U.S. DEPARTMENT OF
HOMELAND SECURITY

United States Coast Guard

ASSESSMENT OF ESSENTIAL FISH HABITAT FOR THE ALASKA FEDERAL/STATE PREPAREDNESS PLAN FOR RESPONSE TO OIL & HAZARDOUS SUBSTANCE DISCHARGES/RELEASES (UNIFIED PLAN)

FINAL

Prepared for:

United States Coast Guard
Seventeenth Coast Guard District
709 W. 9th Street
Juneau, AK 99803

and

United States Environmental Protection Agency
Region 10 Alaska Operations Office
222 W. 7th Street, Box 19
Anchorage, AK 99513-7588

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Prepared by:

Windward Environmental LLC
200 West Mercer Street, Suite 401
Seattle, Washington 98119

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Acronyms

ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ARRT	Alaska Regional Response Team
BA	biological assessment
BMP	best management practice
BSAI	Bering Sea/Aleutian Islands
CFR	Code of Federal Regulations
DNA	deoxyribonucleic acid
DPS	distinct population segment
EEZ	exclusive economic zone
EFH	essential fish habitat
EPA	US Environmental Protection Agency
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
ESU	evolutionarily significant unit
FMP	fishery management plan
FOSC	federal on-scene coordinator
FR	Federal Register
GNIS	Geographic Names Information System
GOA	Gulf of Alaska
GRS	geographic response strategies
HAPC	habitat area of particular concern
IAP	incident action plan
MLLW	mean lower low water
MMS	Minerals Management Service
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NCP	National Contingency Plan
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council

OR&R	Office of Response and Restoration
PAH	polycyclic aromatic hydrocarbon
RP	responsible party
SCP	subarea contingency plan
SMART	special monitoring of applied response technologies
SSC	scientific support coordinator
USCG	US Coast Guard
USFWS	US Fish and Wildlife Service
STAR	spill tactics for Alaska responders
UV	ultraviolet

Executive Summary

This essential fish habitat (EFH) assessment evaluates the potential for adverse effects on species and habitats from the implementation of the *Alaska Federal/State Preparedness Plan for Response to Oil & Hazardous Substance Discharges/Releases Change 3, January 2010* (EPA et al., 2010), hereafter referred to as the Unified Plan. The Unified Plan provides a framework for responding to spills of hazardous materials (e.g., petroleum) throughout the State of Alaska, which includes all contiguous waters to the extent of the exclusive economic zone (EEZ), hereafter referred to as the Action Area. Therefore, EFH in Alaska, including anadromous streams as catalogued by the Alaska Department of Fish & Game (ADF&G) (2014a, b), are within the Action Area and are addressed in this EFH assessment.

The purpose of this document is to:

- Identify and discuss all hazardous material spill response action alternatives permitted in Alaska under the Unified Plan (EPA et al., 2010).
- Identify EFH and managed species in the Action Area.
- Determine the potential for the proposed action to adversely impact EFH or managed species.
- Determine the potential measures for mitigating adverse impacts to EFH or managed species resulting from the proposed action alternatives.
- Satisfy the requirement, pursuant to Section 305(b)(2) of the Magnuson-Stevens Fisheries Management and Conservation Act, commonly referred to as the Magnuson-Stevens Act, that the US Coast Guard (USCG) and US Environmental Protection Agency (EPA) (i.e., the action agencies responsible for the implementation of the Unified Plan) consult with the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NOAA Fisheries) regarding an action that the USCG and/or EPA authorizes, funds, or undertakes that may adversely affect[1] EFH.

This document has been prepared in conjunction with the *Biological Assessment of the Alaska Federal/State Preparedness Plan for Response to Oil & Hazardous Substance Discharges/Releases (Unified Plan)* (Windward and ERM, 2014), hereafter referred to as the biological assessment (BA), which is a highly detailed assessment of the environmental effects of the response actions presented in the Unified Plan (EPA et al., 2010) on various endangered or threatened species in Alaska. This EFH assessment

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

summarizes detailed analyses and background information presented in the BA that pertain to EFH in the Action Area and references the BA (Windward and ERM, 2014) for more detailed information.

ES.1 Response Actions

All fish species managed by NOAA Fisheries and the North Pacific Fisheries Management Council (NPFMC) in Alaska (NMFS, 2014, 2013b, a, 2012a, 2011a; NPFMC, 2009a) are present in the Action Area during at least one life stage. Ultimately, the goal of a response action is to minimize the long-term environmental impacts to these species and their habitat from a hazardous material spill, resulting in a net environmental benefit. In addition to monitored natural attenuation (i.e., no action), mechanical and non-mechanical countermeasures may be implemented in Alaska, although chemical dispersion and *in situ* burning are the only approved non-mechanical countermeasures. In addition, several actions (e.g., monitoring) that are common to all spill response actions (including monitored natural attenuation) would also be implemented.

Once a spill has occurred, the selection of a response action is based on the decision framework outlined in the Unified Plan (EPA et al., 2010), the availability of spill response equipment and personnel, the proximity of spill responders (and equipment) to the spill, and the nature of the spilled material and the environment into which it was spilled. In addition, input from NOAA Fisheries and the US Fish and Wildlife Service (USFWS), hereafter referred to collectively as the Services may be requested or required prior to the implementation of specific response actions (e.g., chemical dispersant application, *in situ* burning).[2] The spill response actions, their potential effects on the environment, including their potential magnitude and spatial and temporal extent, are detailed in Table ES-1.

Several spill response actions have the potential to adversely impact EFH or managed species relative to the baseline condition. For the purpose of this EFH assessment, the baseline condition is characterized as the condition of an area once a spill has occurred and all expected impacts of such a spill. Various mechanisms exist to mitigate or minimize the effects of a spill response action (commonly referred to as best management practices [BMPs]). The specific BMP(s) implemented in any situation would depend on the spill response action, the affected resources, and the conditions at the time of a spill. The goal would be to minimize environmental damage by creating the smallest footprint possible and selecting equipment deployment sites that

[2] As of the writing of this EFH consultation, dispersants are not pre-authorized for use anywhere in Alaska. A new dispersant use and pre-authorization policy has been drafted (included in Appendix A of the BA (Windward and ERM, 2014)), agreed to by all required signatories under the National Contingency Plan (NCP) (40 CFR 300.910) and is in the process of mandatory federal-to-tribal government consultation, State of Alaska public comment, Endangered Species Act Section 7 consultation, and EFH assessment and consultation, prior to finalization and implementation (with the policy taking effect 24 months after finalization).

would not cause more damage than the spilled material. Measures to mitigate or minimize the potential adverse effects from each spill response action are also presented in Table ES-1.

Table ES-1. Response actions and their potential effects, magnitude and extent, and mitigation measures

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent	Measures to Mitigate or Minimize Potential Adverse Effects
Mechanical Countermeasures				
Deflection/Containment				
Booming	deployment, maintenance, and anchoring of booms	possibly reduced access to shallow resources (e.g., forage, refuge/nursery, or spawning habitat) while deployed; destruction of shallow benthic habitat/organisms by anchors while deployed; possibly restricted movement of salmon in freshwater while deployed	temporary, localized, and low-magnitude impacts in shallow areas; negligible impacts in waters deeper than hanging curtains (or "skirts");[a] potential high impacts in freshwater habitats, particularly if migration, feeding, spawning, or rearing are interrupted through physical exclusion by booms and boom skirts (limited to areas of very shallow water (i.e., <18 in); localized indirect impact associated with destruction of shallow benthic habitat/organisms during anchor deployment	consult GRS for proper staging and anchoring areas; avoid anchoring in sensitive habitat (e.g., mudflats, marshes); frequently monitor and adjust booms to adapt to changing conditions; use in conjunction with recovery actions; avoid exclusion booming across streams and, if possible, use deflection booming to allow for fish passage, particularly during spawning times; use appropriate boom curtains
Berming, pits, trenching, or underflow damming	use of heavy equipment or manual construction; placement or excavation of earthen structures	potential disturbance or destruction of habitat when used on shorelines; potential loss of aquatic organisms (including vegetation) from compaction or sedimentation/smothering of invertebrate burrows; potential blockage of fish passage from berming across streams (to contain a marine spill before entering streams)	temporary, localized, and low-magnitude impact on shoreline and terrestrial inland habitats and associated soil and sediment invertebrate communities (i.e., aquatic prey); potential high-magnitude impact on habitat and degradation if mitigation measures not implemented (e.g., avoidance of sensitive habitats such as mudflats, eelgrass, or kelp beds); potential high-magnitude impacts if migration is blocked by berms or dams; disturbance of upland soil and vegetation, resulting in sedimentation of freshwater spawning habitat and reducing reproductive success of salmon (high-magnitude impact)	consult GRS for proper staging areas; transport materials and personnel on cleared or packed ground or lay down plywood to avoid compaction of soil; use in conjunction with recovery actions; line barriers with impermeable materials (e.g., geotextile); consistently monitor earthen barriers and adapt as needed; use additional erosion control measures to reduce sedimentation in nearby aquatic habitat; do not block or divert natural streams unless absolutely necessary; use as little local substrate as possible to construct barriers; avoid destruction of vegetation or other habitat or sediment structural elements; remove barriers once hazardous material has been recovered; properly construct underflow dams to permit the maximum amount of fluid while still containing hazardous material; if possible, create dams such that fish passage is not impeded

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent	Measures to Mitigate or Minimize Potential Adverse Effects
Culvert blocking	placement of blockage (e.g., plug, weir gate), replumbing of outlet	alteration of hydrology while culvert is blocked; obstruction to migration (or general movement) while culvert is blocked	temporary, low-magnitude impact unless implemented during anadromous salmon migration, in which case magnitude would be high	use in conjunction with recovery actions; if possible, avoid the blocking of culverts leading into anadromous streams; allow for water to flow past blockage to the extent practicable (e.g., adjustable weir gate); remove blockage once hazardous material has been recovered
Recovery of Spilled Material				
Skimming or vacuuming	deployment and operation of skimming/vacuuming equipment	entrainment of shallow plankton (e.g., early life stages of several species) in skimmer/vacuum while in operation	although individuals could be impacted, EFH would not likely be impacted; potential low-magnitude impact in freshwater streams and negligible impacts on shorelines; however, vacuuming in sensitive freshwater habitats (e.g., vegetated shorelines, mudflats, wetlands) could result in high-magnitude impacts	consult GRS for proper staging areas; transport materials and personnel on cleared or packed ground or lay down plywood to avoid compaction of soils; consistently monitor collection devices; use mesh screens to exclude fish from vacuums; properly decant water from waste to minimize waste production; use booms to contain hazardous material while implementing recovery actions and adjust boom orientation to adapt to changing sea conditions; properly store, transport, and dispose of waste; avoid skimming or vacuuming in shallow waters (e.g., anadromous streams)
Sorbents	placement and use of sorbent materials (e.g., pads, rolls, beads); maintenance of sorbent materials; anchoring	potential disturbance of intertidal habitat and minor destabilization of shoreline or benthic habitat while being placed or anchored on shoreline; possible destruction of aquatic vegetation while being placed or anchored; slight shading effect	localized and short-term action resulting in temporary, low-magnitude impacts (e.g., minor habitat alteration); impact on habitat degradation could be high if mitigating measures not implemented (e.g., careful placement, avoidance of aquatic vegetation); use of sorbent materials in open water likely to have negligible impacts on fisheries (relative to the baseline condition)	consult GRS for proper staging and anchoring areas; transport materials and personnel on cleared or packed ground or lay down plywood to avoid compaction of soils; consistently monitor collection devices; use sorbents that are appropriate for the spill conditions (considering material, orientation, anchoring); properly store, transport, and dispose of spent sorbents

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent	Measures to Mitigate or Minimize Potential Adverse Effects
Removal/Cleanup[b]				
Removal	removal of contaminated sediment or soil (potentially with backfill of clean material)	severe disturbance of infaunal community and benthic habitat (i.e., prey resource); possible destabilization of soil or sediment; possible destruction of aquatic and terrestrial vegetation	temporary indirect impact caused by intertidal habitat destruction; the duration of indirect impact would be dependent on species present (Peck et al., 1999);[c] indirect impact caused by habitat destruction likely negligible relative to baseline; high-magnitude direct impacts could result if removal carried out on spawning beach; (spatially restricted to areas of removal action); disturbance of upland soil and vegetation could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)	remove contaminated sediment but leave clean sediment to the extent practicable; replace removed sediment with clean backfill as appropriate to maintain shoreline stability; if backfilling, avoid excessive sedimentation of surrounding benthic habitat; use hand tools and light-weight equipment as appropriate to minimize excessive compaction of substrate and/or destruction of vegetation; properly handle, transport, and dispose of waste
Cleaning	on-scene processing of sediment that removes oil/tar balls and return of cleaned material to beach	habitat disturbance; erosion from foot and vehicle traffic; possible destruction of aquatic vegetation	temporary indirect impact caused by intertidal habitat destruction; duration of impact would depend on the species present (Peck et al., 1999);[c] impacts of habitat destruction would likely be negligible relative to baseline but could be high (e.g., if mitigating measures not implemented); spatially restricted to area of sediment cleaning	use hand tools and light-weight equipment as appropriate to minimize excessive compaction of substrate and/or destruction of vegetation; properly handle, transport, and dispose of waste
Vegetation or woody debris removal	removal of aquatic or shoreline vegetation or woody debris	potential for loss of forage, refuge, or spawning habitat (aquatic vegetation) if conducted in certain areas (e.g., eelgrass beds); possible destabilization of shoreline or benthic habitat through removal of vegetation or compaction of sediment, resulting in sedimentation of intertidal and nearshore habitat	temporary, low-to-negligible indirect magnitude impact caused by intertidal habitat degradation; duration of impact would depend on species present (Peck et al., 1999);[c] impacts of habitat destruction could be severe (e.g., if mitigating measures not implemented); spatially restricted to area of debris removal; disturbance of upland soil and vegetation could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)	remove vegetation only to the extent necessary (e.g., leave roots, stalks, as appropriate); use light-weight equipment and hand tools to the extent practicable when working in aquatic vegetation; leave large structural components (e.g., large woody debris) in place to maintain sediment stability; attempt to remove debris prior to contamination (if possible) to minimize the volume of waste

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent	Measures to Mitigate or Minimize Potential Adverse Effects
Flushing/flooding	remobilization of oil for collection	physical displacement of benthic organisms or vegetation; thermal stress and mortality of aquatic organisms if heated water or steam is used	temporary, low-magnitude indirect impact to managed species and EFH caused by intertidal habitat degradation (e.g., mortality of intertidal invertebrates and vegetation); spatially restricted to area of flushing/flooding; magnitude of impacts generally determined by heat of water used (ambient water temperatures result in the lowest-magnitude impacts)	consult GRS for proper staging areas; use in conjunction with containment (e.g., booming) and recovery actions (e.g., skimming/vacuuming); use appropriate water temperature, flow rate, and pressure to minimize sedimentation of shoreline and nearshore habitat as well as mitigate heat stress; properly store, transport, and dispose of recovered wastes
Non-Mechanical Countermeasures				
Dispersants	application of chemical agent	temporary degradation of water quality; short term change in prey base from potential toxicity; acute and chronic exposures to petroleum constituents due to changes in solubility/ bioavailability of oil components; acute exposure to components of dispersants; exposures to oil components would increase in the water column (between 1 and 10 m in depth) relative to the baseline condition	shallow EFH (between 0 and 10 m in depth) would be temporarily impacted by the addition of chemical dispersants and the subsequent increase in oil droplets and dissolved oil components in the water column; direct impacts on individuals of managed species present following a spill from increased concentrations of dissolved toxic components of oil could result in significant mortality (high magnitude impact) of individuals of sensitive species or at sensitive life stages or could result in significant sublethal impacts (also potentially resulting in high magnitude impacts relative to the baseline condition); impacts could occur in more individuals due to the chemical dispersion of oil to 10 m rather than the physical mixing of oil to 1-m depth; impacts on EFH could therefore be of a high magnitude although due to the limited duration of exposure, impacts are not expected to result in long-term effects on populations of managed species; indirect impacts on EFH (i.e., mortality of prey species) could similarly be of a high magnitude, although temporary	appropriately apply dispersants using the prescribed application rate and dispersant-to-oil ratio and approved dispersant formulation (e.g., Corexit® 9500); use spotter aircraft, as appropriate, to guide application and avoid overspray; disperse oil only in approved areas away from shallow (< 10 m deep) water (the current dispersant use guideline requires 10 fathoms [18 m] of water), shorelines, or areas of known spawning or nursery habitat; gather real-time data of spill trajectory and state (e.g., weathering, slick thickness) to inform decision-making; consult ARRT and the Services prior to application (as required)

