from the site of dredging (McCauley et al. 1977).

Noise effects

Dredging equipment and dredging-related activities generate underwater sound pressure waves that may adversely affect EFH. Sources of these underwater sounds originate from vessel propellers, pumps, generators, and from dredge buckets and dragheads coming in contact with the substrate (Clarke et al. 2002, Dickerson et al. 2001). Sound recordings during dredging operations documented increases above background noise levels as far as 1.2 km from the source, and peak sound pressures of 175 decibels (Reine et al. 2014). Injuries associated directly with noise produced by dredging are poorly studied, but effects of similar noises include avoidance of the affected area, increased stress, and temporary shifts in hearing thresholds (Hastings and Popper 2005). Shifts in hearing thresholds may result from exposure to low levels of sound for a relatively long period of time or exposure to high levels of sound for shorter periods (Scholik and Yan 2002, Liu et al. 2013). Threshold shifts can impact a fish's ability to carry out its life functions, such as locating food, mates, or predators.

Potential Conservation Measures for Dredging

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of dredging on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help operators avoid, minimize, and mitigate impacts of dredging on EFH.

General guidelines

- Do not dredge in or near sensitive EFH such as spawning grounds, eelgrass beds, or habitats that support important rearing or spawning habitats and prey sources for fish.

- Perform dredging only during periods that have the least impact on fish and food webs. Establish areal extent and timing guidelines in cooperation with local, state, tribal, and federal fish biologists. Make every effort to dredge only to the authorized depth, using deeper, single-day events rather than shallower, multiple-day events.
- Use only hydraulic dredges and allow no overflow.
- When using a mechanical dredge, increase cycle time and reduce bucket deployment.
- Conduct pre-dredging site sampling and analyses to predict cumulative effects of existing and proposed dredging operations on EFH and organisms. Include all impacts to EFH as part of the permitting process, mitigate for all adverse effects, and monitor mitigation effectiveness.
- Use alternative dredge material disposal options (e.g., upland disposal), and recycle dredged material for beneficial use opportunities.

Loss and alteration of habitat

- Do not place pipelines and accessory equipment used in conjunction with dredging operations close to sensitive EFH and Habitat Areas of Particular Concern (HAPC)—e.g., kelp beds, eelgrass beds, estuarine/salt marshes, etc.
- Do not directly remove or bury habitat features. In cases where features are removed or buried, the operator must mitigate these losses to EFH.

Altered hydrology and geomorphology

- Avoid new dredging projects. Activities that would likely require dredging (such as placement of piers, docks, marinas, etc.) should instead be sited in deeper-water areas or designed to alleviate the need for maintenance dredging. New projects should only be permitted for water-dependent purposes, and only when no feasible alternatives are possible.

Sedimentation, siltation, and turbidity

- Use equipment that generates the least amount of sedimentation, siltation, and turbidity (e.g., environmental buckets instead of excavators).
- Use BMPs, such as the establishing riparian area buffers, to help reduce and control sediment input.
- Make every effort to avoid dredging very fine sediments, such as silt. In general, the finest substrate dredged should be sand (>80% sand).
- Implement light monitoring at treatment (within adjacent EFH) and control sites (area outside of dredging influence) during dredging.
- Incorporate adequate control measures to minimize turbidity where the dredging equipment used is expected to create significant turbidity, especially where effects may be long-lasting (>1 day).
- Explore collaborative approaches between material management planners, pollution control agencies, and others involved in watershed planning to identify point and nonpoint sources of sediment and sediment pollution associated with dredging.
- Have a plan for barge dewatering at the dredge site.
- Make a turbidity monitoring plan.

Release of contaminants

- Monitor sediment contamination levels during dredging and report all effects, preferably in real time. If contamination

is acute, re-evaluate dredging methodology and require methods that do not release contaminants.
- Using best available science, develop procedures for disposal of dredged material that protect EFH and organisms from contaminants.

Entrainment

- Design and implement dredging suction mechanisms that minimize or eliminate entrainment or impingement of fish and their prey sources.

Noise effects

- Clearly report predicted noise levels that will occur during dredging activities.
- Sample and monitor noise levels in real time during dredging activities. If noise levels surpass accepted thresholds for aquatic organisms, cease operations and implement alternative methodology.
- Incentivize development of peer-reviewed studies that identify how noise generated from dredging impacts aquatic organisms and EFH.

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15. Aquaculture

For the purposes of policy development, aquaculture is defined under the National Aquaculture Act of 1980 (16 USC 2801–2810) as the propagation and rearing of aquatic marine organisms for any commercial, recreational, or public purposes. This definition covers all authorized production of marine finfish, shellfish, plants, algae, and other aquatic organisms for: 1) food and other commercial products, 2) wild stock replenishment and enhancement for commercial and recreational fisheries, 3) rebuilding populations of threatened or endangered species under species recovery and conservation plans, and 4) restoration and conservation of aquatic habitat. This chapter summarizes some of the potential impacts of aquaculture on marine and freshwater organisms and the EFH that they inhabit.

Current marine aquaculture facilities in NOAA Fisheries' West Coast Region (WCR) are generally located in nearshore areas. However, one offshore shellfish facility has been permitted and one offshore finfish facility has applied for permits. Shellfish species cultured in the West Coast Region include oysters, clams, mussels, and abalone. Pacific oysters (*Crassostrea gigas*) account for the majority of production. Salmon species (Atlantic salmon, *Salmo salar*, and Pacific salmon and trout, *Oncorhynchus* spp.) are the most commonly produced finfish, but white sea bass (*Atractoscion nobilis*) are also grown. For examples of EFH consultations on aquaculture operations in the West Coast Region, please refer to WCR-2014-1502[7] and WCR-2014-825[8] (for shellfish) and WCRO-2018-00286[9] (for finfish).

Potential Adverse Impacts of Aquaculture

The following factors associated with aquaculture can impact EFH and are described briefly below: release of contaminants, water-quality impacts, introduction of pathogens, establishment and spread of non-native species, benthic impacts, and escapes and releases. Suggested conservation measures related to each of these factors are provided in the following section.

Release of contaminants

Release of contaminants from aquaculture facilities has negative impacts on EFH (Primavera 2006, Burridge et al. 2010), but the degree of impacts depends largely on facility design, operation, and management practices (MacMillan et al. 2003). Chemical contaminants that may be used in aquaculture include antifoulants, herbicides, pesticides, disinfectants, and parasiticides, and drugs such as antibiotics and biologics (for comprehensive reviews see Burridge et al. 2010, AFS 2014). Chemical products can impact EFH in a number of different ways. Antifoulants, herbicides, and pesticides contain metals that can contaminate nearby sediments and are lethal to nontarget organisms (Brooks

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[7] https://www.nws.usace.army.mil/Portals/27/docs/regulatory/NewsUpdates/NMFSBiOpErrataMemoRevisedITS.pdf

[8] https://www.nwp.usace.army.mil/Portals/24/docs/regulatory/NMFS/20140923_NWP_Shellfish_Aquaculture_Programmatic_consultation.pdf

[9] https://wildfishconservancy.org/wp-content/uploads/2022/04/2022_02-16_FinfishRearingReinit_WCRO-2018-00286-3.pdf

and Mahnken 2003b, Burridge et al. 2010). Information on impacts of disinfectants is sparse; however, surfactants used in disinfectants can disrupt endocrine function, and could have other negative impacts on aquatic organisms. Parasiticides can help manage infestations, but are also lethal and could impact reproductive success in nontarget organisms (Haya et al. 2001, Burridge et al. 2010). Antibiotics can cause short-term (days) or long-term (years) contamination of nearby benthic sediments, impacting the microbial community (Scott 2004, Armstrong et al. 2005, Rigos and Troisi 2005). When administered under regulatory guidelines, biologics such as vaccines are not considered a major risk to EFH or aquatic organisms (AFS 2014).

Water-quality impacts

Aquaculture can increase nutrients and turbidity, cause fluctuations in dissolved oxygen (Price and Morris 2013), and could alter nitrogen and phosphorus cycling in EFH (Bouwman et al. 2013). Impacts of facilities vary among aquatic environments; for example, nearshore facilities may have a greater impact on EFH than those sited in deeper, offshore EFH, where operational byproducts are more easily flushed and diluted (Rust et al. 2014). Furthermore, impacts of reduced water quality caused by aquaculture facilities vary, but could be exacerbated by other environmental factors (Ruiz et al. 2001).

Introduction of pathogens

Farming of aquatic organisms can lead to the spread of pathogens from cultured to wild organisms, posing a significant risk to endemic aquatic organisms inhabiting EFH (Waknitz et al. 2003, Mydlarz et al. 2006, Primavera 2006, Suttle 2007, NAAHP 2008, Walker and Mohan 2009, Terlizzi et al. 2012). Diseases can be caused by infectious (bacterial, viral, fungal, parasitic) and noninfectious (nutritional, environmental, pollution, stress) agents (Taksdal et al. 2007), and could be exacerbated by parasitic infestations related to aquaculture facilities (McKibben and Hay 2004, Morton et al. 2005). The spread of disease in aquaculture facilities is influenced by many factors including immune status, stress level, pathogen load, environmental condition, nutritional health, and feeding management (Wedemeyer 1996). While pathogens normally occur in nature, intensive aquaculture can lead to accelerated, density-dependent horizontal transfer of pathogens among individuals (Krkosek 2010). Furthermore, organisms introduced for culture can become vectors for non-native organisms that can cause disease (Ruesink et al. 2005). The type and level of husbandry practices and disease surveillance will also influence the potential spread of pathogens to wild stocks (Trushenski et al. 2015). Climate change has been implicated in increasing the prevalence and severity of infectious pathogens that may cause disease originating from cultured or transplanted aquaculture stocks (Hoegh-Guldberg and Bruno 2010, Price and Morris 2013, Rust et al. 2014).