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent	Measures to Mitigate or Minimize Potential Adverse Effects
In situ burning	use of accelerants and ignition materials; burning	deposition of dense burn residues in benthic habitat and suspension of less-dense residues in water column (i.e., habitat degradation); thermal destruction of very shallow (i.e., within 5 in. of surface) planktonic species (Evans et al., 1988; cited in NMFS, 2003)	localized mortality caused by thermal impacts within very shallow but highly productive ocean surface community, potentially including some early-life-stage individuals within protected fisheries; likely to be of low magnitude to fisheries overall, as well as of short duration; burn residue impacts uncertain but could be long term and of low magnitude (depending on the extent of exposure of individuals); likely to be of low magnitude to fisheries overall; although residues are distributed over a broad area, exposures likely to be localized at discrete locations (e.g., at the point of deposition of a residue).	consult with ARRT and the Services prior to *in situ* burning in order to provide for safety of valued resources; consult GRS for information regarding sensitive resources and appropriate staging areas; conduct burning only in appropriate habitats, avoiding the burning of vegetation; recover burn residues to the extent practicable; gather real-time data of spill trajectory and state (e.g., weathering, slick thickness) to inform decision-making; apply additional fuel as necessary to maintain burn efficiency; use fire booms or other containment, as appropriate, to concentrate oil prior to and during burning
Bioremediation	application of biological organisms to consume the oil or fertilizers to stimulate biodegradation by the natural microbial community	bioactivity may deplete oxygen from the water; possible uptake and concentration of petroleum constituents into marine food chain (although this is consistent with the baseline condition)	magnitude and extent of impacts unclear due to a lack of representative testing, however, available evidence suggests that impacts would be negligible (Prince et al., 2003)	monitor levels of dissolved oxygen and fertilizer nutrients to avoid stimulation to the point of hypoxia/anoxia; monitor the production of carbon dioxide and chemical concentrations over time to ensure efficiency/success of action; prior to implementation, ensure that response action is in accordance with the Unified Plan (EPA et al., 2010) Annex F
Other Response Actions				
Natural attenuation (with monitoring)	long-term monitoring	shoreline habitat disturbance (e.g., sediment compaction, erosion from truck or foot traffic)	low-magnitude long-term impacts caused by sedimentation/smothering of intertidal and nearshore habitat; localized at points of access to shorelines or streams; disturbance of upland soils and vegetation from compaction or erosion could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)	carefully weight all appropriate and potential responses for the given spill area, using GRS and input from the Services, as needed, prior to action selection; establish and carry out long-term monitoring program to monitor attenuation over time; transport any materials and personnel on cleared or packed ground or lay down plywood to avoid compaction of soil and sedimentation of aquatic habitats as a result of monitoring activities; adapt response strategy as appropriate to minimize environmental impacts resulting from hazardous materials (i.e., baseline condition)

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent	Measures to Mitigate or Minimize Potential Adverse Effects
Actions Common to All Responses				
Tracking/ monitoring and mobilization/ demobilization	mobilization of equipment and personnel to and from the site; collection of relevant environmental media	shoreline habitat disturbance (e.g., sediment compaction, erosion from truck or foot traffic)	potential low-magnitude impacts from sedimentation/smothering of intertidal and nearshore habitat (localized at points of access to shorelines); disturbance of upland soils and vegetation from compaction or erosion could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)	use in conjunction with other response actions; transport any materials and personnel on cleared or packed ground or lay down plywood to avoid compaction of soil and sedimentation of aquatic habitats as a result of monitoring activities; use proper decontamination methods to reduce contamination of unaffected areas
Waste handling, treatment, and disposal	collection, storage, and removal of contaminated media (e.g., soil, sediment, debris); decontamination of vessels/vehicles; oil/water separation and treatment	shoreline habitat disturbance (e.g., sediment compaction, erosion from truck or foot traffic)	impacts likely to be negligible relative to the baseline condition; storage of wastes prior to disposal in temporary, permanent, or semi-permanent storage fixtures (e.g., tanks) on soil near aquatic habitat could result in compaction of soil and erosion; small amounts of material could be released as a result of decanting or improper handling.	use in conjunction with other response actions; hold and treat any materials on cleared or packed ground, and avoid placement on vegetation/riparian habitat; lay down plywood to evenly distribute weight of equipment or personnel; dispose of waste only in approved areas; be aware of submerged rocks or shoals that could affect operations on water; allow adequate time for decanting of waste or use oil-water separation equipment; discharge decanted fluid into containment boom in order to minimize reintroduction of wastes into the aquatic environment

[a] Skirts can be up to 60 inches in water depth (or "draft") but tend to be < 18 inches; longer skirts can be used in quiescent waters, whereas shorter skirts are intended for use in flowing waters (e.g., marine habitat) (Alyeska Pipeline Service, 2008).

[b] Removal and cleanup response action alternatives are limited to shoreline and upland terrestrial habitats (e.g., intertidal habitat), so these actions will not have an impact on offshore areas within protected EFH.

[c] Peck et al. (1999) observed that the re-establishment of benthic invertebrate species after a catastrophic disturbance (iceberg-driven scour event) occurred after a 10 days for several pioneering species (e.g., amphipods, isopods), whereas less-mobile, larger and longer-lived species (e.g., large bivalves), although present after 100 to 250 days, did not significantly recolonize nearshore habitat by the end of the 250-day study.

ARRT – Alaska Regional Response Team
EFH – essential fish habitat
GRS – geographic response strategies
NOAA– National Oceanic and Atmospheric Administration
Services – NOAA Fisheries and USFWS
USFWS – US Fish and Wildlife Service

ES.2 ASSESSMENT OF EFFECTS ON EFH

In general, impacts associated with an implementation of the Unified Plan (EPA et al., 2010) are expected to be of low magnitude or negligible (i.e., could result in measurable impacts on specific resources but are not expected to have lasting effects on EFH or measurable impacts on managed species) relative to the expected impacts of a hazardous material spill under the baseline condition (i.e., no action). The most common expected impact of spill response actions would be the destabilization of upland soil or sediment, resulting in the sedimentation of aquatic habitats, which could result in a high-magnitude impact to salmon EFH in anadromous streams if not properly mitigated (or minimized).

The potential for the chemical dispersion of oil to adversely affect EFH is considered in detail in Appendix A, which reviews the toxicity of dispersants and dispersed oil as well as the potential for the exposure of EFH species. The use of chemical dispersants could result in adverse impacts on individuals of many managed species under a variety of circumstances. The planktonic and/or neustonic larvae (which could be present in the upper 10 m of the water column) of many managed species and their prey are at particular risk from exposure to chemically dispersed oil. For individuals present in the water column at a depth of between 1 and 10 m, impacts resulting from chemical dispersion are expected to be greater than those caused under the baseline condition because untreated oil does not generally mix into the water column to depths greater than 1 m; whereas, dispersed oil is expected to be present at concentrations above hazardous levels to depths of 10 m (NRC, 2005) for durations up to approximately 24 hours (Humphrey et al., 1987b; McAuliffe et al. 1980, 1981). Therefore, the use of chemical dispersants has the potential to adversely affect many managed species of fish and invertebrates at sensitive life stages (e.g., planktonic or neustonic life stages) as well as EFH. Any adverse effects on EFH (e.g., reduced water quality, reduced prey base) would be temporary and so are not expected to result in long-term effects on populations of managed species.

Several options could be implemented to partially or wholly mitigate or minimize potential adverse impacts to EFH and managed species (in addition to other valued resources) (see Table ES-1).

ES.3 CONCLUSIONS

Most spill response actions implemented under the Unified Plan (EPA et al., 2010) are unlikely to result in adverse impacts relative to the baseline condition provided that measures to mitigate or minimize potential adverse effects are appropriately implemented. The effects determinations for the response actions identified in the Unified Plan (EPA et al., 2010) are as follows:

- The response actions and components grouped in Table ES-1 under mechanical countermeasures are not likely to adversely affect EFH or managed species relative to the baseline condition.
- The use of chemical dispersants could directly affect many managed fish and invertebrate species at sensitive life stages (e.g., planktonic or neustonic life stages) and would temporarily adversely affect EFH (i.e., water quality and prey availability) in the vicinity of a dispersant's application as compared with the long-term adverse affects of the baseline condition.
- *In situ* burning and bioremediation are not likely to adversely affect EFH and managed species as compared with the baseline condition.
- Effects on EFH from natural attenuation are similar to the baseline condition

The Action Agencies recognize that adverse effects resulting from hazardous materials spill response actions, whether mechanical or chemical and taken independently or in combination, will be shorter in duration relative to the long-term effects on EFH from the spill (baseline condition).

The Action Agencies also recognize that before any hazardous materials spill response actions are implemented, a thorough evaluation of the tradeoffs between the environmental benefits and harm associated with a response action will be undertaken by the federal on-scene coordinator and, when necessary, the Alaska Regional Response Team.

The analyses and findings of this EFH assessment will be an integral part of the decision-making process and will aid in the selection of appropriate responses to the release of oil and hazardous substances in Alaska waters.

1 Introduction

This essential fish habitat (EFH) assessment evaluates the potential for adverse effects on species and habitats from the implementation of the *Unified Plan: Alaska Federal/State Preparedness Plan for Response to Oil and Hazardous Substance Discharges/Releases, Change 3, January 2010* (EPA et al., 2010), hereafter referred to as the Unified Plan. The Unified Plan is jointly prepared by the US Coast Guard (USCG), US Environmental Protection Agency (EPA), Alaska Department of Environmental Conservation (ADEC), and additional members of the Alaska Regional Response Team (ARRT).[3] The Unified Plan provides a strategy for a coordinated, multi-jurisdictional emergency response to a spill or discharge of oil or hazardous substances within the boundaries of the State of Alaska and its surrounding waters, which includes all contiguous waters to the extent of the exclusive economic zone (EEZ),[4] and is hereafter referred to as the Action Area. The effects evaluated in this document are those associated with specific countermeasures used to mitigate or minimize the risks from the spilled or discharged material – not the spilled material itself.

The assessment of EFH is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, commonly referred to as the Magnuson-Stevens Act (MSA). Under the MSA, each federal fishery management plan (FMP) must describe and identify EFH for managed fisheries. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (16 U.S.C. 1802(10)). Federal agencies must consult with the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NOAA Fisheries) regarding any action they authorize, fund, or undertake that may adversely affect[5] EFH, and NOAA Fisheries must provide conservation recommendations to federal and state agencies regarding any action that would adversely affect EFH. This EFH assessment follows NOAA Fisheries EFH guidance (NMFS, 2004) and is consistent with other EFH assessments for Alaska waters (e.g., HDR and URS, 2006; Tetra Tech, 2006; USBLM, 2002; NMFS, 2011b) and for hazardous material spill response planning (NMFS, 2003).

EPA and USCG are the federal agencies responsible for the implementation of the Unified Plan (EPA et al., 2010) (the Action Agencies) and, as such, are the agencies that will use this EFH to support consultation with NOAA Fisheries under the authority of the MSA.

[3] A list of the current ARRT members is provided on the ARRT website at http://alaskarrt.org/ (ARRT, 2013).

[4] The EEZ includes waters up to approximately 200 nautical miles offshore; the first 3 miles are under shared federal and state jurisdiction.

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

EFH consultations and Endangered Species Act (ESA) Section 7 consultations are separate environmental review processes. EFH consultations are conducted by NOAA Fisheries. ESA consultation for actions that may adversely affect ESA-listed (or candidate) species and their critical habitat are conducted by both NOAA Fisheries and the US Fish and Wildlife Service (USFWS), hereafter referred to collectively as the Services. NOAA Fisheries administers the ESA for marine fish and mammals, whereas USFWS administers the ESA for freshwater and terrestrial species. For the purpose of ESA consultation on the Unified Plan, the *Biological Assessment of the Alaska Federal/State Preparedness Plan for Response to Oil & Hazardous Substance Discharges/Releases (Unified Plan)* (Windward and ERM, 2014), hereafter referred to as the biological assessment (BA), was prepared and submitted to the Services in January 2014. The BA serves as the basis for the Biological Opinion to be issued by the Services, which will specify conservation measures for actions (i.e., spill response actions) that may adversely affect listed or candidate species or their critical habitat.

The EFH guidelines enable the Action Agencies to use existing consultation or review procedures to satisfy MSA consultation requirements to the extent that the assessment of the proposed action meets the requirements for EFH assessments (NMFS, 2004). To this end, this EFH assessment summarizes detailed analyses and background information presented in the BA that pertain to EFH in the Action Area and references the BA (Windward and ERM, 2014) for more detailed information.

Six FMPs for fisheries off Alaska are associated with the Action Area: Bering Sea/Aleutian Islands (BSAI) Groundfish FMP, Gulf of Alaska (GOA) Groundfish FMP, BSAI King and Tanner Crab FMP, Alaska Scallop FMP, Alaska Salmon FMP, and Arctic Resources FMP. Together these FMPs describe the management of > 70 species of fish and invertebrates[6] and applicable EFHs. A total of 75 distinct EFHs are described in the FMPs, with some overlap in species between GOA and BSAI groundfish stocks as well as snow crab as a component of the BSAI tanner and king crab fishery and an Arctic Resource. The FMPs and EFHs are described in more detail in Section 1.2.

1.1 RESPONSE PLANNING UNDER THE UNIFIED PLAN

Spill response planning in Alaska is accomplished through the development of a series of inter-related plans, for which the National Contingency Plan (NCP) provides the overarching framework and sets up procedures that are designed to minimize the

[6] The FMPs describe many managed species as being found in certain fisheries (or management categories), although EFH is not clearly defined for every species. For example, several scallop species are present and managed in Alaska, but EFH is defined for only the weathervane scallop. Similarly, squids, octopus, sharks, sculpin, and the forage fish, other demersal rockfish, other flatfish, and shallow-water flatfish complexes are all groups (e.g., management categories) of species noted in the FMPs, but not every species that are in those groups are well described or have defined EFH; often a small number of representative species are described only. As another example, blackspotted and rougheye rockfish are included in the same EFH, as are longspine and shortspine thornyhead rockfish.

imminent threat to human health or the environment from an uncontrolled release of oil or other hazardous substances.

The Unified Plan (EPA et al., 2010) uses the framework and priorities set forth in the NCP and applies them in a regional context (i.e., Alaska). The Unified Plan provides both administrative and technical guidance for members of the response community to follow during emergency response to a spill. The Unified Plan is organized as a series of annexes (A through Z). The administrative guidance establishes how the spill response will be organized, managed, and funded; the technical guidance addresses countermeasures that have been approved for use as part of the response.

Mechanical countermeasures are the main focus of emergency spill response under the Unified Plan (EPA et al., 2010). Details regarding the selection and implementation of a response are provided in documents that were prepared in response to or in support of the Unified Plan (e.g., Nuka Research, 2006; Alaska Clean Seas, 2010; API et al., 2001; NOAA et al., 2010).[7] The Unified Plan also incorporates guidance on the use of non-mechanical countermeasures because of their potential for adverse effects and details the decision process for the selection of a non-mechanical countermeasure in order to support the evaluation of tradeoffs associated with implementation (i.e., magnitude of environmental benefit versus harm) (additional detail is provided in Section 1.1.2).

The Unified Plan (EPA et al., 2010) is supplemented by 10 subarea contingency plans (SCPs), which provide more specific detail for local response planning in large inland and coastal areas of Alaska (Figure1-1). The SCPs set resource protection priorities and incorporate key provisions of local government emergency response plans and applicable information from responsible party (RP) spill response plans. These SCPs are updated regularly, and the updates are reviewed and approved by ARRT to maintain consistency with the Unified Plan. The SCPs also include site-specific geographic response strategies (GRS) developed by multi-stakeholder work groups, including the Services, to protect sensitive resources at specific locations within each subarea. Sensitive resources are broadly defined to include human and cultural resources, as well as species and habitats of concern (i.e., not just EFH-associated resources). GRS incorporate elements of emergency response actions that are intended to minimize impacts on EFH from both the actions and the spilled material. The development of GRS is an ongoing effort, and not all were complete at the time that this EFH consultation was published. Final, draft, and proposed GRS are available on the ARRT website.[8]

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[7] A more complete list of documents describing mechanical countermeasures and their uses is provided in Annex N of the Unified Plan.

[8] Currently found at the following URL: http://alaskarrt.org/

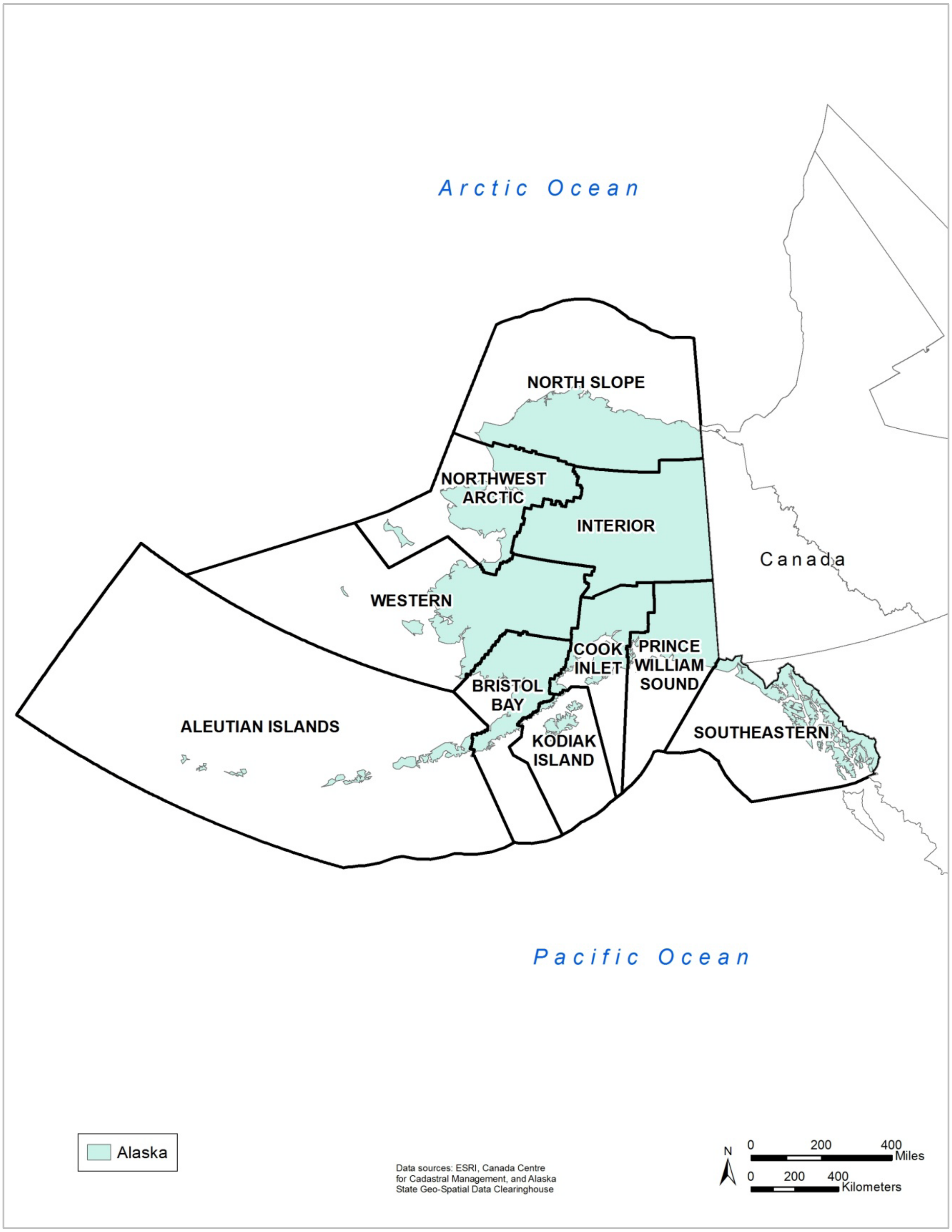
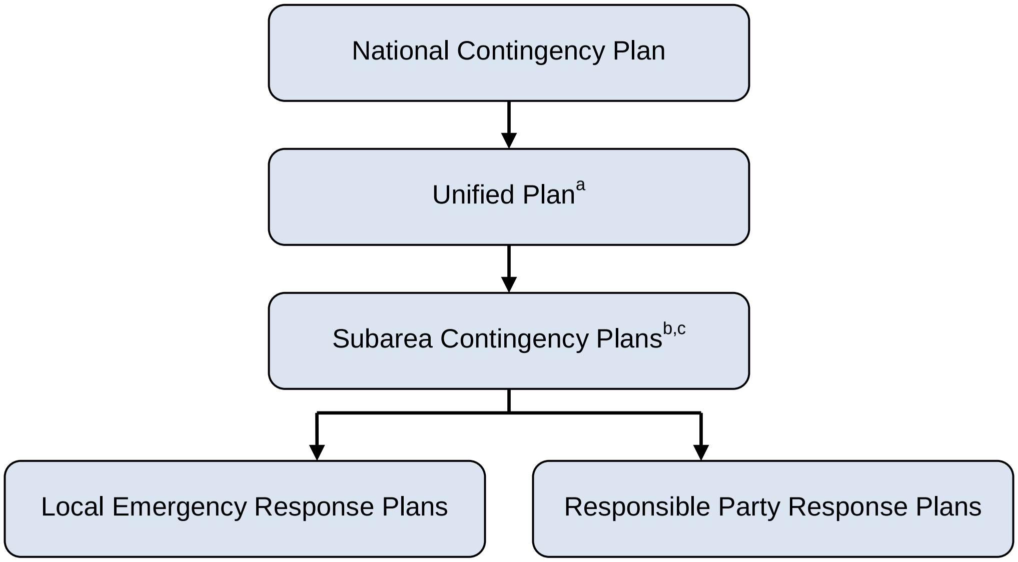


Figure 1-1. Alaska Unified Plan contingency plan subareas

The final level of response planning occurs at the local level and includes vessel- and facility-specific plans. The hierarchy and relationships among the various Alaska spill response plans are provided in Figure 1-2.



[a] Incorporates requirements of State Master Plan, Alaska Regional Contingency Plan, and Federal Area Plan guidance (EPA, 1997)

[b] Include plans for Cook Inlet, Bristol Bay, North Slope, Kodiak Island, Aleutian Islands, Southeast Alaska, Prince William Sound, Western Alaska, Northwest Arctic, and interior Alaska.

[c] Include geographic response strategies, as completed, for sensitive areas within each of the 10 subareas.

Figure 1-2. Integrated oil and hazardous substance spill response planning

The selection and implementation of site-specific response strategies are ultimately at the discretion of the Unified Command (i.e., the team of response leaders who represents the RP and federal, state, and [potentially] local agencies), following the guidance in the Unified Plan (EPA et al., 2010) and in consultation with other members of the response community. Guidance on the structure of this response organization, including a flowchart that shows the relationship among response organizations, is provided in Appendix A of the BA (Windward and ERM, 2014). The coordination of spill response planning and implementation with the requirements of the MSA is also addressed in the Unified Plan.

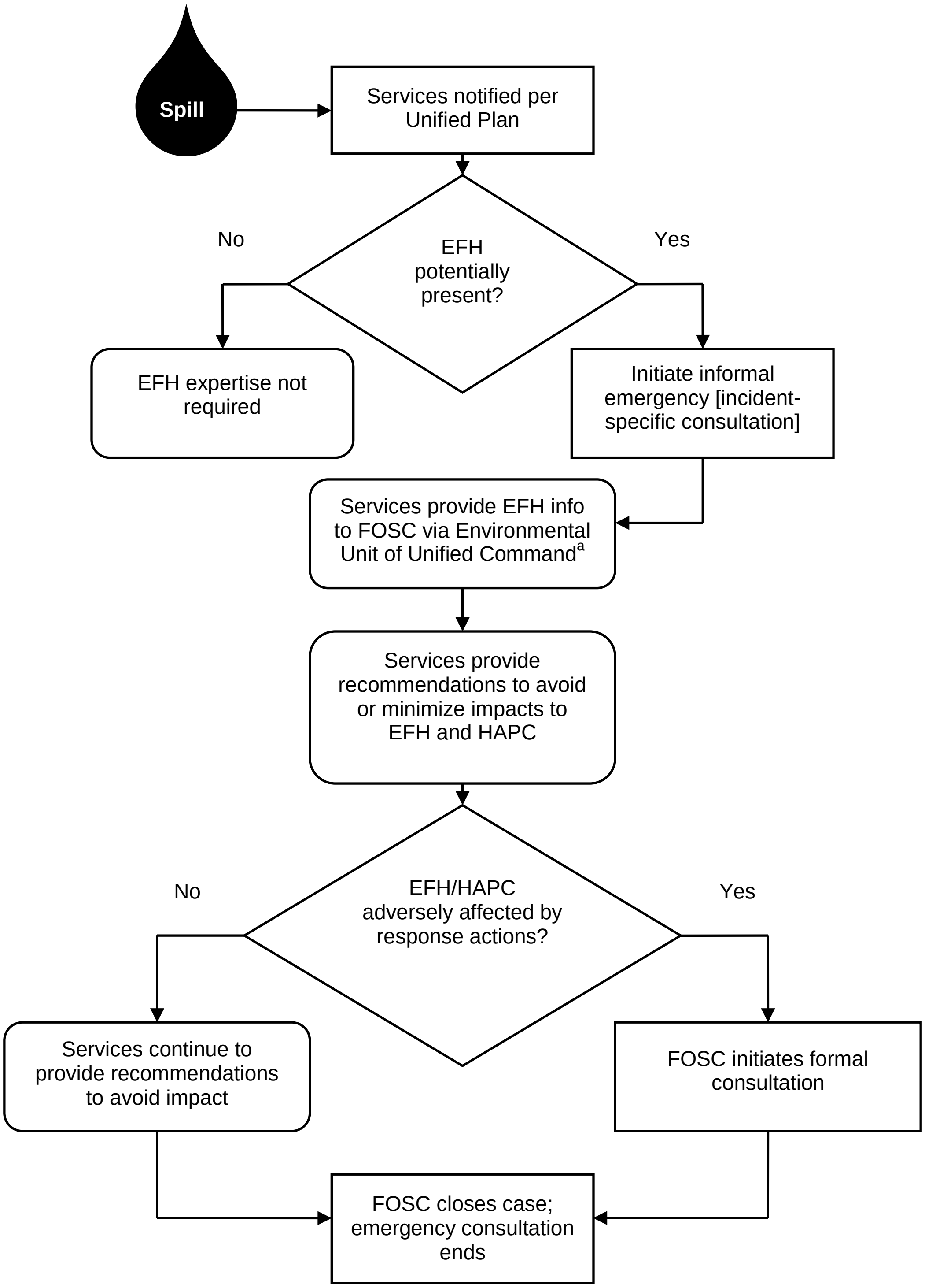
In the event of an unplanned release of oil or hazardous material to the environment, emergency response actions are implemented to achieve the following objectives:

- Human safety and welfare (including the protection of economic resources)
- Control and minimization of the release of oil or hazardous substances
- Environmental protection (including EFH and habitat areas of potential concern [HAPCs])
- Containment, cleanup, and disposal of the spilled material

The Unified Command is responsible for selecting, prioritizing, and implementing the actions that will meet these goals. The selection of the most appropriate response action (or actions) for a given spill is dependent on a number of factors, including the nature and magnitude of the spill, weather, timing, location, accessibility, resources at risk, and likely fate and effects of the material released. Every response strategy has uncertainties, along with potential environmental tradeoffs that are evaluated as part of the action selection process. Response decisions are made using the best information available, with the knowledge that the initial understanding of the event may be incomplete. During a spill, responses are modified as environmental conditions change or additional information becomes available. The spill response community relies on training and training exercises to make the uncertainties manageable. This emergency spill response training, a requirement of the Unified Plan (EPA et al., 2010), is expected to assist decision-making in the face of uncertainty and to ensure that at-risk environmental resources, such as EFH/HAPCs, are properly protected within the scope of resources available or mobilized during an emergency spill response.

1.1.1 Coordination of Response Activities with the MSA

NOAA Fisheries participates in response planning as a service agency with MSA administration responsibilities. Prior to a spill, the Services participate in the development of response methods that are incorporated into the Unified Plan (EPA et al., 2010) and guidance documents and in periodic response training. As members of ARRT, the Services review all SCPs that guide area-specific responses. The Services also provide input into site-specific strategies to protect EFH by participating in the GRS work groups. Once a spill has occurred, the Services are notified, and representatives of the Services join the Incident Command System to advise the federal on-scene coordinator (FOSC) with regard to the development of an incident action plan (IAP) and to provide real-time input on necessary modifications to protective measures as conditions change. This process is outlined in Figure 1-3.



Note: Adapted from EPA (2001)
[a] Federal On-Scene Coordinator.

Figure 1-3. Coordination between response planning and implementation of MSA

1.1.2 Decision Process for Use of Non-Mechanical Countermeasures

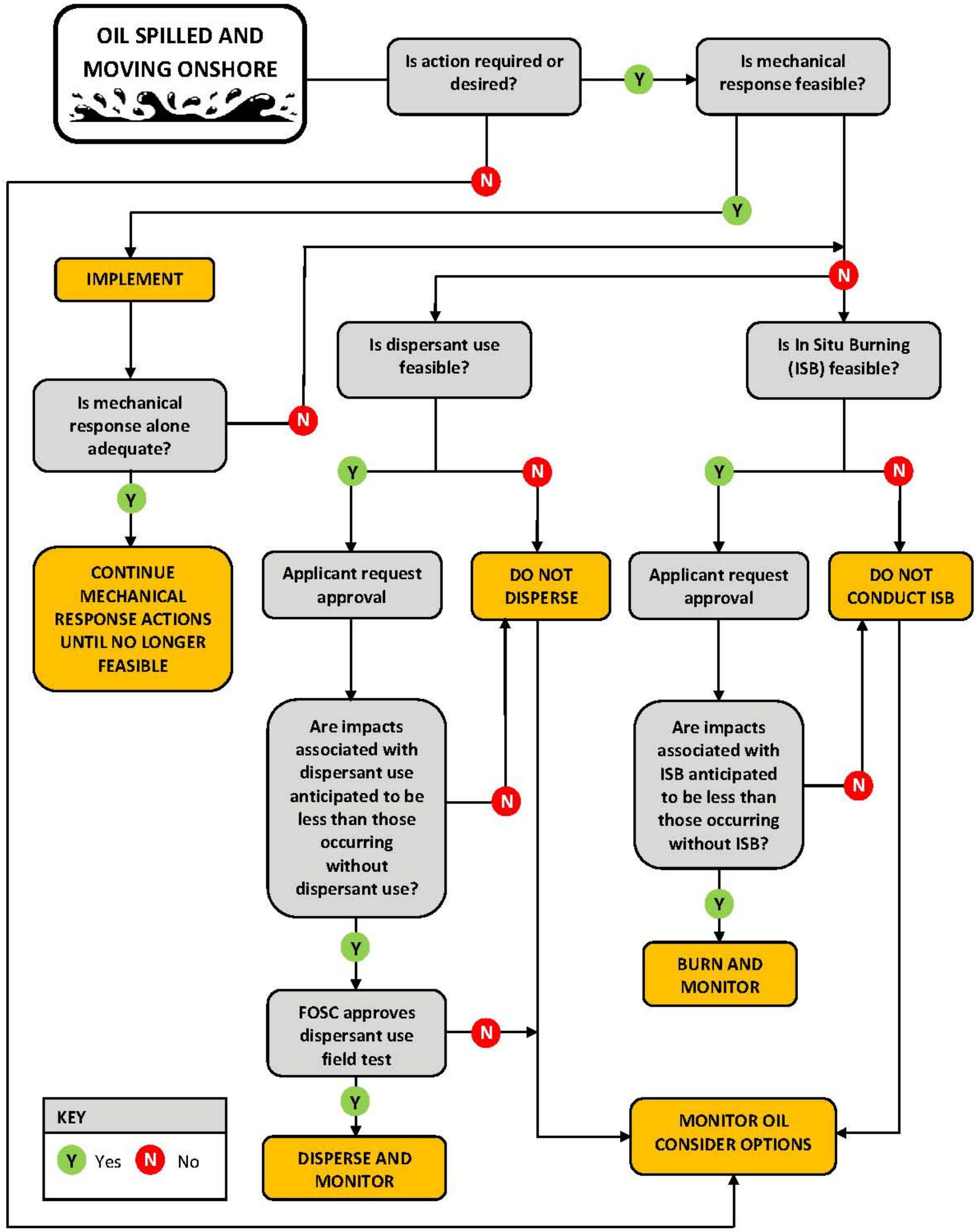
Spill responses in Alaska can be hampered by a number of factors (e.g., the distance between the spill and response equipment and personnel, accessibility, weather, sea conditions, and topography). Dispersants or *in situ* burning can serve as methods for mitigating the impacts of oil when mechanical countermeasures are hampered and the risk of environmental harm from the oil is great. The use of dispersants and *in situ* burning as countermeasures for oil spills requires an additional decision-making process under the Unified Plan (Annex F) (EPA et al., 2010).