Establishment and spread of non-native species

The novel aquaculture structures and/or the cultured species themselves may serve to facilitate establishment and/or proliferation of non-native species and associated fouling pests and diseases. For instance, Forrest et al. (2009) concluded that the introduction and spread of pest species is a potentially important, but often overlooked, consequence of oyster cultivation. Aquaculture infrastructure and gear have been shown to harbor high incidences of non-native species compared to native habitats (Simkanin et al. 2012) and can be a source of marine debris that may transport such species over extensive distances, further contributing to their spread (Astudillo et al. 2009) and creating a biosecurity risk (Campbell et al. 2017). However, Iacarella et al. (2019) indicated that aquaculture gear is an unlikely vector for non-native species in the northeastern Pacific Ocean because of limited movement of shellfish gear and existing cleaning practices.

Benthic impacts

Waste from aquaculture facilities can have negative impacts on benthic EFH (Brooks and Mahnken 2003a, Nash 2005, Naylor 2006, Primavera 2006, Tucker and Hargreaves 2008, Amirkolaie 2011). Both finfish and shellfish facilities can create large amounts of excess waste through uneaten feed and feces (Cranford et al. 2006). Waste accumulation that originates from fish farms could increase potential for disease (Vezzulli et al. 2008) and lead to eutrophication (Reid et al. 2008). Solid waste from aquaculture can increase benthic sedimentation, causing accumulation of organic matter and anoxia, and impacting important vegetation, such as seagrass (Holmer et al. 2008).

Excess feed and feces are the predominant sources of particulate wastes from fish farms. Shellfish operations release feces and pseudofeces, a byproduct of mollusks filtering food from the water column. If allowed to accumulate, particulate waste products may alter biogeochemical processes of decomposition and nutrient assimilation. At sites with poor circulation, waste accumulation can alter the bottom sediment and perturb infaunal communities if wastes are released in excess of the aerobic assimilative capacity of the substrate. Benthic impacts due to particulate waste from marine aquaculture are typically localized and ephemeral in nature (Dumbauld et al. 2009, Rust et al. 2014).

Aquaculture structures, operations, and maintenance can impact the benthic environment by increasing shading and causing displacement of organisms (Dumbauld et al. 2009). Shellfish operations, in particular, may reduce the density or spatial coverage of submerged aquatic vegetation, such as eelgrass.

Escapes and releases

Escape of farmed organisms could pose a threat to wild organisms (McGinnity et al. 2003, Goldburg and Naylor 2005). Technical and operational failures at aquaculture facilities can lead to the escape of farmed organisms into EFH (Schiermeier 2003, Jensen et al. 2010), potentially affecting wild organisms (Ford and Myers 2008, Waples et al. 2012). Escape of farmed fish can lead to reproduction and competition with wild fish, the spread of pathogens (Naylor et al. 2005), and reduced biodiversity in EFH (Wilcove et al. 1998, Bax et al. 2001, D’Antonio et al. 2001, Olenin et al. 2007).

Intentional release of artificially propagated organisms (i.e., for enhancement or restoration) can also pose a threat to EFH and native organisms (Grosholz 2002). Hatchery-raised organisms can have reduced growth (Quinn et al. 2012) and show competitive dominance (Berejikian et al. 2001) and fitness (Reisenbichler and Rubin 1999, Thériault et al. 2011). Furthermore, genetic introgression could alter functional behaviors important for growth and survival (Berejikian et al. 1996, Grant 2011). It is important to note that impacts of released, artificially propagated organisms could range from no effect to the extirpation of native organisms. Other anthropogenic factors in the environment may exacerbate impacts (for review see Pillay 2004).

Potential Conservation Measures for Aquaculture

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of aquaculture on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help aquaculture developers and operators avoid, minimize, and mitigate impacts of aquaculture on EFH.

General guidelines

- Use modern production technologies, proper siting protocols, standardized operating procedures, and BMPs to reduce the risk of environmental damage and degradation that can be caused by aquaculture development and activities (Shumway 2011, Price and Morris 2013, Rust et al. 2014).

Release of contaminants

- Employ BMPs and use vaccines to reduce the need for antibiotics (Forster 2010, Rico et al. 2012, Rust et al. 2014).
- Employ preventative husbandry practices and proper stocking densities to reduce the need for chemical treatments.
- If needed, use only prescribed antibiotics, parasiticides, and other medicines. Use sparingly and in accordance with approved protocols to minimize environmental contamination.

Water-quality impacts

- Site finfish operations appropriately in well flushed, non-depositional areas (Price and Morris 2013). For example, site cages in water at least twice as deep as the cage, in areas with minimum flows of 7 cm/s, or use models (i.e., Aquamodel or depomod) to determine adequacy of site, to avoid water-quality impacts.
- Use BMPs, including siting aquaculture operations outside of nutrient-sensitive habitats, responsible cleaning practices, integration of feed management strategies, use of optimally formulated diets, and other management measures to minimize nutrient discharge.
- Construct wetlands at or near facilities to filter and help remove solids, phosphorus, and nitrogen compounds from aquaculture effluent (Michael 2003).

Introduction of pathogens

- Prevent introduction of pathogens at aquaculture facilities (LaPatra 2003).
- An accredited aquatic organism health professional should regularly inspect crops and perform detailed diagnostic procedures to determine if disease presents a risk.
- Biosecurity plans to prevent or control the spread of pathogens within a farm site, between aquaculture operations, or to wild populations should be developed by veterinarians with expertise in fish culture, or qualified aquatic animal health experts.
- Document all stocking and transplanting activities to improve tracking ability if an outbreak occurs.
- Ensure compliance with federal and state health-control legislation. Import and export certifications and testing for certain types of diseases fall under the jurisdiction of the USDA Animal and Plant Health Inspection Service

(APHIS). States in the WCR all have specific protocols that must be followed when transplanting cultured species into wild environments to minimize the incidence of disease transfer.

Establishment and spread of non-native species

- Assess project areas for susceptibility to, or presence of, invasive organisms. If invasive organisms are present or the site could be susceptible to invasive hosts, design and implement an eradication management and monitoring plan prior to construction phases to eliminate the spread of such organisms. Submit all information on newly discovered invasions or spreading to local conservation or regulatory agencies (fish and wildlife) and organizations:
    - *Washington*: Washington Invasive Species Council Annual Report.[10]
    - *Oregon*: Oregon Invasive Species Council.[11]
    - *California*: Invasive Species Council of California.[12]
- Develop appropriate early detection and rapid response eradication methods for non-native plant and animal species, consistent with federal guidelines, as specified by the National Invasive Species Management Plan.
- Provide and display educational materials on the potential impacts resulting from the release of invasive species into the natural environment to increase public awareness and engender broad cooperation among user groups and stakeholders.
- To the extent feasible, all culture equipment and gear should be marked in a manner that easily identifies the responsible party's name and contact information.
- Aquaculture gear or equipment should not be released into the aquatic environment.
- An inventory management system should be used that tracks the status and location of all equipment. Any gear or equipment that becomes displaced from the culture areas should be retrieved, and any lost gear that was not retrieved should be documented.

Benthic impacts

- Site aquaculture facilities in well-flushed waters. Belle and Nash (2008) recommend siting cages in water at least twice as deep as the cage, with minimum flows of 7 cm/s.
- Use fallowing to reduce benthic impacts. Fallowing is the temporary relocation or suspension of aquaculture operations to allow sediments and the benthic community to recover from excessive nutrient loading (Tucker and Hargreaves 2008).
- Optimize feeding practices and use low-phosphorus feed (MacMillan et al. 2003). Actions that could reduce benthic impacts of feed include:
    - Reducing the use of solids by using highly digestible feed with high nutritional value.
    - Reducing dissolved nitrogen by using feed that contains proper protein and energy content (Amirkolaie 2011).
    - Setting rations to reduce excessive feed and feces.
- Implement benthic monitoring plans to detect nutrient enrichment and effects on benthic habitat and community

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[10] http://www.invasivespecies.wa.gov

[11] http://www.oregoninvasivespeciescouncil.org

[12] http://www.iscc.ca.gov

structure. Establish treatment (facility) and control (nonfacility) sites to evaluate aquaculture effects versus natural and seasonal variability.

- Do not site new aquaculture operations in or above sensitive benthic communities such as eelgrass or other SAV, or near fish spawning habitat. If forage fish spawn is detected on aquaculture gear, cease aquaculture activities in the area until such time as the eggs have hatched and spawn is no longer present.

Escapes and releases

- Use only native or naturalized species unless best available science demonstrates use of non-native or other species would not cause undue harm to wild species, habitats, or ecosystems in the event of an escape.
- Ensure that monitoring and maintenance plans and protocols employ BMPs designed to reduce aquaculture escapes. Plans should provide protocols (e.g., recapture, mitigation) for situations where an escape occurs.
- Use risk assessment tools and empirical models (ICF 2012) to identify and evaluate risks of farmed escapes on wild populations (Waples et al. 2012). The Offshore Mariculture Escapes Genetics Assessment model (OMEGA) is one such tool developed for this purpose and is available from the NOAA Aquaculture website.[13]

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[13] http://www.nmfs.noaa.gov/aquaculture/science/omega_model_homepage.html

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16. Overwater Structures

Potential Adverse Impacts of Overwater Structures

The following factors associated with overwater structures (i.e., marinas, docks, piers, bridges, roads, oil platforms, wind energy structures, houseboats) can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, release of contaminants, impacts to organisms, invasive organisms, and noise effects. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Overwater structures and associated uses can lead to loss and alteration of habitat in EFH (Simenstad et al. 1998, Carrasquero 2001, Nightingale and Simenstad 2001, Johannessen and MacLennan 2007). Overwater structures shade benthic habitats and aquatic primary producers such as seagrass, salt marsh plants, and algae, which are susceptible to light limitation (Kenworthy and Fonseca 1996, Burdick and Short 1999, Glasby 1999, Shafer 1999, Zimmerman 2006, Thom et al. 2008). Seagrasses have particularly high light requirements (Kenworthy and Fonseca 1996), making them especially vulnerable to shading from overwater structures (Zimmerman 2006). Shading added by overwater structures can adversely affect plant composition and productivity and habitat complexity (Haas et al. 2002, Struck et al. 2004, Whitcraft and Levin 2007), potentially impacting higher trophic levels.

Altered hydrology and geomorphology

Overwater structures can alter hydrology and geomorphology in EFH (Carrasquero 2001, Nightingale and Simenstad 2001, Johannessen and MacLennan 2007). High flows can cause excessive scour and erosion around the base of pilings that often support overwater structures, while low flows may result in increased sedimentation (Kelty and Bliven 2003, Edinger and Martin 2010). The accumulation of debris and shell from barnacles, molluscs, and other marine organisms at the base of pilings may also inhibit seagrass growth in the surrounding area (Fresh et al. 1995, Shafer and Lundin 1999, Thom and Shreffler 1996). The resulting changes in substrate and habitat caused by scour or deposition may directly affect fish and shellfish or their habitat (Bowman and Dolan 1982, Penttila and Doty 1990).

Release of contaminants

Overwater structures can be sources of contaminants in EFH. Steel components in the marine environment (e.g., pilings, boat hulls) are either zinc coated or have a zinc anode to protect from corrosion. The introduction of zinc from these materials can result in adverse effects to organisms that inhabit EFH (Bird et al. 1996, Rousseau et al. 2009, Brinkman and Johnston 2012, Calfee et al. 2014). Creosote-treated wood used for pilings and docks (NOAA 2009) can lead to phototoxicity, disturbance of hormone regulation (van Brummelen et al. 1998), and immunotoxicity (Möller et al. 2014) in aquatic organisms that inhabit EFH (Lalonde et al. 2011). Wood treated with alternative chemicals, such as ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA Type C), also leaches contaminants into EFH, but residence time is shorter than creosote (Poston 2001). Copper introduced to the aquatic environment from treated wood products and antifouling hull paints (Neira et al. 2009, NOAA 2009) can cause a range of adverse effects, including altered behavior, impaired olfaction, and mortality (Eisler 2000, Baldwin et al. 2003, Hecht et al. 2007, Sandahl et al. 2007, NOAA 2009). Port and marina structures can impede water movement, potentially concentrating these contaminants in addition to nutrients (Moreno et al. 2009). Contaminants introduced to the marine environments by overwater structures can be taken up by lower trophic levels and transferred up the food chain, impacting growth, survival, reproduction, and ultimately population viability of consumers such as salmon and shellfish (Sethajintanin et al. 2004, Meador et al. 2010, Jenkins et al. 2014, Melwani et al. 2014).

Impacts to organisms

Overwater structures can negatively impact EFH by increasing shade and reducing primary production, growth, density, and diversity of benthic invertebrates (Whitcraft and Levin 2007). Overwater structures can also affect behavior and use of nearshore habitat by pelagic and benthic fish (Able et al. 1998, Simenstad et al. 1999, Carrasquero 2001, Toft et al. 2007, Able et al. 2013, Ono and Simenstad 2014). Ecological conditions during early life-history stages are likely critical determining factors for recruitment and survival, with survival linked to the ability to locate and capture prey and to avoid predation (Britt 2001). The reduced-light conditions found under overwater structures limit the ability of fishes, especially juveniles and larvae, to perform these essential activities and can lead to lower growth rates, fish abundance, and species richness (Able et al. 1998, Able et al. 1999). In addition, the location, width, orientation, and lighting of a structure has been found to impact the migration and movement behavioral patterns of juvenile fishes (Simenstad et al. 1999, Munsch et al. 2014, Ono and Simenstad 2014, Munsch et al. 2017). Prey fish may be more vulnerable to predators that congregate around such structures (Helfman 1981, Petersen and Gadomski 1994, Carrasquero 2001, Willette 2001, Willette et al. 2001, Tabor et al. 2011, Munsch et al. 2017). Permanent moorings and temporary anchorings can damage eelgrass beds and benthic communities (Sargent et al. 1995, Francour et al. 1999, Campbell et al. 2002, Kennish 2002), and grounding of large objects or propeller scarring can smother or destroy shellfish beds and scour aquatic vegetation (Nightingale and Simenstad 2001). Several studies have shown that natural recovery of propeller-scarred seagrass may take over 60 years (Rasheed 1999, Fonseca et al. 2004).

Noise effects

The noise generated by vessel operations concentrates in ports, marinas, and heavily used shipping lanes or routes, and may impact fish spawning, migration, and recruitment behaviors (Stocker 2002, Hildebrand 2005, Codarin et al. 2009). Exposure to continuous noise may also impair hearing in aquatic organisms (Jasny et al. 1999, Scholik and Yan 2002). Small craft with high-speed engines and propellers (e.g., recreational boats with outboard engines) typically produce higher-frequency noise than do larger vessels that generate substantial low-frequency noise; however, overall sound levels are higher for larger vessels, and increase with vessel speed (Kipple and Gabriele 2004). Pile driving can generate intense underwater sound pressure waves that may adversely affect the ecological functioning of EFH, including injury or mortality to fishes (Caltrans 2001, Popper and Hastings 2009). For more information and detail on the impacts of pile driving on EFH, see Chapter 18.

Invasive organisms

Overwater structures provide habitat that enables the establishment of invasive organisms (Cohen et al. 2002, Wasson et al. 2005, Glasby et al. 2007, Bulleri and Chapman 2010, Pearl et al. 2013, Strecker and Olden 2014). The establishment and proliferation of invasive organisms has important consequences for native organisms (Beamesderfer and Rieman 1988, Colle et al. 1989, Blossey and Notzold 1995, Byers 1999, Carrasquero 2001, Cohen 2005, Currant et al. 2008) and represents a significant environmental threat to biological diversity (Vitousek et al. 1996, Simberloff et al. 2005). Some researchers have recommended that coastal managers should consider limiting the amount of artificial hard substrates in estuarine environments (Wasson et al. 2005, Tyrell and Byers 2007).

Potential Conservation Measures for Overwater Structures

The following measures can be undertaken by the action agency to avoid, minimize, mitigate, or otherwise offset impacts of overwater structures on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help action agencies avoid, minimize, and mitigate impacts of overwater structures on EFH.

General guidelines

- Decrease shading impacts during the design phase of all overwater structure projects. Factors such as structure orientation (orient length of structure north–south instead of east–west when possible), height above water, structure width, and decking material can significantly affect overwater structure shading impacts on EFH (Burdick and Short 1999, Fresh et al. 2006, Landry et al. 2008, Shafer et al. 2008).
- Use light-transmitting material on all overwater structure projects. Use grated decking (minimum 40% light transmittance, with >60% of the decking open to sunlight) and increased spacing between deck boards to increase the light transmitted through overwater structures (Fresh et al. 2006, Landry et al. 2008, Shafer et al. 2008). These requirements vary by local and state requirements (e.g., WSL 2019).
- For all overwater structure projects, new and existing, increase elevation of all overwater structures (above mean higher high water line [MHHW]), maximize piling spacing, minimize number of piles, design narrower structures, minimize float size and configuration, reduce the amount of pier area that directly contacts the shoreline, and orient structures N–S to improve light transmittance and SAV growth (Shafer et al. 2008).
- Use upland boat storage to minimize the need for overwater structures.
- Use floating breakwaters whenever possible, and remove them during periods of low dock use. Encourage only seasonal use of docks and off-season haul-out of boats and structures.
- Implement projects that mitigate adverse effects on EFH that remain after implementing all other avoidance and minimization measures.
- Consider cumulative past, present, and foreseeable future impacts of development

projects on EFH in the review process for overwater structure projects.
- Incentivize community-use docks to minimize the proliferation of single-family residential docks along shorelines.

Loss and alteration of habitat

- Do not site overwater structures in areas that are occupied by, or determined to be suitable to support, sensitive habitat (e.g., SAV, salt marsh). Mitigate on-site for any and all losses of such important EFH.
- Conduct surveys during the growing season and provide an inventory of presence and location of important marine vegetation (eelgrass, kelp, macroalgae, intertidal wetland vascular plants, etc.) and of relative abundance of and habitat use by important forage fishes such as herring, surf smelt, or sandlance prior to permitting overwater structure projects. All impacts to these organisms and their respective habitats must be mitigated for.
- Site or relocate boathouses to land above the Highest Astronomical Tide line, or offshore of the –5-m MLLW contour, to minimize shading.
- Place floats in deep water to avoid impacts from propeller scour, shading, etc., and reduce the need for navigational dredging.
- Design only nongrounding floats, and require existing floats that ground to be rebuilt.
- Relocate all persistently moored vessels in waters deep enough that the bottom of the vessel remains a minimum of 18 inches off the substrate during extreme low tide events. This will prevent adverse grounding impacts to benthic habitat. If a vessel must be moored over SAV or rocky reef habitats with less than 18 inches between the bottom of the vessel and the substrate at low tides, then float stops should be utilized. This will prevent adverse grounding impacts to benthic habitat.
- Use midline float mooring anchors, if placed within SAV or habitat suitable for SAV, to prevent chain scour to the substrate. This will prevent adverse impacts to SAV and other benthic habitat.

Altered hydrology and geomorphology

- Minimize impacts to hydrology and nearshore processes by avoiding floats that ground at low tide (incorporate stops on piles).
- Any cross or transverse bracing should be placed above mean higher high water to avoid impacts to water flow and circulation.