Decisions regarding the use of dispersants must take into account the resources at risk, the size of the spill, the physicochemical properties of the type of oil spilled, the feasibility of the response actions, and site-specific conditions (e.g., weather, sea state, the presence of ice). The overarching criterion for decision-making is that the application of chemical dispersants will result in a net environmental benefit for humans, wildlife (e.g., ESA-listed or candidate species), and fisheries (including EFH).

As of the writing of this EFH consultation, dispersants are not pre-authorized for use anywhere in Alaska. A new dispersant use policy and pre-authorization plan has been drafted (ARRT, 2014), agreed to by all required signatories under the NCP (40 CFR 300.910) and is in the process of mandatory federal-to-tribal government consultation and State of Alaska public comment process, as well as ESA Section 7 and EFH consultations, prior to finalization and implementation (with the policy taking full effect 24 months after finalization). The intent of the new draft pre-authorization plan is to:

- Provide an administrative tool to ensure the well-regulated availability of the supplies and equipment necessary to respond quickly and effectively to oil spills
- Include safeguards such that pre-authorization:
  - Applies only within the first 96 hours of a spill
  - Applies only to crude oil spills from tanker vessels bound to or from a US port(s) (i.e., non-innocent passage)
  - Applies to a well-defined, risk-based zone that consists of tanker traffic areas through which crude oil is shipped
- Require emergency consultation with the Services prior to application
- Ensure the development of avoidance areas within each of the five affected subareas wherein dispersant approval protocols will follow a case-by-case procedure
- Ensure the ability to implement robust dispersant efficacy monitoring (i.e., special monitoring of applied response technologies [SMART] Tier I-III) capabilities within a prescribed time window

In the absence of pre-authorization, the FOSC must formally request to use dispersants anywhere in Alaska waters. The FOSC works with the RP, NOAA's scientific support coordinator (SSC), the Environmental Unit of the Incident Command System, and other resource agencies to complete a detailed, comprehensive checklist and application and submit them to the incident-specific ARRT for expedited approval. This request documents the conditions under which the dispersant would be applied and the environmental tradeoffs associated with the decision. ARRT considers each request on a case-by-case basis. The EPA representative to ARRT must concur, modify, or reject the request. If State of Alaska waters or interests are involved or threatened by the spill, the state's representative to ARRT must also concur, modify, or reject the request. EPA and State of Alaska representatives must be in agreement as to the disposition of the FOSC's dispersant use request. Figure 1-4 illustrates this decision process.



Source: ARRT (2014)

Figure 1-4. Conceptual decision process for *in situ* burning or dispersant use under the Unified Plan

Subsea dispersant use is not a component of the dispersant response action identified in the Unified Plan (EPA et al., 2010) because it was not conceived of as a response option until the Deepwater Horizon oil spill in the Gulf of Mexico in 2010. The *ARRT Dispersant Use Plan for Alaska* (ARRT, 2014), once finalized and approved, will replace Appendix I in Annex F. The draft language included in Appendix A of the BA (Windward and ERM, 2014) indicates that any request for subsea dispersant use will be considered on a case-by-case basis following the procedures for dispersant use authorization, with requirements for emergency ESA Section 7 and EFH consultation and effectiveness monitoring. As more conclusive scientific information on the subsea application of dispersants becomes available, the potential impacts of this response method and any recommended mitigation measures will be further analyzed, evaluated, and incorporated into the Unified Plan, as appropriate.

Decision-making regarding *in situ* burning (Figure 1-4) should take into account the same information as that considered for dispersant use (described above and in Revision 1 to In Situ *Burning Guidelines for Alaska* (ADEC et al., 2008), which is included in Annex F of the Unified Plan (EPA et al., 2010)). *In situ* burning can be considered if mechanical countermeasures are ineffective and burning is feasible and can be conducted at a safe distance from populated areas or sensitive resources (i.e., EFH). *In situ* burning is included as part of the emergency consultation process with the Services, which provide recommendations regarding how to avoid or minimize impacts to EFH from burning oil or *in situ* burning activities.

No other non-mechanical countermeasures (e.g., bioremediation) have been approved for use in Alaska; any proposal would require approval by ARRT, of which the Services are members.

1.2 ESSENTIAL FISH HABITAT WITHIN THE ACTION AREA

EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (MSA § 3(10)). EFH is described in the FMPs, which are developed by Regional Fishery Management Councils and implemented by NOAA Fisheries. The North Pacific Fishery Management Council (NPFMC) has prepared and implemented six FMPs for fisheries in Alaska. The NPFMC (2009b) describes the FMPs as follows:

- **Bering Sea/Aleutian Islands Groundfish FMP –** This FMP (NMFS, 2013a) includes all species of groundfish (e.g., pollock, cod, flatfish, sablefish, rockfish) and management measures for vessels using trawl, longline, pot, and/or jig gear. In-season management of these fisheries is conducted by NOAA Fisheries in Juneau.
- **Gulf of Alaska Groundfish FMP –** This FMP (NMFS, 2013b) includes most of the same major groundfish target species as those included in BSAI, except for a few species that are managed by the State of Alaska and are not included in this

FMP. Many of the management measures mirror those of the BSAI groundfish FMP.

- **Bering Sea/Aleutian Islands King and Tanner Crab FMP –** This FMP (NMFS, 2011a) includes fisheries for king and Tanner crab (e.g., red king crab [*Paralithodes camtschaticus*], blue king crab [*Paralithodes platypus*], and golden king crab [*Lithodes aequispina*}; Tanner crab [*Chionoecetes bairdi*}; and snow crab [*Chionoecetes opilio*]). In-season management of these fisheries is provided by the Alaska Department of Fish and Game (ADF&G) in Kodiak.
- **Alaska Scallop FMP –** This FMP (NMFS, 2014) was developed to control fishing efforts in the weathervane scallop fishery. Only nine vessels are permitted under a license limitation program. In-season management of the fishery is provided by ADF&G in Kodiak.
- **Alaska Salmon FMP –** This FMP (NMFS, 2012a) was developed to prohibit salmon fishing in the EEZ, except by a limited number of vessels using troll gear in Southeast Alaska. All other salmon fisheries are conducted in state waters and are managed by the State of Alaska.[9]
- **Arctic Resources FMP –** Although there are currently no commercial fisheries in the Arctic Management Area, this FMP (NPFMC, 2009a) was developed by NPFMC in recognition of the different and changing ecological conditions of the Arctic, including warming trends in ocean temperatures, the loss of seasonal ice cover, and the potential long-term effects of these changes on the Arctic marine ecosystem. More prolonged (i.e., longer duration) ice-free seasons coupled with warming waters and changing ranges of fish species could create conditions that could lead to commercial fishery development in the US Arctic EEZ (NPFMC, 2009a). Although the range of several salmon species includes the Arctic Management Area, they are managed under a different FMP (NPFMC, 2009a).

The management areas governed by each FMP are provided by NOAA Fisheries through their online EFH mapping tool (NOAA, 2014). Legal descriptions of the management areas are provided in each FMP. The fish species addressed by each FMP are listed in Table 1-1. Each FMP provides narrative and tabular descriptions of EFH for each species addressed by life stage (i.e., egg, larval, early and/or late juvenile, and adult stages) if sufficient data are available.

[9] Note that salmon EFH includes State of Alaska waters, which is an area larger than the managed fishery and overlaps with the State of Alaska management area. The FMP was developed because MSA mandates that NOAA manage salmon and/or FMP species throughout their entire life cycle.

Table 1-1. Managed species addressed in FMPs

Common Name	Species	Applicable EFH (or management category)	Fisheries Management Plan					
			BSAI Groundfish	GOA Groundfish	BSAI Crab	Alaska Scallop	Alaska Salmon	Arctic Species
Alaska plaice	*Pleuronectes quadrituberculatus*	Alaska plaice	X	X				
Alaska skate	*Bathyraja parmifera* [a]	skate	X	X				
Aleutian skate	*Bathyraja aleutica* [a]	skate	X	X				
Arctic cod	*Arctogadus glacialis*	Arctic cod						X
Arrowtooth flounder	*Atheresthes stomias*	arrowtooth flounder	X	X				
Atka mackerel	*Pleurogrammus monopterygius*	Atka mackerel	X	X				
Bering Sea scallop	*Chlamys behringiana* [b]	weathervane scallop				X		
Bering skate	*Bathyraja interrupta* [a]	skate	X	X				
Bigmouth sculpin	*Hemitripterus bolini* [c]	sculpin	X	X				
Blackspotted rockfish	*Sebastes melanostictus* [d]	blackspotted/rougheye rockfish	X	X				
Blue king crab	*Paralithodes platypus*	blue king crab			X			
Boreal clubhook squid	*Onychoteuthis borealjaponica* [e]	squid	X	X				
Butter sole	*Isopsetta isolepis* [b]	rex sole/other flatfish complex (BSAI), northern and southern rocksole/ shallow water flatfish (GOA)	X	X				
Butterfly sculpin	*Hemilepidotus papilio* [c]	sculpins		X				
Canary rockfish	*Sebastes pinniger* [b]	yelloweye rockfish/other demersal rockfish		X				
Capelin	*Mallotus villosus* [f]	capelin	X	X				
China rockfish	*Sebastes nebulosus* [b]	yelloweye rockfish/other demersal rockfish		X				
Chinook salmon	*Oncorhynchus tshawytscha*	Chinook salmon					X	
Chum salmon	*Oncorhynchus keta*	chum salmon					X	

Table 1-1. Managed species addressed in FMPs

Common Name	Species	Applicable EFH (or management category)	Fisheries Management Plan					
			BSAI Groundfish	GOA Groundfish	BSAI Crab	Alaska Scallop	Alaska Salmon	Arctic Species
Coho salmon	*Oncorhynchus kisutch*	coho salmon					X	
Copper rockfish	*Sebastes caurinus*[b]	yelloweye rockfish/other demersal rockfish		X				
Dover sole	*Microstomus pacificus*	Dover sole		X				
Dusky rockfish	*Sebastes variabilis*	dusky rockfish	X	X				
Eastern Pacific bobtail squid	*Rossia pacifica*[e]	squid		X				
Eastern Pacific red octopus	*Octopus rubescens*[g]	octopus	X	X				
English sole	*Parophrys vetulus*[b]	northern and southern rocksole/shallow water flatfish		X				
Eulachon	*Thaleichthys pacificus*[f]	eulachon	X	X				
Flapjack octopus	*Opisthoteuthis californiana*[g]	octopus	X	X				
Flathead sole	*Hippoglossoides elassodon*	flathead sole	X	X				
Giant or robust clubhook squid	*Moroteuthis robusta*[e]	squid	X	X				
Giant Pacific octopus	*Enteroctopus dofleini*[g]	octopus	X	X				
Golden king crab	*Lithodes aequispina*	golden king crab			X			
Great sculpin	*Myoxocephalus polyacanthocephalus*	sculpin	X	X				
Greenland turbot	*Reinhardtius hippoglossoides*	Greenland turbot	X					
Grooved Tanner crab	*Chionoecetes tanneri*[b]	Tanner crab			X			
Kamchatka flounder	*Atheresthes evermanni*	Kamchatka flounder		X				
Longhead dab	*Pleuronectes proboscidea*[b]	rex sole/other flatfish complex	X					

Table 1-1. Managed species addressed in FMPs

Common Name	Species	Applicable EFH (or management category)	Fisheries Management Plan					
			BSAI Groundfish	GOA Groundfish	BSAI Crab	Alaska Scallop	Alaska Salmon	Arctic Species
Longspine thornyhead rockfish	*Sebastolobus altivelis* [h]	thornyhead rockfish	X	X				
Octopus (un-named)	*Graneledone boreopacifica*[g]	octopus	X					
Octopus (un-named)	*Japetella diaphana*[g]	octopus	X	X				
Octopus (un-named)	*Octopus* sp. Jorgensen[g]	octopus	X	X				
Octopus (un-named)	*Benthoctopus oregonensis*[g]	octopus	X					
North Pacific bigeye octopus	*Octopus californicus*[g]	octopus		X				
Northern rock sole	*Lepidopsetta polyxystra*	northern rock sole	X	X				
Northern rockfish	*Sebastes polyspinus*	northern rockfish	X	X				
Pacific cod	*Gadus macrocephalus*	Pacific cod	X	X				
Pacific ocean perch	*Sebastes alutus*	Pacific ocean perch	X	X				
Pacific sand lance	*Ammodytes hexapterus*[f]	Forage fish complex	X	X				
Pacific sleeper shark	*Somniosus pacificus*[i]	shark	X	X				
Pink salmon	*Oncorhynchus gorbuscha*	pink salmon					X	
Pink scallop	*Chlamys rubida*[b]	weathervane scallop				X		
Plain sculpin	*Myoxocephalus jaok* [c]	sculpin	X	X				
Quillback rockfish	*Sebastes maliger*[b]	yelloweye rockfish/other demersal rockfish		X				
Red Irish lord	*Hemilepidotus hemilepidotus* [b]	sculpin		X				
Red king crab	*Paralithodes camtschaticus*	red king crab			X			
Red or magistrate armhook squid	*Berryteuthis magister*	squid	X	X				
Rex sole	*Glyptocephalus zachirus*	rex sole/other flatfish complex	X	X				

Table 1-1. Managed species addressed in FMPs

Common Name	Species	Applicable EFH (or management category)	Fisheries Management Plan					
			BSAI Groundfish	GOA Groundfish	BSAI Crab	Alaska Scallop	Alaska Salmon	Arctic Species
Rock scallop	*Crassadoma gigantean*[b]	weathervane scallop				X		
Rosethorn rockfish	*Sebastes helvomaculatus*[b]	yelloweye rockfish/other demersal rockfish		X				
Rougheye rockfish	*Sebastes aleutianus*[d]	blackspotted/rougheye rockfish	X	X				
Sablefish	*Anoplopoma fimbria*	sablefish	X	X				
Saffron cod	*Eleginus gracilis*	saffron cod						X
Salmon shark	*Lamna ditropis*[i]	shark	X	X				
Sand sole	*Psettichthys melanostictus*[b]	northern and southern rocksole/shallow water flatfish		X				
Scarlet king crab	*Lithodes couesi*[b]	golden crab			X			
Shortraker rockfish	*Sebastes borealis*	shortraker rockfish	X	X				
Shortspine thornyhead rockfish	*Sebastolobus alascanus*[h]	thornyhead rockfish	X	X				
Smoothskin octopus	*Benthoctopus leioderma*[g]	octopus	X	X				
Snow crab	*Chionoecetes opilio*	snow crab			X			X
Sockeye salmon	*Oncorhynchus nerka*	sockeye salmon					X	
Southern rock sole	*Lepidopsetta bilineata*	southern rock sole	X	X				
Spiny dogfish	*Squalus acanthias*[i]	shark	X	X				
Spiny scallop	*Chlamys hastata*[b]	weathervane scallop				X		
Starry flounder	*Platichthys stellatus*[b]	rex sole/other flatfish complex		X				
Tanner crab	*Chionoecetes bairdi*	Tanner crab			X			
Tiger rockfish	*Sebastes nigrocinctus*	yelloweye rockfish/other demersal rockfish		X				

Table 1-1. Managed species addressed in FMPs

Common Name	Species	Applicable EFH (or management category)	Fisheries Management Plan					
			BSAI Groundfish	GOA Groundfish	BSAI Crab	Alaska Scallop	Alaska Salmon	Arctic Species
Triangle Tanner crab	*Chionoecetes angulatus*[b]	Tanner crab			X			
Vampire squid	*Vampyroteuthis infernalis*[g]	octopus		X				
Walleye pollock	*Theragra chalcogramma*	walleye pollock	X	X				
Warty sculpin	*Myoxocephalus verrucosus* [c]	sculpin	X					
Weathervane scallop	*Patinopecten caurinus*	weathervane scallop				X		
White scallop	*Chlamys albida*[b]	weathervane scallop				X		
Yellow Irish lord	*Hemilepidotus jordani* [c]	sculpin	X	X				
Yelloweye rockfish	*Sebastes ruberrimus*	yelloweye rockfish		X				
Yellowfin sole	*Limanda aspera*	yellowfin sole	X	X				

Note: Table includes several managed species for which EFH is not clearly defined (e.g., scallops other than weathervane scallop) or that are within groups with generalized EFH (e.g., squid or octopus species).

a Skates are assessed as a group; the list of individual species may be incomplete.

b The FMP(s) define EFH that applies to this species, although the EFH is specifically named for an applicable surrogate species (from the same management category) in the FMP (as well as in this table).

c Sculpins are assessed together; the list of individual species may be incomplete.

d Blackspotted and rougheye rockfish are assessed together.

e Squid species are assessed together; the list of individual species may be incomplete.

f Capelin, eulachon, and Pacific sand lance are representatives of the forage fish complex; only capelin and eulachon have defined EFH.

g Octopuses are assessed together; the list of individual species may be incomplete.

h Thornyhead rockfish are assessed together.

i Shark species are assessed together; the list of individual species may be incomplete.

BSAI – Bering Sea and Aleutian Islands
FMP – fisheries management plan
GOA – Gulf of Alaska
EFH – essential fish habitat

For all species except salmon, EFH includes only marine and/or estuarine waters. EFH for salmon includes both marine and fresh waters. Marine EFH for the salmon fisheries in Alaska includes all estuarine and marine areas used by Pacific salmon of Alaska origin, extending from the influence of tidewater and tidally submerged habitats to the limits of the EEZ (NMFS, 2012a). Freshwater EFH for Alaska salmon fisheries includes all streams, lakes, ponds, wetlands, and other water bodies in the state currently or historically accessible to salmon. ADF&G maintains a web-based catalog of waters that are important for the spawning, rearing, or migration of anadromous fish in the *Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes* and the *Atlas to the Catalog of Waters Important for Spawning, Returning or Migration of Anadromous Fishes* (ADF&G, 2014a, b). However, it is important to note that additional streams, lakes, ponds, wetlands, and other water bodies that may not have been surveyed or mapped (including nearly all coastal waters) provide important habitat for anadromous fish and are included as EFH (NMFS, 2012a).

HAPCs are areas within EFH that are of particular ecological importance to the long-term sustainability of managed species, are of a rare type, or are especially susceptible to degradation or development (NMFS, 2004). HAPCs are meant to provide for greater focus of conservation and management efforts. The 22 HAPCs in the Action Area (NOAA, 2012a) are:

- Alaska Seamount Habitat Protection Areas
    - Chirikov and Marchand Seamounts
    - Dall Seamount
    - Denson Seamount
    - Derickson Seamount
    - Dickens Seamount
    - Giacomini Seamount
    - Kodiak Seamount
    - Odessey Seamount
    - Patton Seamount
    - Quinn Seamount
    - Sirius Seamount
    - Unimak Seamount
    - Welker Seamount
    - Brown Seamount
    - Bowers Seamount

- Bowers Ridge Habitat Conservation Zone
  - Ulm Plateau
  - Bowers Ridge
- Gulf of Alaska Coral Habitat Protection Areas
  - Fairweather FN1
  - Fairweather FN2
  - Fairweather FS1
  - Fairweather FS2
  - Cape Ommaney 1

Maps of the HAPCs in the Action Area are available on the Internet (NOAA, 2014) and include all of the HAPCs located in the North Pacific Region, which roughly corresponds to the Action Area. The HAPCs include open-water areas that extend beyond the continental shelf (e.g., seamounts that rise from the continental slope or abyssal plain) in areas where response actions could be implemented. Additional information regarding species- and life stage-specific habitat associations (within these HAPCs) are provided in the FMPs (NMFS, 2011a, 2012a, 2013a, b, 2014; NPFMC, 2009a).

1.2.1 Types of habitat within the Action Area

The Action Area is characterized by a diverse array of arctic, boreal, and temperate ecosystems composed of terrestrial and aquatic habitats. For the purpose of this EFH assessment, habitat types are identified based on their importance in the distribution of species included in the FMPs and the various response actions that could be selected for use in those habitats. Habitat designations in this EFH assessment (consistent with those used in the Unified Plan (EPA et al., 2010)) are identified below and briefly described in the subsections that follow.

- Riverine, lacustrine, wetland, and riparian habitat
- Shoreline (in marine environments from mean lower low water [MLLW] to 1,000 yds [914 m] inland from the highest tide mark [the farthest extent of USCG upland jurisdiction])
- Nearshore (in marine environments from MLLW to 20 m deep or 100 m offshore, whichever is greater)
- Open water (> 20 m deep or > 100 m offshore to the EEZ boundary)
- Sea ice (including leads [large fractures in the ice] and polynyas [areas of open water within the ice])

These habitat descriptions differ somewhat from the descriptions of EFH in the FMPs, and these differences are clarified in the following subsections.

1.2.1.1 Riverine, lacustrine, wetland, and riparian habitats

For the purpose of this EFH assessment, only those watersheds identified as bearing anadromous salmon species during some life stage are defined as EFH in this assessment. Terrestrial habitats that are not within these watersheds are not of interest for this EFH assessment because potential impacts to outside habitats are unlikely to result in adverse impacts to EFH. Terrestrial habitats are not included in any EFH, although impacts on riparian habitat resulting from an implementation of the Unified Plan could influence anadromous fish EFH.

Alaska has a complex system of riverine, lacustrine, and riparian habitats[10] as a result of the significant year-round precipitation and snow melt during the summer months. According to the USGS Geographic Names Information System (GNIS), the State of Alaska has > 9,500 named rivers and > 3,300 named lakes (USGS, 2012). Riverine, lacustrine, and riparian habitats are important for many fish species, but are particularly important as salmon EFH (ADF&G, 2014a, b). Eulachon are also anadromous (spawning in freshwater and rearing and maturing in estuaries and oceans), although their EFH does not include freshwater habitat (NMFS, 2005a, b, 2013a, b). Among upland habitats, riparian habitat has the greatest influence on freshwater habitat of anadromous fish (by providing and regulating terrestrial and aquatic nutrients and invertebrate prey, stabilizing soils/preventing sedimentation, and controlling water temperature through shading), and impacts to riparian habitat are the most likely to influence anadromous fish (i.e., salmon) EFH.

Freshwater wetlands, which are abundant in Alaska due to heavy seasonal snowmelt and precipitation, and impermeable substrates that impede drainage provide important filtration mechanisms that maintain water quality and provide optimal breeding and rearing habitat for anadromous fish species. Vegetation associated with wetlands is uniquely adapted to the permanent or seasonal saturated conditions. Bogs and fens (collectively known as peatlands) are wetlands that are characterized by highly organic soil, limited drainage, and, in the case of bogs, lower pH (the pH of fens can vary widely). Water might not be visible at the surface of a bog, and some bog surfaces can appear fairly dry during the peak of the growing season when the water table is low. In the Arctic, snow melt in the summer is often the primary source of the water in bogs. Marshes contain seasonal, open-water features and often form adjacent to lakes, streams, and coastal bays. Marshes are also characterized by saturated soil because they receive water from adjacent surface water bodies or groundwater; marshes are generally not very acidic. Peatlands, marshes, and wooded swamps are also present in Alaska coastal areas.

Freshwater wetlands may provide off-stream refuge habitat for managed salmon species and are included in their EFHs. Coastal wetlands may provide important

[10] Riverine habitat is associated with flowing water bodies (e.g., rivers, streams); lacustrine habitat is associated with lakes. Riparian habitat is the vegetated shoreline of both types of water features.

habitat for marine and estuarine fish and invertebrates at various life stages (e.g., wetland vegetation may provide spawning substrate for mature individuals or productive forage habitat or refuge for embryos, larvae, or early juveniles). Based on the definitions of habitat in the FMPs, it is not clear whether coastal marshes are included in the EFHs of managed species, although impacts to coastal marshes could affect freshwater habitats (through saltwater intrusion) (NMFS, 2013a, b, 2012a).

1.2.1.2 Shoreline

Shoreline is defined as the area between MLLW and 1,000 yds (914 m) inland from the highest tide mark (i.e., furthest extent of USCG upland jurisdiction) along a marine or estuarine body of water. According to the former Alaska Coastal Management Program, Alaska's coastline is approximately 44,000 mi long (ADNR, 2006). The physical and biological characteristics of shorelines in Alaska are highly variable. NOAA's Environmental Sensitivity Index (ESI) maps (NOAA OR&R, 2008) define the many types of shoreline habitat that are potentially present in Alaska (Table 1-2).

Table 1-2. Shoreline habitat types potentially present in Alaska

Habitat Type	Habitat
Exposed	rocky shores; exposed rocky banks
	solid man-made structures
	rocky cliffs with boulder talus base
	wave-cut platforms in bedrock, mud, or clay
	scarps and steep slopes in clay or sand
	sand beaches (fine-, medium-, or coarse-grained)
	tundra cliffs
	mixed sand and gravel beaches
	gravel beaches (can include pebbles, cobbles, or boulders)
	riprap (man-made)
	exposed tidal flats
Sheltered	sheltered scarps in bedrock, mud, or clay; sheltered rocky shores (impermeable)
	sheltered, solid man-made structures; sheltered rocky shores (permeable)
	sheltered rocky rubble shores
	riprap (man-made)
	peat shorelines
	sheltered tidal flats
	vegetated low banks
	saltwater and brackish marshes
	freshwater marshes
	scrub-shrub wetlands
	inundated low-lying tundra

Based on: NOAA OR&R (2008)
NOAA – National Oceanic and Atmospheric Administration
OR&R – Office of Response and Restoration

The shoreline, including the intertidal zone, is the area where marine plants (including kelp and sea grasses) receive sufficient sunlight to create both habitat and food for other species. The shoreline also represents the interface between upland soil and marine or estuarine sediment habitats; alterations to shorelines can have a marked influence on sedimentation in intertidal and subtidal (i.e., nearshore) habitats (EPA, 1992; NOAA, 1994a). For example, the removal of vegetation or natural debris (e.g., driftwood, large rocks) or the alteration of local hydrology (e.g., damming) can also alter the physical configuration of the shorelines and the habitat function (e.g., disturb benthic invertebrate habitat) (NOAA, 1994a; Herkül et al., 2011; Conlan and Kvitek, 2005).

1.2.1.3 Nearshore

Nearshore is defined as the area between MLLW and 20 m deep or 100 m offshore, whichever is greater, and includes estuaries and river deltas. These areas are strongly influenced by tides and nearshore currents. Nearshore habitats are highly productive and are used as areas of refuge, feeding, and spawning by several managed species. Some nearshore areas, such as those in the Beaufort and Chukchi Seas, are covered in ice for the majority of the year (MMS, 2007). Some fish species (e.g., Arctic cod [*Arctogadus glacialis*] and saffron cod [*Eleginus gracilis*], which are associated with ice floes) likely live in these areas throughout the year.

The nearshore environment (as defined for the purpose of this EFH assessment) includes beach/intertidal habitat as well as a portion of the inner continental shelf (as defined in FMPs). The inner continental shelf, which extends to depths of 50 m (rather than 20 m), spans both nearshore and open-water habitats as defined in this EFH assessment (Section 1.2.1).

Nearshore estuaries are rich in organic and detrital material that provides energy and essential nutrients to algae, plankton, and invertebrate species such as polychaete worms, mysids, and amphipods. These species provide the foundation for estuarine and nearshore trophic interactions that benefit forage fish, flatfish, groundfish, and invertebrates during larval and juvenile life stages, including several of those species identified in this assessment (Table 1-1). The presence, abundance, and biodiversity of Alaska fish species in nutrient-rich, nearshore nursery habitats are well documented in the literature (Abookire et al., 2000; Abookire and Piatt, 2005; Norcross et al., 1995; Johnson et al., 2012).

1.2.1.4 Open water

Open water is defined as the area adjacent to the coast that is > 20 m deep or > 100 m offshore to the EEZ boundary. In Alaska, open-water habitat is typically discussed in reference to geographic or oceanographic features (e.g., Bristol Bay, Cook Inlet, Prince William Sound, Beaufort Sea). Alaska is surrounded by the North Pacific Ocean to the south and the Arctic Ocean to the north. The GOA and the Bering Sea represent major subregions within the North Pacific Ocean; the Beaufort and Chukchi Seas are subregions of the Arctic Ocean. These subregions include the continental shelf and the open water past the continental shelf.

The Beaufort Sea has a narrow continental shelf that extends as far as 80 km (50 mi) off the coast (NOAA, 2011). The shelf has an average water depth of approximately 37 m (120 ft). The water depth in the Beaufort Sea reaches a maximum of approximately 3,810 m (12, 500 ft) (NOAA, 2011). The Chukchi Sea is shallow, with an average depth of approximately 40 to 50 m (130 to 164 ft), and features a shelf that is approximately 480 km (300 mi) wide. The maximum water depth in the Chukchi Sea beyond the shelf is approximately 975 m (3,200 ft). Depths on the continental shelf in the GOA can be as great as 200 m (660 ft) (US Navy, 2011), and the width of the shelf ranges from approximately 6 to 200 km (4 to 125 mi). Depths in the GOA beyond the shelf range from 130 m to > 3,660 m (430 ft to > 12,000 ft) (US Navy, 2011). The Bering Sea has a broad shelf, the majority of which is < 150 m (~500 ft) deep (NASA, 2012).

The continental shelf provides some of the most important open-water habitats in Alaska. These areas serve as rich feeding grounds and migratory pathways for a wide variety of marine mammals, fish, and invertebrates.

Beyond the continental shelf in the southern GOA and south of the Aleutian Islands, ancient volcanic activity caused the formation of many seamounts (i.e., extinct volcanoes that are fully submerged in the ocean), some of which are now highly productive EFH and managed HAPC (NMFS, 2010). Seamounts create an impediment to the flow of ocean currents, and the change in flow results in the formation of eddies (White et al., 2007). The eddies concentrate plankton and neuston and facilitate the settling of larvae in the areas around the seamounts (Morato and Clark, 2007; Atwood et al., 2010; Pitcher et al., 2007).

Many of the habitats identified in FMPs are within "open water." Specifically, open-water habitats include bays or fjords (assuming a depth > 20 m), inner continental shelf between 20 and 50 m in depth,[11] middle continental shelf (50 to 100 m in depth), outer continental shelf (100 to 200 m in depth), upper continental slope (200 to 1,000 m in depth), lower continental slope (1,000 to 3,000 m in depth), and basin (> 3,000 m in depth). It is assumed that open waters also include island pass habitats which are defined in FMPs in terms of the force of currents moving between islands rather than the depth of water.