Release of contaminants

- Do not use treated wood for any structures. Use alternatives such as concrete, steel, or composites (recycled plastic, etc.).
- Take measures to eliminate loss of flotation materials (typically polystyrene foam) through the requirement of full enclosure of flotation materials.
- Require rub strips on treated wood piles or timbers that are abraded by vessels (fender piles) or docks (guide piles) to reduce physical breakup of the piles.
- Encourage removal of treated wood structures (piles and decking) in aquatic areas to decrease overall shading and contamination.

Impacts to organisms

- Conduct in-water work during the time of year when EFH-managed organisms and their prey are least affected.
- Fit all pilings and navigational aids, such as moorings and channel markers,

with devices to prevent perching by piscivorous birds and mammals.

- Orient night lighting such that illumination of the surrounding waters is reduced or eliminated.
- Site all anchored moorings and moored vessels in areas devoid of SAV. This will prevent adverse shading impacts to SAV and subsequent mitigation needs.

Invasive organisms

- Assess project areas for susceptibility to, or presence of, invasive organisms. If invasive organisms are present or the site could be susceptible to invasive hosts, design and implement an eradication management and monitoring plan prior to construction phases to eliminate the spread of such organisms. Submit all information on newly discovered invasions or spreading to local conservation or regulatory agencies (fish and wildlife) and organizations:
    - *Washington*: Washington Invasive Species Council Annual Report.[14]
    - *Oregon*: Oregon Invasive Species Council.[15]
    - *California*: Invasive Species Council of California.[16]
- Develop appropriate early detection and rapid response eradication methods for non-native plant and animal species, consistent with federal guidelines as specified by the National Invasive Species Management Plan.
- Provide and display educational materials on the potential impacts resulting from the release of invasive species into the natural environment to increase public awareness and engender broad cooperation among user groups and stakeholders.

Noise effects

- Incentivize ship designs that include technologies capable of reducing noise generated and transmitted to the water column, such as the use of muffling devices already required for land-based machinery that may help reduce the impacts of vessel noise.
- Evaluate the effects of proposed and existing vessel traffic and associated underwater noise for potential impacts to sensitive areas (e.g., migration routes, spawning areas) so that minimization efforts can be made.
- Exclude vessels or limit specific vessel activities, such as high intensity, low-frequency sonar, to known sensitive EFH if evidence indicates that these activities could have an effect on aquatic organisms.
- Drive piles during low tide periods when substrates are exposed in intertidal areas. This minimizes the direct impacts to fish from sound waves and minimizes the amount of sediments resuspended in the water column.
- Use a vibratory hammer to install piles, when possible. Under those conditions where an impact hammer is required (i.e., substrate type and seismic stability), the pile should be driven as deep as possible with a vibratory hammer prior to the use of the impact hammer. This will minimize noise impacts.

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[14] http://www.invasivespecies.wa.gov
[15] http://www.oregoninvasivespeciescouncil.org
[16] http://www.iscc.ca.gov

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17. Water Intake and Discharge Facilities

Human population growth continues to increase demands on water resources for water supply (Li and Wang 2010, Elimelech and Phillip 2011) and human, urban, and industrial waste disposal (USEPA 1984, Grady et al. 1998, Epstein 2002, Parnell 2003, Kress et al. 2004). Increasingly, saltwater is desalinated for use as potable water (Lattemann and Höpner 2008), impacting marine EFH (Roberts et al. 2010). Wastewater systems treat water contaminated by human and urban uses and discharge this treated effluent directly into EFH, potentially with negative impacts on organisms (Porter and Janz 2003, Barber et al. 2012). Cooling-water withdrawals can entrain organisms, impacting food web structure in EFH (Newbold and Iovanna 2007a,b), and industrial facilities produce contaminated effluent that is released directly into EFH (Eljarrat et al. 2007). Furthermore, reduction and contamination of water resources could be exacerbated by climate change in some areas (Mesa et al. 2002, Deegan and Buchsbaum 2005, Caron et al. 2009, Elimelech and Phillip 2011).

This chapter is divided into five sections that outline some of the adverse impacts of water intake and discharge facilities that adversely impact EFH, including Desalination Facilities, Cooling-Water Intake Facilities, Sewage Discharge Facilities, Combined Sewage Overflow, and Industrial Discharge Facilities. Suggestions for avoidance, minimization, and mitigation of these impacts on EFH are provided for each section.

Desalination Facilities

Potential adverse impacts of desalination facilities

(Adapted from Roberts et al. 2010.)

The following factors associated with desalination facilities can impact EFH and are described briefly below: release of contaminants, entrainment and impingement, and alterations to water quality. Suggested conservation measures related to each of these factors are provided in the following section.

Release of contaminants

Chemicals used during pre-treatment and membrane-cleaning of desalination intakes can be toxic to organisms inhabiting EFH (Elimelech and Phillip 2011). Susceptibility to these contaminants varies by species and life stage; however, juvenile stages of fish may be especially susceptible to these chemicals, even at low levels of contamination (Gould et al. 1994).

Entrainment and impingement

Water intakes located in or connected to EFH can entrain and impinge fish (Zydlewski and Johnson 2002, Ellsworth et al. 2010). Entrainment can subject juvenile fish to physical abrasion and rapid pressure changes (Mussen et al. 2014, Zeug and Cavallo 2014). Intake pipes at diversions can stress or disorient fish through entrainment or impingement and can also create conditions that favor predators such as larger fish and birds (Moyle and Israel 2005). Entrainment and impingement often result in the death of fish, and may have cumulative adverse impacts on fish populations (Swanson et al. 2005, Kimmerer 2008, Grimaldo et al. 2009). Seawater intake at desalination facilities can entrain and impinge marine organisms, leading to direct mortality (Newbold and Iovanna 2007b). Nonlethal entrainment or impingement can stress or disorient fish, creating conditions that favor predators such as larger fish and birds (NOAA 1994).

Alterations to water quality

Desalination operations can have negative impacts on water quality in EFH (Zhou et al. 2013). Brine effluent is highly saline and is denser than surrounding water, which could impact benthic communities (Tularam and Ilahee 2007, Del-Pilar-Russo et al. 2008, Roberts et al. 2010, Phillips et al. 2012). Corals, mangroves, aquatic vegetation, and seagrasses have all shown negative responses to increased salinity associated with brine discharge (Raventós et al. 2006, Garcia et al. 2007). Water temperature in brine discharge plumes can be significantly higher than surrounding waters, affecting behavior and physiology of aquatic organisms (Blaxter 1969). In addition, increased water temperatures in the upper strata of the water column can increase water column stratification, which inhibits the diffusion of oxygen into deeper water. This can lead to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations in EFH, especially those that contain excess nutrients (Kennedy et al. 2002).

Potential conservation measures for desalination facilities

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of desalination facilities on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of desalination facilities on EFH.

General guidelines

- Develop and implement BMPs to avoid and minimize impacts to EFH during facility construction (e.g., minimizing noise, prohibiting construction below the mean high water line, developing a stormwater pollution prevention plan).
- Conduct evaluations of facility development effects on EFH, followed by a minimum of three years of monitoring operational effects on EFH.
- Mitigate for any and all impacts to EFH and the biota it supports that cannot be avoided through BMP project design or operations (for examples, see Guidelines for Desalination Plants in the Monterey Bay National Marine Sanctuary).[17]
- Only consider desalination when existing alternatives (e.g., wastewater recycling) are not feasible.
- Design, site, and operate desalination plants with the lowest possible carbon footprint to avoid or minimize cumulative impacts, including contributions to emissions (e.g., CO_2, CH_4) that accelerate global warming.
- Do not locate desalination plants, intakes, or discharges in or near Habitat Areas of Particular Concern (HAPCs). Do not locate desalination facilities in or near areas of high biological productivity, such as upwelling centers.

Release of contaminants

- Design the facility to minimize impacts of effluent on EFH and organisms or ecological processes therein.

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[17] https://nmsmontereybay.blob.core.windows.net/montereybay-prod/media/resourcepro/resmanissues/pdf/050610desal.pdf

- Provide a complete list of all chemicals used during construction and operation of the desalination facility. Include quantities for routine use (e.g., cleaning of filter membranes), deleterious effects on aquatic biota, and vetted protocols for storage and disposal. Include a detailed HazMat spill prevention and response plan for chemicals, as needed.
- Evaluate and report on the feasibility of using alternative pretreatment techniques such as ozone pretreatment, subsurface intakes, and membrane filtration. Such alternatives can reduce the need for the use of chemicals.

Entrainment or impingement

- Do not site desalination facilities in or near biologically productive areas (e.g., kelp forests or other dense beds of submerged aquatic vegetation) since entrainment and impingement impacts are in large part dictated by the biological productivity at the site.
- Facility designs must attempt to reduce or eliminate entrainment and impingement. Design subsurface intakes as opposed to traditional open-water intakes, if at all feasible. Other options to reduce entrainment and impingement include:
    - Vertical and radial beach wells.
    - Horizontal directionally drilled (HDD) and slant-drilled wells.
    - Seabed filtration systems or other subseafloor structures.
- Subsurface intakes must be used rather than traditional open-water intakes, where feasible. However, subsurface intakes must not:
    - Cause saltwater intrusion into aquifers.
    - Exacerbate coastal erosion.
    - Negatively impact coastal wetlands that may be connected to the same aquifer.
- If facility uses an open-water intake, developer plans must show plans to minimize entrainment and impingement, such as:
    - Placing the intake structure to avoid sensitive or highly productive habitat.
    - Screening the intake ports.
    - Increasing the number of intake ports or decreasing the intake velocity.

  The project proponent must provide appropriate and applicable estimates of entrainment/impingement rates and the impacts associated with various intake velocities and screen mesh sizes. Evaluations should use local data, including diurnal and seasonal variations in planktonic abundance and location.
- In cases where a subsurface intake is not feasible, use existing pipelines to minimize impacts to the seafloor. If a new pipeline is necessary, developers must evaluate seafloor or subseafloor placement to minimize disturbances to EFH.
- Any impacts to EFH and the biota it supports that cannot be avoided through project design or operations require appropriate mitigation. The necessary level of mitigation will be determined through the use of a biologically based model, such as the habitat production foregone method, in order to account for all “non-use” impacts to affected biota. Mitigation projects should attempt to directly offset the impacted species or habitat (in-place, in-kind mitigation).

Altered water quality

- Determine the feasibility of diluting brine effluent by blending it with other existing discharges.
- Evaluate potential for an integrated regional water-supply project with other water suppliers and agencies considering water-supply projects in the area.

- Discharge brine in an area with high circulation and not located in or near ecologically sensitive areas (e.g., HAPCs).
- Desalination plants proposing to co-locate with power plant once-through cooling systems must include an assessment of the impacts, along with alternative intake and outfall structures that would avoid or minimize these impacts. Evaluate the continued availability and reliability of the feedwater source and assess the impacts that would occur from operating the intake and outfall structures without the use of the power plant once-through cooling structures.
- Evaluate measures that minimize impacts from desalination plant discharge, including:
    - Discharging effluent to an area with greater circulation or greater depth.
    - Increasing the number of diffusers.
    - Increasing the diffuser velocity while minimizing the volume at each outlet.
    - Diluting brine with seawater or another discharge, or using a subsurface discharge structure.
- The project proponent should provide a detailed evaluation of the projected short- and long-term impacts of the brine plume on marine organisms, based on a variety of operational scenarios and oceanographic conditions. Modeling should address different types of seasonal ocean circulation patterns, including consideration of "worst case scenarios".
- Avoid areas with limited water circulation that can "trap" the brine discharge, such as enclosed bays or estuaries. Instead, discharge brines in areas with strong tidal currents to achieve more rapid dilution of the brine by the receiving waters.
- Include results of accepted plume models to illustrate how the plume will behave during variable oceanographic conditions. The plume model should estimate salinity concentrations at the discharge point, as well as where and when it would reach ambient ocean concentrations. The extent, location, and duration of the plume where the salinity is 10% above ambient salinity should also be provided.
- The project proponent should provide information on the physical and chemical parameters of the brine plume, including salinity, temperature, metal concentrations, pH, and oxygen levels. These water-quality characteristics of the discharge should conform to California Ocean Plan requirements and should be as close to ambient conditions of the receiving water as feasible.
- Implement a continuous monitoring program to verify the actual extent of the brine plume, and to determine if the plume is impacting EFH. If it is, mitigation for the EFH impact should be required.

Cooling-Water Intake Facilities

Potential adverse impacts of cooling-water intake facilities

The following factors associated with cooling-water intake facilities can impact EFH and are described briefly below: altered hydrology, entrainment and impingement, and construction and maintenance. Suggested conservation measures related to each of these factors are provided in the following section.

Altered hydrology

Instream and riparian habitat morphology (Tabacchi et al. 1998) and survival of embryonic and larval life stages of fish (Cederholm and Reid 1987, DeVries 1997, Quinn 2005) can be negatively affected by anthropogenic changes in volume and timing of stream discharge. Commercial and domestic water uses associated with cooling-water intake facilities can alter hydrologic processes in EFH. Upstream water use can decrease river flows (Caldwell et al. 2012), alter the transport of sediments (Christie et al. 1993, Fajen and Layzer 1993) and organic matter, reduce water depths, alter water chemistry (NPPC 1986), and exacerbate extreme diel temperature patterns (Zale et al. 1993). Alterations to instream habitat and sediment transport caused by upstream water use can lead to decreases in survival of fish embryos (Lohse et al. 2008, Deitch et al. 2009), impediments to fish migration (Deegan and Buchsbaum 2005), and reduction of invertebrate populations (McKay and King 2006) that support fish production (Deitch et al. 2009).

The volume and timing of freshwater delivery to estuary EFH is also impacted by upstream water use at intakes, affecting water residence time, temperature, salinity, water quality, and stratification of the water column (Kimmerer 2002, Flemer and Champ 2006). Thermal effluents can alter the benthic community or kill marine organisms, especially larval fish (Blaxter 1969), and impacts can be severe in nearshore EFH (Schiel et al. 2004, Foster 2005).

Entrainment and impingement

Entrainment and impingement at cooling-water intake facilities can be a significant source of mortality in fish populations (Newbold and Iovanna 2007a,b, White et al. 2010). Water intakes located in or connected to EFH can entrain and impinge fish (Zydlewski and Johnson 2002, Ellsworth et al. 2010). Entrainment can subject juvenile fish to physical abrasion and rapid pressure changes (Mussen et al. 2014, Zeug and Cavallo 2014). Intake pipes at diversions can stress or disorient fish through entrainment or impingement, and can also create conditions that favor predators such as larger fish and birds (Moyle and Israel 2005). Entrainment and impingement often result in the death of fish, and may have cumulative adverse impacts on fish populations (Swanson et al. 2005, Kimmerer 2008, Grimaldo et al. 2009). Nonlethal entrainment or impingement can stress or disorient fish, creating conditions that favor predators such as larger fish and birds (NOAA 1994).

Construction and maintenance

Impacts to aquatic habitats can result from construction-related activities and routine operation and maintenance for cooling-water intake facilities. Dredging associated with construction of cooling-water intake facilities can cause turbidity and sedimentation in nearby waters, degraded water quality, and disturbed substrates (Williams and Thom 2001). As benthic material is disturbed, suspended particulate matter is transported from the site to other locations where it would not otherwise occur (Uncles and Stephens 2010). Toxic biocides or heat treatments are routinely used to clean intake and discharge structures at water-cooling intake facilities. These toxic materials are often permitted and released, either intentionally or accidentally, into sensitive EFH (NMFS 2011).

Potential conservation measures for cooling-water intake facilities

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of cooling-water intake facilities on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of cooling-water intake facilities on EFH.

General guidelines

- All unavoidable impacts to EFH must be mitigated for, both in place and in kind, or as determined through the permitting process. Alternatively, a habitat equivalency analysis could be reviewed, to be approved in conjunction with NOAA.
- Avoid constructing new facilities with once-through cooling systems. All new facilities, regardless of size, should utilize dry cooling (air-cooled) or closed-cycle cooling systems to prevent or minimize impacts.
- Utilize air-cooling and wastewater systems in lieu of building new intake pipes and facilities. If intake pipes and facilities must be built, do so during low-flow periods and tidal stage.
- Implement erosion and sediment control BMPs, and have an equipment spill and containment plan and appropriate materials onsite.
- Utilize alternative water resources, such as reclaimed municipal wastewater or brackish groundwater for cooling-water supply, to reduce impacts to EFH.
- Do not locate facilities that rely on surface water in or near critical EFH, such as estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments.

Altered hydrology

- Redesign and operate existing facilities to create flow conditions that provide for passage and proper timing of life-history stages.
- Monitor facility operations to assess impacts on water temperatures, dissolved oxygen, and other applicable parameters, and use adaptive management to minimize impacts.

Entrainment or impingement

- Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems) according to the most updated NMFS fish passage policies.
- Design intake structures to minimize entrainment or impingement.
- Screen water diversions on all fish-bearing streams. Screening sizes and materials must follow guidelines outlined in the most updated fish screening criteria reports and memorandums. In marine habitats, screening design must minimize impacts to prey items of EFH managed species.

Construction and maintenance

- Use the least damaging antifouling alternatives, such as screens constructed with anti-fouling coatings or materials and self-cleaning systems, to minimize impacts to EFH. Do not use biocides (e.g., chlorine) to prevent fouling.

Sewage Discharge Facilities

Potential adverse impacts of sewage discharge facilities

The following factors associated with sewage discharge facilities can impact EFH and are described briefly below: release of contaminants, construction and maintenance, and loss and alteration of aquatic vegetation. Suggested conservation measures related to each of these factors are provided in the following section.

Release of contaminants

Municipal sewage treatment facilities can discharge large volumes of nutrient-enriched effluent into EFH. Impacts can include eutrophication and harmful algal blooms (O'Reilly 1994, Buck et al. 1997, Goldburg and Triplett 1997, Shumway and Kraeuter 2000, Anderson et al. 2002, Deegan and Buchsbaum 2005), reduced primary production (Parker et al. 2012), and alteration to aquatic vegetation (Levinton 1982, Touchette and Burkholder 2000, Cloern 2001, Cardoni et al. 2010) and fish food web structure (Kennish 1998).

Municipal sewage treatment facilities can also discharge large volumes of effluent containing domestic and industrial contaminants (Islam and Tanaka 2004, Christensen et al. 2009) that may impact fish physiology and community structure in freshwater and marine EFH (Porter and Janz 2003). Wastewater contains pharmaceuticals and other contaminants that can disrupt endocrine function (Brodeur et al. 1997), cause larval deformities (Bodammer 1981), increase larval mortality (Klein-MacPhee et al. 1984, Nelson et al. 1991), impair reproduction (Thurberg and Gould 2005), and harm internal organs and reduce growth in fish (Johnson et al. 2002). Microorganisms entering aquatic habitats through sewage effluents can pose a threat to aquatic organisms (Oliveri 1982, Bossart et al. 1990, Islam and Tanaka 2004).