It is important to recognize that marine and freshwater ecosystems and processes in Alaska are complex and interconnected (Hopcroft et al., 2008; Hood and Zimmerman, 1987; Hood et al., 1981), even though the evaluation of these processes is beyond the scope of this assessment. Water temperature, salinity, and depth; the intensity of tides and currents; and the amount of day light often have a significant influence on fish and invertebrate habitat. Large-scale marine processes and factors (e.g., fish and

[11] The inner continental shelf is defined in FMPs as being between 1 and 50 m depth, but, for the purpose of this EFH assessment, only depths greater than 20 m are categorized as open water.

invertebrate migration and dispersion patterns, nutrient cycling) rely on complex chemical, biological/ecological, hydrological, and topographic interactions, all of which occur under the constant influence and variability of extreme weather and climate events. These many factors combined seasonally fuel primary and secondary production at a scale that creates and supports some the most highly productive marine habitats and fisheries on the planet.

Many managed fish and invertebrate species discussed in this EFH assessment spend their entire lives in open waters (NMFS, 2013b, a, 2014; NPFMC, 2009a). Many other species, particularly larval marine fish and invertebrates, are transported and distributed by tides and currents from offshore to nearshore nursery areas. The relationship and movement between marine and nearshore processes and species presence in Alaska have been well documented in the life histories of species such as walleye pollock (*Theragra chalcogramma*), red king crab (*Paralithodes camtschatica*), and yellowfin sole (*Limanda aspera)* and rock soles (*Lepidopsetta polyxystra* and *Lepidopsetta bilineata*) (NMFS, 2011a, 2013b, a). Larval forms of each species are transported and concentrated in nutrient-rich nearshore habitat. Later, many of these species migrate to open waters to assume their late juvenile and adult life stages in open pelagic waters or on benthic substrates.

1.2.1.5 Sea ice

Sea ice is frozen sea water and a dominant seasonal feature along the Alaska continental shelf. There are several types of ice cover in Alaska. Shorefast ice is a solid ice cover that is attached to land and the bottom of the sea along the shallow continental shelf. Pack ice is not attached to land and can drift but remains a solid sheet. Leads and pressure ridges can form in both shorefast and pack ice. Leads are cracks that form in sea ice as a result of wind, exposing long stretches of open water (Wadhams, 2003). Although leads often refreeze, they become weak points that are likely to break when the ice is under stress. Broken ice is also common and forms when cracks and leads do not refreeze. Persistent areas of open water (i.e., polynyas) can also form within the ice as a result of oceanographic and meteorological conditions. Melting ice is associated with phytoplankton blooms that support marine food webs at northern latitudes (Wadhams, 2003; Thomas and Dieckmann, 2010). Several species of fish are also associated with pack ice and ice leads (e.g., Arctic cod and saffron cod) (Sigler et al., 2011; NPFMC, 2009a).

Marine ecosystems are sensitive to changes in sea ice (Sigler et al., 2011), particularly the timing and duration of ice melt and ice formation. Sea ice cover and conditions are controlled by a complex feedback process between atmospheric and oceanic factors (e.g., atmospheric temperature, water temperature, water chemistry) that determine the annual cycle of ice formation and ice melt (Kinnard et al., 2011; Thomas and Dieckmann, 2010). Historically, sea ice cover is greatest during the winter months when temperatures are lowest (NOAA, 2011). In some locations, the sea ice melts during the summer; in other locations, it remains intact year-round. Sea ice that does not melt during the summer or over multiple summers is referred to as multi-year ice. Overall, the ice in the northern hemisphere has been shrinking at a rate of 3.4% per decade since the 1980s due to rising global temperatures, with higher negative trends in Arctic regions during the summer and autumn (Comiso and Nishio, 2008; cited in Kinnard et al., 2011).

Sea ice, like terrestrial habitats, is not explicitly included in EFH. Ice leads and polynyas, although intrinsically associated with sea ice, are more appropriately associated with open-water or nearshore habitats; the relationships between nearshore or open-water habitats (as defined in this document) and the habitat types defined in the FMPs are described in Sections 1.2.1.5 and 1.2.1.6, respectively.

1.2.2 ESA-listed fish species with EFH in the Action Area

Two species of ESA-listed salmonids (i.e., Chinook salmon [*Oncorhynchus tshawytscha*] and coho salmon [*Oncorhynchus kisutch*]) representing distinct population segments (DPS)[12] from the Columbia River and Puget Sound basin are included in the Alaska Salmon FMP (Table 1-3). In Alaska, these listed salmon occur only as late juveniles and adults and are thought to constitute only a small percentage of the overall catch of salmon in Alaskan waters. Spawning occurs in Washington and Oregon, where these species remain during early life stages (i.e., embryo, fry, smolt). NOAA Fisheries has designated critical habitat for each of the six Chinook salmon DPS (70 FR 52488 2005); however, all of the designated watersheds are freshwater rivers and streams located outside of Alaska. No critical habitat has been designated in Alaska for the Lower Columbia River coho salmon evolutionarily significant unit (ESU), and none has been proposed for designation (NMFS, 2012b). Both species use nearshore and open-water habitats in the GOA and Aleutian Islands; coho salmon also use nearshore and open-water habitat in the Bering Sea (north to Point Hope) and in southeast Alaska.

An evaluation of the potential effects of response actions on ESA-listed salmon species is presented in the BA (Windward and ERM, 2014), which presents detailed descriptions of their life history, population status, habitat requirements, and current stressors and threats. These ESA-listed salmonid populations may be vulnerable to contaminants, a reduction in their prey base (as a result of contaminant exposure or vacuuming/skimming), and other nearshore and shoreline response actions (e.g., vegetation removal, beach cleaning, and booming). Potential adverse effects of spill response actions on salmon EFH are discussed in Section 3 and Appendix A.

[12] A DPS is the smallest unit of a species that can be considered for conservation under ESA.

Table 1-3. DPS/ESU and ESA status of salmon and steelhead species with EFH in the Action Area

DPS/ESU	ESA Status	Sources Confirming Presence in Alaska Waters
Chinook Salmon		
Puget Sound	threatened	Crane et al. (2000), Templin and Seeb (2004)
Lower Columbia River	threatened	Crane et al. (2000), Templin and Seeb (2004), Wahle and Vreeland (1978)
Upper Columbia River (spring run)	endangered	Wahle et al. (1981)
Snake River (fall run)	threatened	Good et al. (2005), Crane et al. (2000), Templin and Seeb (2004)
Snake River (spring/summer run)	threatened	Wahle et al. (1981)
Upper Willamette River	threatened	Good et al.(2005), NOAA Fisheries (64 FR 41835, 1999)
Coho Salmon		
Lower Columbia River	threatened	Morris et al. (2007)
Steelhead Trout		
Lower Columbia River	threatened	McKinnell et al. (1997)
Middle Columbia River	threatened	McKinnell et al. (1997)
Upper Columbia River	endangered	McKinnell et al. (1997)
Snake River Basin	threatened	McKinnell et al. (1997)
Upper Willamette River	threatened	none

ESA – Endangered Species Act
DPS – distinct population segment
ESU – evolutionarily significant unit

2 Potential Response Actions

Hazardous material spill response has three primary phases: control, recovery, and cleanup. Spill responses are generally categorized as mechanical or non-mechanical countermeasures. Supporting activities include mobilization to and from the response area; the handling, treatment, and disposal of recovered materials; and the tracking or monitoring of spills. All components of a response action incorporate best management practices (BMPs) that help to avoid or minimize the impacts on EFH. It is the FOSC's role to ensure that appropriate BMPs are implemented during response actions. These BMPs are outlined in Section 5 of this document.

Natural attenuation (i.e., the lessening of impacts through evaporation, weathering, natural [i.e., physical] dispersion, or biodegradation) represents a no action alternative but may include initial reconnaissance and long-term monitoring activities to assess the consequences of natural attenuation. Natural attenuation is very similar to the baseline condition, with the exception that impacts related to spill tracking and monitoring are incrementally greater than the baseline condition.

The response strategy that is employed in the event of a spill depends on several factors, such as the type and amount of material spilled; the proximity of the spill to the shore, populated areas, or important resources; and sea and weather conditions. In the case of a petroleum release, the selection of an appropriate response can vary depending on whether the product is refined or crude oil because the chemical characteristics of the material influence the success of the countermeasure. For example, chemical dispersion is intended for the treatment of a spill of heavy petroleum such as crude oil.

Table 2-1 identifies the response actions that are appropriate for specific habitat types. The potential impacts of response actions on EFH/HAPC are discussed in Section 3. A detailed discussion of hazardous material spill response actions is provided in Section 2 of the BA (Windward and ERM, 2014).

Table 2-1. Response actions appropriate for specific habitat types

Response Action	Habitat[a]						
	Wetlands	Shoreline	Nearshore	Open Water	Sea Ice	Terrestrial Habitat	Riverine, Lacustrine, and Riparian
Mechanical Countermeasures							
Deflection/Containment							
Booming	X		X	X			X
Berming, pits, trenching, or underflow damming		X			X	X	
Culvert blocking	X						X
Recovery of Spilled Material							
Skimming	X		X	X			X
Vacuuming		X			X		X
Sorbents	X	X	X	X	X	X	X
Removal/Cleanup							
Removal (of contaminated substrate)	X	X			X	X	
Cleaning (of contaminated substrate)	X	X			X		
Vegetation or woody debris removal	X	X	X			X	X
Flushing/flooding		X					
Non-Mechanical Countermeasures							
Dispersants[b]			X[c]	X	X		
In situ burning[b]	X	X	X	X	X	X	X
Bioremediation[b,d]	X		X	X	X	X	X
Other Response Actions							
Natural attenuation (with monitoring)	X	X	X	X	X	X	X
Actions Common to All Responses							
Reconnaissance, mobilization, and demobilization	X	X	X	X	X	X	X
Waste handling, treatment, and disposal	X	X	X	X	X	X	X

a The names of habitat types in this table are consistent with the definition of habitats in supporting documents of the Unified Plan but are not necessarily consistent with the names of EFH used in FMPs.

b *In situ* burning and use of chemical or biological agents as part of the response action require prior approval.

c Not recommended for use in areas near protected resources (e.g., EFH, HAPCs); the current dispersant use guideline requires 10 fathoms [18 m] of water (ARRT, 2014).

d Bioremediation is not currently approved for use under the Unified Plan (EPA et al., 2010), but bioremediation agents are included as approved on the NCP product schedule.

3 Potential Effects of Response Actions on EFH and Managed Species

This section discusses impacts that could reasonably be expected to occur as a result of implementation of a spill response action. The duration and magnitude of these potential impacts are meant to be qualitative rather than quantitative. In addition, although information regarding potential impacts of the various response actions is available, quantitative impact analyses for the various response actions are not always available.

The underlying assumption for any response action is that in the event of a spill, the implementation of a response action would provide greater protection for sensitive resources than the baseline condition (i.e., no response to spilled materials). Decisions made during an emergency spill response are focused on protecting and reducing risks to humans and environmental resources, including but not limited to EFH and managed species, from exposure to a spilled material. During an emergency spill response, the Services identify known locations of sensitive habitats (e.g., known spawning areas) and then gather additional information to provide recommendations to the FOSC in order to avoid or minimize adverse impacts to managed fisheries and EFH from both the spill and the response activities. These recommendations are incorporated into the site-specific IAP agreed to and implemented by the Unified Command. Various programmatic and action-specific elements that are intended to mitigate or minimize adverse impacts to managed species and EFH are discussed in Section 5.[13]

The impacts are described in terms of their anticipated duration (i.e., temporary or long-term) and magnitude (i.e., low or high). For the purpose of this EFH assessment, the terms used to describe duration and magnitude are defined as follows:

- Duration
  - **Temporary –** Impacts last only for the duration of the response action or for less than a year beyond the cessation of the response action.
  - **Long-term –** Impacts last for more than a year beyond the time of the response action (including permanent impacts).
- Magnitude
  - **Negligible –** No change in a managed species or resource (e.g., food, refuge, spawning habitat, migratory corridor) condition is anticipated.

[13] Additional information related to the mitigation of adverse impacts to ESA-listed fish is provided in the BA (Windward and ERM, 2014).

- **Low –** A change in a resource (e.g., food, refuge, spawning habitat, migratory corridor) condition is unlikely to result in measureable changes in local populations of managed species.
- **High –** A major change in a resource (e.g., food, refuge, spawning habitat, migratory corridor) condition is expected to result in measurable changes to EFH or local populations of managed species.

It is important to note that response activities will have a gradient of potential effects in terms of both duration and magnitude, depending on various factors such as the life stage, specific sensitivities or vulnerabilities to various stressors, the type of hazardous material spilled, the season and location of the spill, and the nature and scale of the response action. The durations and magnitudes defined in this section are intended to be qualitative rather than quantitative descriptors of potential impacts.

Table 3-1 provides a summary of the potential effects of spill response actions on EFH. Measures that can be implemented to mitigate or minimize the potential impacts of spill response actions are discussed in Section 5.

Table 3-1. Response actions, components, and effects

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent
Mechanical Countermeasures			
Deflection/Containment			
Booming	deployment, maintenance, and anchoring of booms	possibly reduced access to shallow resources (e.g., forage, refuge/nursery, or spawning habitat) while deployed; destruction of shallow benthic habitat/organisms by anchors while deployed; possibly restricted movement of salmon in freshwater while deployed	temporary, localized, and low-magnitude impacts in shallow areas; negligible impacts in waters deeper than hanging curtains (or "skirts");[a] potential high impacts in freshwater habitats, particularly if migration, feeding, spawning, or rearing are interrupted through physical exclusion by booms and boom skirts (limited to areas of very shallow water (i.e., <18 in); localized indirect impact associated with destruction of shallow benthic habitat/organisms during anchor deployment
Berming, pits, trenching, or underflow damming	use of heavy equipment or manual construction; placement or excavation of earthen structures	potential disturbance or destruction of habitat when used on shorelines; potential loss of aquatic organisms (including vegetation) from compaction or sedimentation/smothering of invertebrate burrows; potential blockage of fish passage from berming across streams (to contain a marine spill before entering streams)	temporary, localized, and low-magnitude impact on shoreline and terrestrial inland habitats and associated soil and sediment invertebrate communities (i.e., aquatic prey); potential high-magnitude impact on habitat and degradation if mitigation measures not implemented (e.g., avoidance of sensitive habitats such as mudflats, eelgrass, or kelp beds); potential high-magnitude impacts if migration is blocked by berms or dams; disturbance of upland soil and vegetation, resulting in sedimentation of freshwater spawning habitat and reducing reproductive success of salmon (high-magnitude impact)
Culvert blocking	placement of blockage (e.g., plug, weir gate), replumbing of outlet	alteration of hydrology while culvert is blocked; obstruction to migration (or general movement) while culvert is blocked	temporary, low-magnitude impact unless implemented during anadromous salmon migration, in which case magnitude would be high
Recovery of Spilled Material			
Skimming or vacuuming	deployment and operation of skimming/vacuuming equipment	entrainment of shallow plankton (e.g., early life stages of several species) in skimmer/vacuum while in operation	although individuals could be impacted, EFH would not likely be impacted; potential low-magnitude impact in freshwater streams and negligible impacts on shorelines; however, vacuuming in sensitive freshwater habitats (e.g., vegetated shorelines, mudflats, wetlands) could result in high-magnitude impacts

Table 3-1. Response actions, components, and effects

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent
Sorbents	placement and use of sorbent materials (e.g., pads, rolls, beads); maintenance of sorbent materials; anchoring	potential disturbance of intertidal habitat and minor destabilization of shoreline or benthic habitat while being placed or anchored on shoreline; possible destruction of aquatic vegetation while being placed or anchored; slight shading effect	localized and short-term action resulting in temporary, low-magnitude impacts (e.g., minor habitat alteration); impact on habitat degradation could be high if mitigating measures not implemented (e.g., careful placement, avoidance of aquatic vegetation); use of sorbent materials in open water likely to have negligible impacts on fisheries (relative to the baseline condition)
Removal/Cleanup[b]			
Removal	removal of contaminated sediment or soil (potentially with backfill of clean material)	severe disturbance of infaunal community and benthic habitat (i.e., prey resource); possible destabilization of soil or sediment; possible destruction of aquatic and terrestrial vegetation	temporary indirect impact caused by intertidal habitat destruction; the duration of indirect impact would be dependent on species present (Peck et al., 1999);[c] indirect impact caused by habitat destruction likely negligible relative to baseline; high-magnitude direct impacts could result if removal carried out on spawning beach; (spatially restricted to areas of removal action); disturbance of upland soil and vegetation could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)
Cleaning	on-scene processing of sediment that removes oil/tar balls and return of cleaned material to beach	habitat disturbance; erosion from foot and vehicle traffic; possible destruction of aquatic vegetation	temporary indirect impact caused by intertidal habitat destruction; duration of impact would depend on the species present (Peck et al., 1999);[c] impacts of habitat destruction would likely be negligible relative to baseline but could be high (e.g., if mitigating measures not implemented); spatially restricted to area of sediment cleaning
Vegetation or woody debris removal	removal of aquatic or shoreline vegetation or woody debris	potential for loss of forage, refuge, or spawning habitat (aquatic vegetation) if conducted in certain areas (e.g., eelgrass beds); possible destabilization of shoreline or benthic habitat through removal of vegetation or compaction of sediment, resulting in sedimentation of intertidal and nearshore habitat	temporary, low-to-negligible indirect magnitude impact caused by intertidal habitat degradation; duration of impact would depend on species present (Peck et al., 1999);[c] impacts of habitat destruction could be severe (e.g., if mitigating measures not implemented); spatially restricted to area of debris removal; disturbance of upland soil and vegetation could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)
Flushing/flooding	remobilization of oil for collection	physical displacement of benthic organisms or vegetation; thermal stress and mortality of aquatic organisms if heated water or steam is used	temporary, low-magnitude indirect impact to managed species and EFH caused by intertidal habitat degradation (e.g., mortality of intertidal invertebrates and vegetation); spatially restricted to area of flushing/flooding; magnitude of impacts generally determined by heat of water used (ambient water temperatures result in the lowest-magnitude impacts)

Table 3-1. Response actions, components, and effects

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent
Non-Mechanical Countermeasures			
Dispersants	application of chemical agent	temporary degradation of water quality; short-term change in prey base from potential toxicity; acute and chronic exposure to petroleum constituents due to changes in solubility/bioavailability of oil components; acute exposure to components of dispersants; exposure to oil components would increase between 1 and 10 m in the water column relative to the baseline condition	temporary impacts to shallow EFH (between 0 and 10 m in depth) through the addition of chemical dispersants and the subsequent increase in oil droplets and dissolved oil components in the water column; direct impacts on individuals of managed species present following a spill from increased concentrations of dissolved toxic components of oil, resulting in high-magnitude impact (i.e., significant mortality of individuals of sensitive species or at sensitive life stages) or significant sublethal impacts (also potentially resulting in high-magnitude impacts relative to the baseline condition); more individuals could be impacted due to the chemical dispersion of oil to 10 m rather than the physical mixing of oil to 1-m depth; impacts on EFH could therefore be of a high magnitude, although due to the limited duration of exposure, impacts would not likely result in long-term effects on populations of managed species; indirect impacts on EFH (i.e., mortality of prey species) could similarly be of a high magnitude, although temporary
In situ burning	use of accelerants and ignition materials; burning	deposition of dense burn residues in benthic habitat and suspension of less-dense residues in water column (i.e., habitat degradation); thermal destruction of very shallow (i.e., within 5 in. of surface) planktonic species (Evans et al., 1988; cited in NMFS, 2003)	localized mortality caused by thermal impacts within very shallow but highly productive ocean surface community, potentially including some early-life-stage individuals within protected fisheries; likely to be of low magnitude to fisheries overall, as well as of short duration; burn residue impacts uncertain but could be long term and of low magnitude (depending on the extent of exposure of individuals); likely to be of low magnitude to fisheries overall; although residues are distributed over a broad area, exposures likely to be localized at discrete locations (e.g., at the point of deposition of a residue).
Bioremediation	application of biological organisms to consume the oil or fertilizers to stimulate biodegradation by the natural microbial community	bioactivity may deplete oxygen from the water; possible uptake and concentration of petroleum constituents into marine food chain (although this is consistent with the baseline condition)	magnitude and extent of impacts unclear due to a lack of representative testing; however, available evidence suggests that impacts would be negligible (Prince et al., 2003)

Table 3-1. Response actions, components, and effects

Response Action	Component	Potential Effects on EFH or Managed Species	Potential Magnitude and Extent
Other Response Actions			
Natural attenuation (with monitoring)	long-term monitoring	shoreline habitat disturbance (e.g., sediment compaction, erosion from truck or foot traffic)	low-magnitude long-term impacts caused by sedimentation/smothering of intertidal and nearshore habitat; localized at points of access to shorelines or streams; disturbance of upland soils and vegetation from compaction or erosion could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)
Actions Common to All Responses			
Tracking/ monitoring and mobilization/ demobilization	mobilization of equipment and personnel to and from the site; collection of relevant environmental media	shoreline habitat disturbance (e.g., sediment compaction, erosion from truck or foot traffic)	potential low-magnitude impacts from sedimentation/smothering of intertidal and nearshore habitat (localized at points of access to shorelines); disturbance of upland soils and vegetation from compaction or erosion could result in sedimentation of freshwater spawning habitat, reducing reproductive success of salmon (high-magnitude impact)
Waste handling, treatment, and disposal	collection, storage, and removal of contaminated media (e.g., soil, sediment, debris); decontamination of vessels/vehicles; oil/water separation and treatment	shoreline habitat disturbance (e.g., sediment compaction, erosion from truck or foot traffic)	impacts likely to be negligible relative to the baseline condition; storage of wastes prior to disposal in temporary, permanent, or semi-permanent storage fixtures (e.g., tanks) on soil near aquatic habitat could result in compaction of soil and erosion; small amounts of material could be released as a result of decanting or improper handling.

[a] Skirts can be up to 60 inches in water depth (or "draft") but tend to be < 18 inches; longer skirts can be used in quiescent waters, whereas shorter skirts are intended for use in flowing waters (e.g., marine habitat) (Alyeska Pipeline Service, 2008).

[b] Removal and cleanup response action alternatives are limited to shoreline and upland terrestrial habitats (e.g., intertidal habitat), so these actions will not have an impact on offshore areas within protected EFH.

[c] Peck et al. (1999) observed that the re-establishment of benthic invertebrate species after a catastrophic disturbance (iceberg-driven scour event) occurred after a 10 days for several pioneering species (e.g., amphipods, isopods), whereas less-mobile, larger and longer-lived species (e.g., large bivalves), although present after 100 to 250 days, did not significantly recolonize nearshore habitat by the end of the 250-day study.

EFH – essential fish habitat

3.1 MECHANICAL COUNTERMEASURES

This section describes the various mechanical countermeasures that can be implemented as part of a spill response action. The habitat types in which mechanical countermeasures can be implemented are provided in Table 2-1.

3.1.1 Deflection/containment

The purpose of deflection is to control the flow of oil into sensitive habitats such as coastal wetland, shoreline, intertidal, nearshore, or subtidal habitats or freshwater streams. Containment is similar to deflection, although the primary purpose is to control the movement of oil so that it can be more easily recovered through mechanical means (if possible).

It is assumed that under most circumstances, the deflection and containment of hazardous materials will result in minimal impacts to EFH relative to the unobstructed movement of hazardous materials, such that a response to contain or deflect those materials from sensitive habitats will have a beneficial effect on managed fish and invertebrates or their prey relative to the baseline condition. Under certain circumstances (e.g., hazardous material has already impacted soft sediment, coastal marshes, aquatic vegetation, or other sensitive habitats), deflection or containment actions may result in the increased permeation of contaminants into sediment and a longer-term impacts to associated habitats.

Booming

Booming in shallow marine habitats (e.g., nearshore, intertidal or subtidal waters) or in freshwater habitats may require the use of anchors to maintain the optimal positioning of booms implemented to deflect or contain hazardous material at the water's surface. Anchoring in soft sediment, mudflats, or other sensitive substrates may result in the localized degradation of benthic habitat through scouring, smothering, and otherwise physically disturbing the sediment. If booms are anchored during inclement weather (e.g., strong wind and wave action), anchors may drag through sediment, causing more severe impacts to soft substrates. It is expected that demersal species (or life stages) of fish and invertebrates use benthic and epibenthic habitats for forage, refuge (e.g., vegetated nursery habitat), and/or spawning (e.g., sculpin nesting) (NMFS, 2011a, 2012a, 2013a, b, 2014; NPFMC, 2009a). The degradation of benthic habitat could result in reduced prey availability in the immediate vicinity of anchoring, which would attenuate over time as the disturbed benthic community matures. The recolonization and recovery of benthic communities in northern regions to pre-disturbance conditions could require many years (Peck et al., 1999; Conlan and Kvitek, 2005), indicating a long-term impact. Recolonization by some species could be rapid (Peck et al., 1999), depending on the season. For example, disturbance during the spring could result in impacts that would last longer than those from disturbance during the summer (Herkül et al., 2011), potentially resulting in a temporary impact (i.e., months rather than years until recovery). Based on the range of potential responses by the benthic community to disturbances from anchoring, it is difficult to assess the general magnitude of impacts from anchoring. Due to the small area that would be affected by anchoring, it is expected that any impacts to EFH or managed species would be temporary and of low magnitude.

Booms equipped with hanging curtains may provide a barrier to movement or migration if placed in inappropriate locations (e.g., shallow mouths of creeks). For example, deploying booms in very shallow water (e.g., < 18 in deep), where the boom and curtain extend across the entire depth of the water column, could make the water impassible for fish or invertebrates. Exclusion from preferable forage, refuge, or spawning habitat could occur in extreme cases (resulting in reduced feeding and growth, increased predation, and impeded reproductive behavior and success) (NMFS, 2003). NMFS (2003) suggested that even shallow booming across the mouth of anadromous spawning streams could have significant impacts on salmon species. These impacts could be of low to high magnitude, depending on the location and season of boom deployment. Impacts would be temporary, lasting only as long as the booms were in place. Using proper boom curtain lengths (or no curtain at all, if conditions allow) could mitigate any potential exclusion of managed species from EFH by allowing fish and invertebrates to navigate around boom equipment. In the case of migrating and/or spawning salmon, proper boom placement and orientation could mitigate potential impacts caused by placing booms across stream mouths. For example, the use of more than one boom (e.g., in a "fixed cascaded array") (Nuka Research, 2006) could divert oil away from sensitive areas without obstructing migration into or out of streams.

Neustonic or shallow-dwelling nektonic managed species or prey could be constrained by booms with shorter curtains. Individuals that are restricted by booms and curtains could be exposed to crude oil trapped within the containment equipment (rather than excluded from the crude oil). However, it is assumed that the number of individuals contained within the booms will be far fewer than the number exposed to an unconstrained oil spill in the absence of booming or other containment. Furthermore, the exposure of neustonic or shallow-dwelling nektonic species to concentrated crude oil is consistent with the baseline condition.

Deploying booms in nearshore and shoreline habitats as well as in freshwater streams could result in minor alterations in hydrologic dynamics, causing temporary and localized changes in water temperature, the concentration of suspended sediment (NMFS, 2003), and sediment transport (e.g., deposition of sediment) as well as related parameters (e.g., dissolved oxygen). Minor changes in water quality can have a high-magnitude impact on early-life-stage salmon (i.e., egg, alevin, fry, and smolt) (Lloyd, 1987; Thomas et al., 1986; Brett, 1952) and their prey (Nebeker et al., 1992; Alabaster, 1988; Lowell and Culp, 1999). High-magnitude impacts could also affect other anadromous fish (e.g., eulachon) or those that reside in shallow, nearshore (e.g., intertidal) habitat at sensitive life stages (e.g., Pacific sand lance [*Ammodytes hexapterus*], capelin [*Mallotus villosus*]).

Any foot traffic that occurs in freshwater streams during boom deployment could result in the disturbance of salmon or eulachon spawning habitat or forage habitat (e.g., mudflats) (NMFS, 2003). Impacts would likely be localized, although the disturbance of spawning habitat at certain times of the year (i.e., during embryonic development) could have direct impacts on early-life-stage anadromous fish (NMFS, 2003). Therefore, depending on the location and season of boom deployment in anadromous streams, impacts could be of low or high magnitude. The duration of impacts would likely be temporary, limited to the duration of foot traffic in streams. This assumes that foot traffic would not result in a significant alteration of freshwater habitat, such as significant sedimentation, the removal of riparian vegetation, or the removal of large woody debris or other stream structural elements.

According to NOAA (1994a, b), booming has a low-magnitude impact in aquatic habitats.

Berms, Pits, Trenches, or Underflow Dams

The use of berms, pits, and/or trenches to contain spilled material generally requires the deployment of heavy machinery. The use of heavy machinery in upland areas can result in the loss of upland vegetation and the compaction and runoff of soil (EPA, 1992), potentially leading to sedimentation and the smothering of benthic communities in intertidal habitat or spawning habitat (e.g., for salmon redds) in freshwater streams. Foot traffic to and from containment areas and equipment can also contribute to compaction. Soil and sediment erosion can be mitigated or minimized through the use of geotextiles or silt curtains to trap soil or resuspended sediment (EPA, 1992). Compaction can be mitigated or minimized through the placement of plywood or other materials that help to distribute weight over a broader surface (Nuka Research, 2006).

The use of berms, pits, and/or trenches on sea ice is unlikely to result in similar impacts. Physical barriers and berms could have a high-magnitude impact in small rivers or streams but would likely have negligible or low-magnitude impacts elsewhere (e.g., sediment instability) (NOAA, 1994a, b).

The use of damming as an option to block the flow of hazardous materials into sensitive aquatic habitats (e.g., freshwater streams) could exclude fish and invertebrates (and their prey) from entering or exiting dammed areas that contain EFH (e.g., nearshore, intertidal, and subtidal spawning, rearing, forage, and refuge habitats). If dams are constructed during periods of spawning or migration, these impacts could be significant. For example, migration could be halted and spawning might not be possible. For this reason, dams should be constructed to protect sensitive habitat (e.g., anadromous fish streams) from contamination and removed once there is no longer a threat of contamination (Nuka Research, 2006).

The use of earthen barriers in the terrestrial environment away from freshwater or coastal environments will not result in adverse impacts to managed species or EFH.

Culvert Blocking

Culvert blocking consists of plugging, blocking, or partially covering culverts downstream of a hazardous material spill. Any action that completely blocks or plugs a culvert could restrict the flow of water to freshwater streams, resulting in altered hydrology and/or biogeochemistry (e.g., flow, nutrient delivery) as well as the interrupted migration of fish or invertebrates. One option would be to only partially block a culvert, which would contain hazardous material while allowing for fluid and nutrient transport as well as migration. In addition, culvert blocking might require additional foot traffic and/or the use of heavy equipment, which could result in the compaction of sediment, destruction of vegetation, and sedimentation of freshwater streams or coastal habitat (EPA, 1992).

As with dams, any culvert blocking, plugging, or covering should be removed once there is no longer a threat of contamination (Nuka Research, 2006) because the exclusion of upstream and downstream migration of certain species (particularly salmon and eulachon) could result in high-magnitude impacts (e.g., interrupted spawning).

3.1.2 Recovery of spilled material

Skimming/Vacuuming

Skimming and vacuuming are two potential methods for recovering spilled material from the surface of water (or when pooled in upland habitat). Skimmers and vacuums are generally attached to heavy machinery, the use of which, along with the additional foot traffic, could cause the sedimentation of aquatic habitat (EPA, 1992).

Because skimmers and vacuums draw up floating material (i.e., contamination) and water in large quantities, it is possible that small fish or invertebrates could also be drawn into containment vessels. This would likely result in the mortality of managed fish or invertebrate individuals or their prey during sensitive life stages of through concentrated exposure to hazardous materials or physical damage from contact with the skimming equipment. In order to limit this potential impact, skimmers and vacuums are often equipped with mesh screens to exclude debris (or organisms) from being entrained in equipment (ITOPF, 2012). Some smaller individuals (e.g., plankton and neuston) in the immediate vicinity of skimmers or vacuums may pass through debris mesh and perish. For many species (e.g., salmon, demersal fish) the rate of encounter with skimmers or vacuums will likely be low, particularly in the marine environment where fish and invertebrates live in deeper waters and are widely distributed (NMFS, 2003).