Construction and maintenance

Impacts to aquatic habitats can result from construction-related activities and routine operation and maintenance of sewage discharge facilities. Dredging associated with construction of water intake or outlet facilities can cause turbidity and sedimentation in nearby waters, degraded water quality, and disturbed substrates (e.g., Williams and Thom 2001). As benthic material is disturbed, suspended particulate matter is transported from the site to other locations where it would not otherwise occur (Uncles and Stephens 2010). Toxic biocides or heat treatments may be used to clean discharge structures at sewage facilities (NMFS 2011).

Loss and alteration of aquatic vegetation

Submerged aquatic vegetation (SAV) is an important component to EFH (Rozas and Odum 1988) and requires relatively clear water in order to allow adequate light transmittance for metabolism and growth. Sewage effluent, which is high in N, C, and P compounds, can cause or enhance algal blooms and, in some cases, cause eutrophic conditions in EFH, depressing oxygen, diminishing light transmittance through the water, and reducing SAV (Goldsborough 1997). Eutrophication can also alter the physical structure of SAV (Short et al. 1993) and may increase susceptibility of eelgrass to diseases (Deegan and Buchsbaum 2005).

Potential conservation measures for sewage discharge facilities

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of sewage discharge facilities on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate impacts of sewage discharge facilities on EFH.

General guidelines

- Develop programs and projects to reuse treated municipal wastewater and minimize the volume discharged to EFH. Common uses include cooling-water uses, agricultural irrigation, landscaping, and large grassy areas such as golf courses and recreational fields.
- Upgrade wastewater treatment facilities from the standard secondary treatment level. Tertiary treatments can include denitrification, increased pathogen removal, or other customization depending upon end use and need.
- Develop and enforce strong pretreatment programs for industrial and institutional users in the wastewater system (e.g., plating operations for metals, dentists for mercury, hospitals for medications) to reduce the amount of these contaminants entering the system. Many municipalities have these programs already and need to increase participation and enforcement of existing programs.
- Develop, incentivize, and enforce collection programs for personal care products and medications that otherwise end up in the wastewater treatment system and subsequently in EFH.

Release of contaminants

- Pretreat industrial and institutional flows.
- Incentivize collection of unused personal care products and medications.

Construction and maintenance

- Use the least damaging antifouling alternatives, such as screens constructed with anti-fouling coatings or materials and self-cleaning systems, to minimize impacts to EFH. Do not use biocides (e.g., chlorine) to prevent fouling.
- Schedule maintenance so that organisms inhabiting EFH are not affected.

Loss and alteration of aquatic vegetation

- Develop, implement, and increase treated sewage reuse opportunities.
- Denitrify wastewater if nitrogen enrichment is impacting SAV.
- Use constructed wetlands to remove nutrients from wastewater flows prior to discharge.
- Adjust temperature of discharge by using cooling ponds or towers.

Combined Sewage Overflow

Potential adverse impacts of combined sewage overflow

Combined sewage overflow (CSO) can lead to the release of contaminants into EFH. Impacts to EFH caused by the release of contaminants from CSO are described below. Suggested conservation measures related to this factor are provided in the following section.

Release of contaminants

Under normal conditions, combined sewer systems (CSS) transfer untreated sewage and runoff to wastewater treatment plants (WWTPs). However, this may not be the case during significant storm flows, and large amounts of untreated nutrients and chemicals may bypass WWTPs and their holding facilities and flow directly into EFH (Phillips et al. 2012). CSO can be an important point source for pesticides, herbicides, fertilizers, and urban pollutants such as pharmaceuticals that are contained in overflow sewage (Gasperi et al. 2008, Johnson and Sumpter 2014). Many of these contaminants can bioaccumulate in fish (Anderson and MacRae 2006), and increased impervious surfaces and climate change-induced flooding could increase CSO-derived pollutants in EFH (Gamerith et al. 2012).

Potential conservation measures for combined sewage overflow

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of CSO on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help avoid, minimize, and mitigate impacts of CSO on EFH.

General guidelines

- Conduct routine maintenance and inspection to prevent blockages of combined sewer systems.
- Develop, implement, and increase outreach or inspections of facilities and areas likely to contribute to or cause CSO (e.g., restaurants improperly disposing of grease, homeowners or landscapers disposing of greenwaste into a CSS).
- Increase capacity or separate the municipal and storm sewers in frequently overwhelmed areas.
- Add capacity to WWTP holding ponds, especially if new developments are being built with a CSS.
- Implement new development, and retrofit existing development with numerous infiltration-based BMPs (e.g., vegetate swales, infiltration basins) to accommodate all flows, even those during storms.
- Institute and enforce programs such as stenciling storm sewers, outreach to identified problem areas and neighborhoods, etc., to reduce and prevent the release of contaminants into EFH.

Industrial Discharge Facilities

Potential adverse impacts of industrial discharge facilities

Industrial discharge facilities (IDF) can cause the release of contaminants into EFH. Impacts to EFH caused by the release of contaminants from IDF are described below. Suggested conservation measures related to this factor are provided in the following section.

Release of contaminants

IDF may release contaminants that can have deleterious effects on EFH and organisms (Johnson and Sumpter 2014). A variety of toxic synthetic organic compounds are released from IDFs into EFH (Longwell et al. 1992, Kennish 1998). These toxic chemicals can have various impacts on fish, including reduced egg quality, disrupted development, and reduced survival (Islam and Tanaka 2004, Orrego et al. 2005).

Metals and other trace elements are commonly found in industrial effluent that flows into EFH (Kennish 1998). Metals impact coastal (Arifin et al. 2012) and estuarine EFH (Du Laing et al. 2009), and can have numerous negative impacts on aquatic organisms (Bodammer 1981, Klein-MacPhee et al. 1984, Lang and Dethlefsen 1987, Gould et al. 1994).

Petroleum products originating from IDF can be a major stressor on aquatic vegetation (Lin and Mendelssohn 1996, Culbertson et al. 2008) and organisms in EFH (Kennish 1998).

Potential conservation measures for industrial discharge facilities

The following measures can be undertaken by the action agency on a site-specific basis to avoid, minimize, and mitigate impacts of IDF on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The guidelines represent a short menu of actions that could help developers avoid, minimize, and mitigate for impacts of IDF on EFH.

General guidelines

- Do not site discharge points near shellfish beds, submerged aquatic vegetation, reefs, fish spawning grounds, and similar fragile and productive EFH.
- Determine predevelopment benthic productivity by sampling the benthos prior to any construction activity related to installation of new or modified facilities. Implement BMPs to maintain habitat quality during construction. Include seasonal restrictions on development or maintenance activities, use cofferdams, and conduct work at low tide to reduce impacts to EFH. Seasonal restrictions during construction and maintenance operations will help avoid impacts to EFH during species' critical life-history stages (e.g., spawning and egg development periods). Seasonal work windows must be based on documented, accurate periodicity of species of concern.

Release of contaminants

- Improve wastewater treatment systems to minimize contaminant discharge.
- Improve water-use efficiency at the facility to generate less wastewater.

- Develop appropriate modeling studies for plume effects and other parameters of concern in cooperation with resource agencies before finalizing outfall design. Recommendations that involve agencies and were developed as a consequence of the study results must be incorporated in the construction and operation plans for these facilities as enforceable permit conditions.
- Ensure that maximum permissible discharges are appropriate for the given project setting, and specify any and all operational procedures, performance standards, and BMPs that must be observed to address all reasonably foreseeable contingencies over the life of the project.
- Develop an adaptive management plan. Plans must include representatives from appropriate agencies, as they will participate in future consultations for administering the management plan. The management plan must include monitoring protocols designed to measure discharge and potential impacts to EFH.
- Install diffusers on outlets to maximize the rate of dispersion and dilution.
- Use the most effective technology to treat discharge. Implement measures that reduce discharge of biocides and other toxic substances.
- Mitigate the ecological damage arising from outfall maintenance activities.
- If biocides must be used, they must be specifically designed for their intended use, they must be applied as directed by the manufacturer, and the minimal effective dose must not be exceeded.
- Use land treatment and upland disposal or storage for any sludge or other remaining wastes after wastewater processing is concluded. Use of vegetated wetlands as biofilters and pollutant assimilators for large-scale discharges should be limited only to circumstances where other less-damaging alternatives are not available, and the overall environmental impacts to EFH of such an action have been evaluated and vetted by appropriate agency personnel.
- Do not locate pipelines and treatment facilities in or near wetlands and streams.
- Do not site discharges near eroding waterfronts or where receiving waters cannot assimilate the amount of anticipated discharge.
- The design capacity for all facilities must satisfy present and foreseeable needs, and best available technologies must be implemented to reduce impacts to EFH.

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18. Pile Driving and Removal

Potential Adverse Impacts of Pile Driving and Removal

The following factors associated with pile driving and removal can impact EFH and are described briefly below: loss and alteration of habitat, altered hydrology and geomorphology, sedimentation, siltation, and turbidity, release of contaminants, and noise effects. Suggested conservation measures related to each of these factors are provided in the following section.

Loss and alteration of habitat

Depending on the substrate, piling material, the number of piles, and their spacing, the impacts of piling placement on EFH may be significant (Williams 1988, Thom et al. 1994, Nightingale and Simenstad 2001). Locating pilings in seagrass beds resulted in direct removal of seagrass during dock construction; however, different installation and removal techniques may influence the extent and magnitude of piling impact on EFH. Jetting—a technique where water is jetted through a pipe to erode earth while installing a piling—tends to cause greater disruption to seagrass than driving piles with a vibratory or impact hammer. Moreover, jetting may disrupt adjacent vegetation, resulting in bare areas around pilings that are subject to scour. Conversely, pile driving uses a low-pressure pump to produce a starter hole, followed by driving piling sharpened on one end with a vibratory or an impact hammer into the substrate. This technique reduces the physical removal and disturbance of seagrasses in the area of the piling.

Regardless of the technique, these activities directly impact the substrate and associated biota. Bare areas around the base of pilings placed in seagrass beds ranged between 0.89 m to 2 m in diameter in St. Andrew Bay, Florida (Shafer and Robinson 2001). The accumulation of debris and shells from barnacles, mollusks, and other marine organisms at the base of the pilings may inhibit the ability of seagrasses to recolonize the area surrounding the pilings (Shafer and Lundin 1999), and may shift the community from biota normally associated with sand, gravel, mud, or eelgrass substrates to communities associated with shells (Penttila and Doty 1990). The presence of pilings can alter sediment distribution and bottom topography, creating small depressions that preclude eelgrass growth. For example, impressions approximately 1 m deep formed around individual pilings associated with a large pier in North Carolina (Miller et al. 1983). Although these changes in hydrology and sediment deposition vary with substrate type, habitat changes associated with pilings may alter the local plant and animal communities (Penttila and Doty 1990, Thom et al. 1994).

Altered hydrology and geomorphology

The long-term presence of pilings, with or without associated overwater decking, may impact adjacent benthic communities, including seagrass, by altering currents. Pilings can have adverse effects to EFH by the altering of wave energy and substrate composition (Kahler et al. 2000, Carrasquero 2001, Nightingale and Simenstad 2001, WDFW 2006). When placed in moving water, pilings may disrupt the flow of water, which can either cause scour and erosion around the base of the pilings or increased sedimentation across a larger area, depending on pier orientation, water movement, and how pilings affect water movement (Kelty and Bliven 2003). For example, in an analysis of 20 large piers in the Southern California Bight, no appreciable effect of pier and piling placement was found on adjacent shorelines (Noble 1978); however, a similarly large pier in North Carolina produced a permanent trough over 3 m deep under the pier, with scouring around individual pilings over 1 m deep (Miller et al. 1983). In the Tim Ford Reservoir, Tennessee, a modeling experiment showed a reduction in reservoir flushing associated with multi-slip docking facilities, which led to degraded water quality by increasing coliform bacteria, decreasing dissolved oxygen, and increasing algal densities and sedimentation (Edinger and Martin 2010). The resulting changes in sediment composition caused by scour or deposition related to pilings may affect fish and shellfish that prefer or depend on specific substrate and sediment types (Bowman and Dolan 1982, Nightingale and Simenstad 2001, WDFW 2006).

Sedimentation, siltation, and turbidity

The long-term presence of pilings, with or without associated overwater decking, may impact adjacent benthic communities, including seagrass, by increasing sediment accumulation and bioturbators (organisms that disturb benthic habitats through their activities). Pile installation and removal activities related to construction of overwater structures may result in elevated levels of suspended sediment and organic particles in the water column, which can reduce light penetration and lower photosynthetic rates (Dennison 1987). If suspended sediment loads remain high for an extended period of time, fish may suffer gill injury and potentially mortality (Nightingale and Simenstad 2001, Wilber and Clarke 2001) and reduced feeding ability (Benfield and Minello 1996). The persistence of high suspended sediment levels and associated impacts are dependent upon type of sediment (i.e., denser sand particles settle more quickly than silt), duration of activity, hydrology, and other physical factors of the site. Additionally, the contents of suspended material may result in short-term oxygen depletion, which may impact higher trophic levels (Nightingale and Simenstad 2001). For more information and detail on the impacts of sedimentation on EFH, see Chapter 2.

Release of contaminants

The long-term presence of pilings, with or without associated overwater decking, may impact adjacent benthic communities, including seagrass, by leaching contaminants from chemically treated timber. Overwater structures such as marinas, wharves, and piers use treated wood to reduce biological decay, which is accomplished by applying chemicals to the wood to stop biofouling. Contaminants in wood regularly leach into the surrounding environment and have an adverse effect on EFH.

Research has demonstrated that contaminants introduced into marine environments are adsorbed or absorbed by marine organisms and potentially transferred up the food chain, ultimately affecting animal reproduction and population viability (Poston 2001, Sethajintanin et al. 2004, Meador et al. 2010, Jenkins et al. 2014, Melwani et al. 2014). Outmigrating juvenile Chinook salmon (*Onorhynchus tshawytscha*) in an urban estuary in Seattle, Washington, accumulated 3–5× more polychlorinated biphenyls (PCBs) when migrating through the developed east side of the estuary rather than the more natural, west side (Meador et al. 2010). Fish from the Willamette River in Portland Harbor, Oregon, tested positive for 25 PCBs, 15 organochlorine (OC) pesticides, and levels of mercury up to 0.52 µg/g (Sethajintanin et al. 2004). Many states regulate the use of contaminants, including OCs, PCBs, butylins, lead, and silver, following studies showing severe effects on fish and wildlife. Mussels have been used to assess bioaccumulation of contaminants in California waters for over forty years (Graham 1972, Melwani et al. 2014). An investigation of contaminant levels in mussels along the California coast found a vast improvement, with OC and PCB levels 75% lower than during the 1980s. Some of the steepest declines were exhibited in the San Francisco Bay (Melwani et al. 2014), potentially due to declines in petroleum refineries, use of creosote, motor vehicle use, and wood-burning.

Creosote, ammoniacal copper zinc arsenate (ACZA), and chromated copper arsenate (CCA Type C) are the most common chemicals used to treat wood used in pilings. In treated wood products, the main active ingredients of concern affecting fishery resources are polycyclic aromatic hydrocarbons (PAHs) in creosote, and copper. PAHs are released from creosote-treated wood; PAHs have been reported to cause cancer, reproductive anomalies, immune dysfunction, impaired growth and development, and other impairments in fish, depending on concentration and duration of exposure (Poston 2001, Johnson et al. 2007, Spearow et al. 2011). Adult and juvenile Chinook and coho (*O. kisutch*) salmon were tested for concentrations of PCBs, dichlorodiphenyltrichloroethane (DDT), PAHs, and OC pesticides from estuaries in Washington and Oregon (Johnson et al. 2007). The most widespread contaminants included PCBs, DDT, and PAHs, with greater levels in Chinook salmon, which spend more time than coho in estuaries foraging on contaminated organisms (Johnson et al. 2007). Concentrations of PAHs were especially high in estuaries closer to developed areas, such as Duwamish Estuary, Willapa Bay, Grays Harbor, and Yaquina Bay (Johnson et al. 2007). Copper has been found to have significant effects on fish behavior and olfaction (Baldwin et al. 2011, McIntyre et al. 2012, Sovová et al. 2014). When exposed to levels of copper as low as 5 µg/L, salmonids exhibited an impaired sense of smell and decreased startle response, caused by a pronounced depletion of ciliated sensory and nonsensory cells in the olfactory rosette (Baldwin et al. 2011, McIntyre et al. 2012, Sovová et al. 2014). The decreased startle response has adverse implications for predator avoidance, and may indirectly cause increased mortalities through predation (McIntyre et al. 2012).

A common mitigation for activities and development in the nearshore includes the removal of existing creosote-treated pilings. In some cases, the long-term benefits to EFH from removing a consistent source of contamination may outweigh the temporary adverse effects of turbidity. Pile installation and removal can disturb aquatic habitats by resuspending bottom sediments and recirculating toxic metals, hydrocarbons, hydrophobic organics, pesticides, pathogens, and nutrients into the water column (USEPA 2000). Any toxic metals, organics, pathogens, or viruses absorbed or adsorbed to fine-grained particulates in the sediment may become biologically available to organisms.

Noise effects

Pile driving generates intense underwater sound pressure waves that may adversely affect the ecological functioning of EFH. These pressure waves can cause physiological and behavioral impacts. Injuries in fish associated directly with pile driving include rupture of the swim bladder, internal hemorrhaging, and behavior alterations (Popper and Hastings 2009). Of the reported fish kills associated with pile driving, all have occurred during use of an impact hammer on hollow steel piles (Popper and Hastings 2009, Halvorsen et al. 2011).These effects can occur even when piles are driven on land adjacent to water. Injury is expected when fish are exposed to either a peak pressure that exceeds 206 dB (decibel) re: 1 µPa (Pascal), or a size-dependent cumulative sound exposure level (SEL) that exceeds 187 dB for fishes larger than 2 g, or 183 dB for fishes smaller than 2 g (Halvorsen et al. 2011). Observed behavioral changes in response to underwater sound include increased startle responses, changes in swimming activity, and increases in stress hormones (Hastings and Popper 2005); however, more studies are needed to measure the behavior response to pile driving.

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 (Halvorsen et al. 2011). Larger piles can cause injury or death because greater energy is required and higher sound levels are produced (Feist et al. 1996). Wood and concrete piles may produce lower sound pressures than hollow steel piles of a similar size, and firmer substrates require more energy to drive piles so more intense sound pressures can be produced (Feist et al. 1996). For more information and detail on the impacts of pile driving-related underwater noise, see Chapter 19.

Potential Conservation Measures for Pile Driving and Removal

The following measures can be undertaken by the action agency on a site-specific basis to avoid, minimize, and mitigate impacts of pile driving and removal on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The options represent a short menu of actions that could help land managers avoid, minimize, and mitigate impacts of pile driving and removal on EFH.

General guidelines

- Drive and remove piles when water current is reduced (i.e., centered on slack current) in areas of strong current, to minimize the number of fish exposed to adverse levels of underwater sound.
- Drive and remove piles during low tide periods when substrates are exposed in intertidal areas. This minimizes the direct impacts to fish from sound waves and minimizes the amount of sediments resuspended in the water column.
- Encircle the pile with a silt curtain that extends from the surface of the water to the substrate, where appropriate and feasible, if within suitable SAV habitat or contaminated sediments.
- Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for pile-driving projects.

Pile driving

- Avoid driving piles with an impact hammer when fish are present. Alternatives include vibratory hammers or press-in pile drivers.
- Use a vibratory hammer to install piles, when possible. Under those conditions where impact hammers are required

  (i.e., substrate type and seismic stability), the pile should be driven as deep as possible with a vibratory hammer prior to the use of the impact hammer, to minimize noise impacts.
- Implement measures to attenuate the sound or minimize impacts to aquatic resources during piling installation. Methods to mitigate sound impacts include, but are not limited to:
  - Using noise attenuation devices such as wood blocks, bubble curtains, or a dewatered cofferdam.
  - Driving piles during low-water conditions for intertidal areas.
  - Utilizing appropriate work windows that avoid impacts during sensitive times of the year (e.g., anadromous fish runs and spawning, larval and juvenile development periods).
  - Monitoring sound levels and halting pile driving before cumulative SEL injury thresholds are reached. Resume pile driving after 12 hours.

Pile removal

- Minimize the suspension of sediments and disturbance of the substrate when removing piles. Methods include, but are not limited to:
  - Removing piles with a vibratory hammer rather than a direct pull or clamshell method, when pile length and quality permits.
  - Removing piles slowly to allow sediment to slough off at or near the mudline.
  - Hitting or vibrating the pile first, to break the bond between the sediment and the pile. This minimizes the likelihood of the pile breaking and reduces the amount of sediment slough.
  - Encircling the pile or piles with a silt curtain that extends from the surface of the water to the substrate.
- Remove creosote-coated piles completely, rather than cutting or breaking off, if the piles are structurally sound.
- Cap all holes left by piles with clean, native sediments.

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19. Noise Pollution

Potential Adverse Impacts of Noise Pollution

Noise pollution can have several negative impacts on EFH. The following factors associated with noise pollution can impact organisms inhabiting EFH and are described briefly below: physiological impacts to fish, auditory impacts to fish, and behavioral impacts to fish. Suggested conservation measures related to each of these factors are provided in the following section.

Physiological impacts to fish

Vessel activity, sonar, seismic surveys, and industrial activity cause noise pollution that can negatively impact organisms inhabiting EFH (Linton et al. 1985, Stocker 2002, Hastings and Popper 2005, Jasny et al. 2005, Wysocki et al. 2006). Impacts to fish depend on frequency and magnitude of noises (Hildebrand 2005, Popper and Hastings 2009, Halvorsen et al. 2011, Halvorsen et al. 2012), which can vary widely among and within activities (Feist et al. 1996) and among different environments (Rogers and Cox 1988). Smaller fish species can be more sensitive to underwater noise than larger ones (Yelverton et al. 1975), but all life stages, from embryos, larvae, and fry (Booman et al. 1996) to adult stages, can be negatively impacted by noise (Bendell 2011). Similar to fish, noise pollution can also impact marine invertebrates physically (Andre et al. 2011) and behaviorally (WDFW 2006, Wale et al. 2013).

Auditory impacts to fish

Noise pollution can damage auditory tissue leading to hearing impairment and loss (Heathershaw et al. 2001, Hastings and Popper 2005). Temporary hearing loss may result from exposure to low levels of sound for a relatively long period of time, or exposure to high levels of sound for shorter periods (Scholik and Yan 2002, Liu et al. 2013). Temporary hearing loss can affect auditory-dependent life functions, such as locating food, mates, or predators, and fish exposed to noise may not regain hearing even after termination of the noise exposure (Scholik and Yan 2002, McCauley et al. 2003, Wang et al. 2020).

Behavioral impacts to fish

Behavior of fish can be impacted by noise pollution; however, impacts vary among species (Popper 2011, Popper and Fay 2011) and by source and intensity of sound (Hastings and Popper 2005). Noise can interfere with feeding (Wale et al. 2013, Voellmy et al. 2014), communication (Wahlberg and Westerberg 2005, Codarin et al. 2009, Slabbekoorn et al. 2010), and reproduction (Popper 2011). Audible communication in fish is used during territorial disputes (Sebastianutto et al. 2011) and competition for food (Voellmy et al. 2014), and in warning others of predators (Slabbekoorn et al. 2010). Anthropogenic sounds that falsely trigger these responses can induce expenditures of energy that is then unavailable for other processes, such as growth and reproduction (Stocker 2002). Schools of fish have been shown to disperse when noise sources approach (e.g., fishing boats; De Robertis and Handegard 2013). Noise can also hinder territorial dominance (Sebastianutto et al. 2011), reduce foraging, and increase inactivity and social behavior, indicating stress- or fear-related defense (Voellmy et al. 2014). Noise can also affect behaviors that influence distribution of fish (Skalski et al. 1992, Engås et al. 1996, Engås and Løkkeborg 2002, Slotte et al. 2004, Hastings and Popper 2005).

Potential Conservation Measures for Noise Pollution

The following measures can be undertaken by the action agency to avoid, minimize, and mitigate impacts of noise pollution on EFH. Not all of these suggested measures are necessarily applicable to any one project or activity that may adversely affect EFH. More specific or different measures based on the best and most current scientific information may be developed prior to, or during, the EFH consultation process, and then communicated to the appropriate agency. The options represent a short menu of actions that could help land managers avoid, minimize, and mitigate impacts of noise pollution on EFH.

General guidelines

- Develop minimization strategies for noise impacts that consider the frequency, intensity, and duration of exposure, and evaluate possible reductions of each of these three factors.
- Assess the "acoustic footprint" of a given sound source and develop standoff ranges (i.e., safe distances) for various impact levels.
    - Standoff ranges can be calculated by using damage risk criteria for species exposure, source levels, sound propagation conditions, and acoustic attenuation models. Development of a standoff range implies that sound sources will be relocated or reduced, since the fish are more difficult to control. Because the potential number of species affected and their location is most likely unknown, development of a generic approach for mitigation by using the species with the most sensitive hearing would produce a precautionary approach to reducing impacts on all animals (Heathershaw et al. 2001).
- Recommend an assessment and designation of "acoustic hotspots" that are particularly susceptible to acoustic impacts, and reduce sound sources around them. These hotspots may include seasonal areas for particularly susceptible life-history activities like spawning or breeding (Jasny et al. 2005).
- Recognize that reducing noise intensity at the source primarily relies on technological solutions, and use "quiet" technology in marine engines.
- Encourage the use of sound-dampening technologies for vessels and port/marine infrastructure to reduce ocean noise impacts to aquatic organisms.

Explosives

- Evaluate the need to use explosives and use practical alternatives, if available.
- Bubble curtains, created by injecting compressed air into the water column, were highly effective at reducing the mortality of caged bluegills (*Lepomis macrochirus*) during detonation of a 2-kg high-explosive charge. The bubble curtain reduced peak pressure, impulse, and energy flux density by 88–99%.
- Surround the explosion with a bubble curtain or other sound attenuation device to minimize the extent of the habitat area where sensitive, priority, or endangered species could be injured.
- As they do for explosions, bubble curtains ameliorate adverse effects of pile driving (Wursig et al. 2000).
- Rather than a single large charge, use a series of smaller charges that are separated by delays that are longer than the duration of the blast wave. Using blasting caps with timing delays reduces each detonation to a series of small explosions (Keevin 1998). The

effectiveness of delays and defining a delay period that provides maximum protection requires further examination.
- Plan the blasting program to minimize the size of explosive charges per delay and the number of days that explosives are used.
- Avoid using underwater explosives in areas supporting productive fishery habitats. Encourage the use of less destructive methods whenever possible. In some cases, the use of mechanical devices (e.g., ram hoe, clamshell dredge) may reduce impacts associated with rock and ledge removal.

Surveys

- Avoid areas and times of year when sensitive priority and endangered species, such as smaller juveniles or spawning adults, are present. If surveys must be conducted in the presence of these species and life stages, do so when abundances are relatively low.
- Use marine vibroseis instead of airguns, when possible.
- Use the least-powerful airguns that will meet the needs of the survey.
- Survey the smallest area possible to meet the needs of the survey.
- Avoid times of year when sensitive, priority, and endangered species are present. If it is not practical to conduct the activity when species are absent, avoid doing so when the smallest, and therefore most vulnerable, life stages are present.
- Do not conduct the activity where it could affect spawning adult species.

Pile driving

- When possible, avoid driving piles when fish are present, especially the younger salmon life stages and spawning adults.
- Where tidal currents can be strong, drive the piles when the current is reduced (i.e., centered on slack current) to minimize the number of fish exposed to adverse levels of underwater sound. Strong currents can bring more fish into close proximity to the pile than weak currents.
- When driving piles in intertidal or shallow subtidal areas, do so during periods of low tide; sound does not propagate as well in shallow water as it does in deep water.
- Avoid driving piles with an impact hammer when fish are present. Alternatives include vibratory hammers or press-in pile drivers.
- In cases where an impact hammer must be used, drive the piles as far as possible with a vibratory hammer or other method that produces lower levels of sound before using an impact hammer.
- Select piles that are made of alternate materials that produce less-harmful sounds than those from hollow steel piles, such as concrete or untreated wood instead of steel.
- Implement measures to attenuate the sound. Such measures include the use of a bubble curtain, a dewatered pile sleeve, or a cofferdam. Monitor the sound levels during pile driving to ensure that the attenuation measures are functioning as expected.
- Monitor, and report back to NMFS, the sound levels during pile driving to verify that the assumptions in the analysis were correct and to ensure that any attenuation device is properly functioning. Develop monitoring and reporting protocols according to guidance provided by the Fisheries Hydroacoustic Working Group (Caltrans 2020). The report should be provided to NMFS according to the individual project requirements, but no later than 90 days after completion of the pile driving.
- Monitor sound levels and halt pile driving before cumulative SEL injury thresholds are reached. Resume pile driving after 12 hours.

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