Although individual fish may be impacted, EFH is not expected to be impacted by skimming or vacuuming. Skimming would likely have a low-magnitude impact in freshwater streams and a negligible impact on shorelines; however, vacuuming in sensitive freshwater habitats (e.g., vegetated shorelines, mudflats, wetlands) could result in high-magnitude impacts (NOAA, 1994a, b). Neither type of equipment will exclude fish or invertebrates from necessary resources, permanently alter habitat, or greatly reduce the supply of prey items. Allowing hazardous materials to remain on the surface of the ocean could result in the significant mortality of shallow, neustonic, and planktonic species that live near the surface of the ocean. The removal of hazardous materials through the use of skimmers or vacuums could be beneficial to managed fish and invertebrate species and their prey relative to the baseline condition.

The use of decanting equipment as a method for reducing the volume of waste produced during vacuuming or skimming could inadvertently reintroduce hazardous substances into the aquatic environment (NMFS, 2003), although the amount of material reintroduced would likely be much less than the amount that was originally removed that would have remained in the environment without the response action (i.e., baseline condition). Skimming or vacuuming conducted on sea ice is unlikely to have an adverse impact on managed species or EFH. Skimming or vacuuming under the sea ice would likely have impacts similar to those described above for other aquatic habitats.

The use of skimming/vacuuming in the terrestrial environment, away from freshwater or coastal environments, will not result in adverse impacts to managed species or EFH.

Sorbents

Sorbents are materials that, when placed in contact with hazardous materials, absorb or adsorb the materials as a means of removal. The placement of sorbents along shorelines or on the surface of open water may require the use of anchoring equipment. This equipment could adversely impact benthic habitat, particularly during inclement weather when winds could drag anchors through soft sediment). The placement of sorbent materials along shorelines could also exclude or hinder species that spawn in intertidal habitat (e.g., capelin, Pacific sand lance).

In addition, foot traffic in freshwater streams associated with the deployment of sorbents could disturb salmon or eulachon spawning or forage habitat (e.g., mudflats) (NMFS, 2003). Although, these impacts would likely be localized, any disturbance of spawning habitat at certain times of the year (i.e., during embryonic development) could have high-magnitude direct impacts on early-life-stage anadromous fish (NMFS, 2003).

Sorbent materials deployed over a broad area on the surface of open water could result in temporary, localized shading effects, which have been shown in some circumstances (such as under permanent overwater piers, docks) to adversely influence the foraging behavior of fish (NMFS, 2003). However, deploying sorbent materials that are constructed of translucent materials could minimize shading effects (NMFS, 2003).

Any major contamination of shorelines from a hazardous material spill could result in the significant mortality of early-life-stage forage fish (Lee et al., 2011), so the use of sorbents to partially contain hazardous materials is likely to result in less harm than would be expected under the baseline condition.

It is possible that heavy machinery would be required to deploy, reposition, and recover sorbents from aquatic or terrestrial habitats, and thus sedimentation (similar to that described for booming) could occur. The use of sorbents in the terrestrial environment, away from freshwater or coastal environments would likely result in negligible impacts to managed species or EFH.

The use of sorbents on sea ice would likely have no adverse impact on managed species or EFH. The use of sorbents under sea ice would likely have a negligible impact on managed species or EFH because none of the impacts listed in this section, above, apply to this type of habitat.

3.1.3 Removal/cleanup actions

Removal and cleanup actions are intended to minimize impacts of hazardous material spills on habitats by removing or cleaning the natural material that has been or is anticipated to be affected by the spill. For example, sediment and vegetation removal and cleaning and flushing/flooding are used to clean shorelines that have already been affected by a spill.

Removal of Substrate

The removal of substrate is one option for remediating shorelines, freshwater streams or lakes, terrestrial habitats, or sea ice that have been affected by a hazardous material spill. The removal of sediment could temporarily impact a small number of managed species that spawn along shorelines (e.g., capelin, Pacific sand lance). If sediment were to be removed between spawning and the hatching of fish or invertebrates, large numbers of early-life-stage individuals could be inadvertently destroyed. However, this impact would likely be negligible as compared with that of the baseline condition. Allowing the sediment to remain in place would likely result in the chemical disturbance of the community, which could also have lasting impacts on benthic communities from chronic exposure to hazardous materials (Humphrey et al., 1987a; Peterson et al., 2003). It is not known whether the removal of sediment, and subsequent destruction of benthic habitat, would result in incrementally greater short-term impacts on EFH than those expected if the hazardous materials were to remain in place (i.e., baseline condition or natural attenuation). Recovery from physical disturbance is a natural process that could require several years (Peck et al., 1999; Herkül et al., 2011), whereas the chronic exposure to hazardous materials associated with baseline condition could affect a larger number of species over a longer period of time (i.e., population and community-level toxic responses rather than localized physical disturbance) (Peterson et al., 2003). Therefore, it is likely that the impact of substrate removal (when used appropriately) would be negligible (or beneficial) compared with the baseline condition.

The replacement of contaminated sediment with clean sediment could help to restore a shoreline's stability, although any placement of large volumes of sediment would need to be executed carefully as to avoid the burial of benthic habitat, which could also result in the significant disturbance of infaunal communities (Lake, 2000).

The removal of upland soil through the use of heavy machinery or hand tools could result in the increased sedimentation of intertidal or freshwater habitat (EPA, 1992). The removal of sea ice is not expected to have an adverse impact on managed fish or invertebrate species.

Cleaning of Beaches

The cleaning of beaches, which involves the use of heavy machinery and/or hand tools to remove small amounts of sediment, is a less invasive option for the removal of spilled material from shorelines than the removal of large amounts of substrate. The impacts of beach cleaning would be the same as those identified for the removal of substrate (above), although the severity of habitat disturbance would likely be less due to the fact that only small amounts of sediment would be removed, whereas the removal of substrate response action would involve the excavation or removal of large quantities of sediment.

Vegetation/Debris Removal

Vegetation removal involves the cutting and removal of aquatic or upland vegetation that has been affected by a hazardous material spill. Both the root structures of plants and the presence of large woody debris contribute to sediment and soil stability, so the complete removal of vegetation (e.g., including the roots) would likely result in the increased sedimentation of intertidal and freshwater habitats (NMFS, 2003). Limiting the removal of aquatic plants to the stalks, fronds, and/or leaves (i.e., leaving the roots intact) could mitigate or minimize this impact.

Vegetation is also an important component of nearshore and intertidal habitats; eelgrass and kelp provide refuge, spawning substrate for various managed or otherwise ecologically important fish and invertebrate species (e.g., Pacific herring [*Clupea pallasii*], and forage habitat for other species (e.g., Atka mackerel [*Pleurogrammus monopterygius*]) (NMFS, 2013a). The removal of vegetation could have high-magnitude impacts in freshwater habitats and vegetated shorelines (NOAA, 1994b) that could potentially last up to 2 years (NOAA, 1994a).

Debris removal involves the removal of woody debris (i.e., driftwood, downed trees) that has been or is anticipated to be affected by hazardous materials spills from shorelines or freshwater habitats in order to minimize the exposure of fish and other species to those hazardous materials. The removal of large woody debris from shorelines or freshwater habitats could result in the sedimentation of spawning habitat, altered hydrology, or reduced in-stream complexity[14] in freshwater habitat (NMFS, 2003). Woody debris in the nearshore or freshwater habitat is used by fish and invertebrate prey species, and the loss of this debris could result in a marginal decrease in available prey. The impact of debris removal on aquatic and shoreline habitats would be low or negligible (NOAA, 1994a, b).

The removal of contaminated vegetation or debris from the terrestrial environment, away from freshwater or coastal environments, would not result in adverse impacts to managed species or EFH.

Flushing/Flooding

The flushing or flooding of shorelines involves the use of large volumes of water to flush and remobilize the hazardous materials resulting from a spill from the shoreline so that it can be collected in booms and recovered rather than left in place. The process of using large volumes of water to wash the sediment can also mobilize the sediment and result in the sedimentation of intertidal habitat (NOAA, 1994a). Depending on the sediment type, this would likely have a temporary, negligible to low- magnitude impact (e.g., impacts on sand/gravel shorelines would be of low magnitude) (NOAA, 1994b). However, the flushing or flooding of spawning beaches could disturb early-life-stage individuals (e.g., capelin, Pacific sand lance), resulting in a high-magnitude impact.

In addition, if the water used in the flushing or flooding process is warm, significant stress, disturbance, or the mortality of aquatic organisms in the immediate vicinity of the response action could result (NOAA, 1994a). The use of ambient water temperatures would minimize or eliminate these impacts (Nuka Research, 2006), although warm water flushing would likely be more effective in removing certain materials (e.g., crude oil) (NOAA, 1994a).

3.2 Non-Mechanical Countermeasures

This section describes the various non-mechanical countermeasures that can be implemented as part of a spill response action. The habitat types in which non-mechanical countermeasures can be implemented are provided in Table 3-1.

[14] Habitat complexity is equivalent to a greater amount of potential refuge and microhabitat, leading to more stable and diverse prey populations (Heck and Wetstone, 1977; Gorham and Alevizon, 1989; Butler, 1988; Quinn and Peterson, 1996).

3.2.1 Application of dispersants

Chemical dispersants (i.e., Corexit® products), [15] are mixtures of solvents and surfactants that have been developed to interact with crude oil in a marine setting (NRC, 2005). Chemical dispersants are specifically intended for use in saltwater environments (rather than freshwater streams or lakes) and deeper waters (rather than nearshore, intertidal or subtidal habitats) (NRC, 2005). The addition of chemical dispersants alters the interaction of crude oil with sea water by facilitating the formation of oil droplets, which then disperse into the water column (NRC, 2005). Dispersion is intended to reduce the amount of oil that rests at the ocean surface, thereby protecting sensitive shoreline and estuarine habitats, as well as human and environmental health, and increase the rate of biodegradation (NRC, 2005). Additional information regarding dispersants including a detailed evaluation of potential effects of dispersants on EFH is provided in Appendix A.

The distribution of dispersants and dispersed oil in a water column would likely be limited by density and salinity gradients to the upper 10 m of the water column (NRC, 2005; NOAA, 2012b). Fish and invertebrate species present within this depth range could be exposed to dispersants or dispersed oil following a response action depending on the season of deployment. The likelihood of such an exposure is presented in Appendix A.

Fish and invertebrates would most likely be exposed to chemical dispersants and chemically dispersed oil during sensitive, early life stages (e.g., as eggs or planktonic larvae). Exposures to dispersed oil would likely be greater than exposures to untreated crude oil (Ramachandran et al., 2004; Milinkovitch et al., 2011a; Milinkovitch et al., 2011b) because chemical dispersants increase the concentration of oil (as droplets) in the water column (NRC, 2005) as well as the solubility of the components of oil (e.g., PAHs) (Yamada et al., 2003). Although acute toxicity tests have shown that chemically dispersed oil is generally less toxic than crude oil (Appendix A), sublethal impacts associated with PAH exposures (e.g., abnormal growth, reduced reproduction, increased oxidative stress, deoxyribonucleic acid [DNA] damage, community-level responses in plankton) (Payne et al., 2003; Jung et al., 2009; Ordzie and Garofalo, 1981) could be increased by chemical dispersion (Lee et al., 2011).

The seasonal presence of early-life-stage individuals in the upper water column at the time of dispersant application would likely influence the magnitude of impacts on specific species (for example, if shallow-dwelling eggs or larvae were not present during the season that oil is spilled, there would be no exposure). At least one managed species would likely be present in shallow habitat during all seasons of the year (NMFS, 2014, 2013b, a, 2012a, 2011a). Thus, the time of year (i.e., season) would

[15] Corexit® 9500 is currently stockpiled for future use as an oil spill countermeasure in Alaska, and Corexit® 9527 is also approved for use in Alaskan waters; stockpiles of the latter dispersant formulation were largely exhausted during the Deepwater Horizon oil spill incident. No other chemical dispersant is currently approved for use in Alaska.

not preclude the exposure of all managed species. Second, Alaska experiences extreme solar conditions (e.g., up to 24-hours of full sun), particularly in polar areas. The toxicity of PAHs, which are made more bioavailable through the application of chemical dispersants, is increased through ultra-violet (UV) exposure (Barron and Ka'aihue, 2001; Barron et al., 2008; Almeda et al., 2013). Many plankton and early-life-stage fish and invertebrates are translucent, so there is a greater likelihood of photo-enhanced toxicity to those individuals.[16]

The potential for PAHs to induce olfactory impairment in homing fish species (e.g., salmon) does not appear to have been studied; however, Brannon et al. (1986) reported that Chinook salmon exposed in the laboratory to Prudhoe Bay crude oil at concentrations similar to those documented in actual spills returned to the hatchery at the same frequency and time as did the control fish (i.e., fish that were not exposed to crude oil). This suggests that the crude oil does not cause olfactory impairment in salmon or that the combination of the exposure concentration and duration did not preclude the olfactory neurons from recovering. Thus, it is unknown whether chemically dispersed oil would interact with fish homing abilities.

Impacts to prey species (e.g., plankton) from an exposure to chemically dispersed oil could initially be of high magnitude (e.g., mortality of the most sensitive species, altered reproduction and/or community structure) (Lee, 2013; Scholten and Kuiper, 1987; Harrison et al., 1986; Zhang et al., 2013) but then decrease. At least one species of copepod has been reported to selectively avoid droplets of dispersed oil (Abbriano et al., 2011). Communities of plankton could be rapidly replenished by individuals from outside of the affected area (Abbriano et al., 2011) or be resistant to long-term effects of crude oil spills for various reasons (e.g., season of spill and rate of plankton biomass production) (Varela et al., 2006). Similarly, benthic species, which could be exposed to dispersed oil/oil-mineral aggregates in intertidal habitats, could metabolize or otherwise eliminate the oil within a year or 2 (Humphrey et al., 1987a; Cross and Thomson, 1987; Mageau et al., 1987). According to Abbriano et al. (2011) and Varela et al. (2006), prey items present in the shallow water column could be impacted by the application of chemical dispersants, but those impacts would be temporary.

Of the 85 managed species identified in the various FMPs (Table 1-1), 72 could potentially be adversely impacted at an early life stage (i.e., as eggs, larvae, or early juveniles) by chemically dispersed oil (Appendix A). The impact on individual planktonic or benthic prey species could be of high magnitude, but the impact on the overall prey base (as a component of EFH) would likely be temporary and of low magnitude relative to the baseline condition.

[16] This is a point of uncertainty in the analysis presented in Appendix A. The influence of UV irradiance on chemically dispersed oil toxicity has not been extensively studied.

It is important to note that neustonic or shallow-dwelling nektonic species, which could be the most impacted by chemically dispersed oil, would likely be exposed to crude oil under the baseline condition, potentially resulting in adverse impacts.

3.2.2 *In situ* burning

In general, fish and invertebrates would not be directly affected by *in situ* burning because the transfer of heat through the water column (beyond approximately 5 in. in depth) would be retarded by the high specific heat[17] of water (Evans et al., 1988; NMFS, 2003). Several managed species of fish have neustonic or shallow-dwelling nektonic larvae (and prey) that may be present in the upper 5 in. of the water column during *in situ* burning. The magnitude of impacts to individual species would be determined by the season in which the *in situ* burning occurs (for example, if the larvae of specific species were absent from the neustonic/shallow nektonic community, no direct impact on those species would occur). Similarly, neustonic and shallow-dwelling nektonic prey species could be impacted by heat, although the mixing of the water column would likely result in a rapid recovery once burning had ceased (Abbriano et al., 2011).

Fish and invertebrates that feed near the water's surface or in the water column would not likely come into contact with burned oil residues in any substantial quantity. They would also not likely selectively consume residues from either the water column or the sea floor, inasmuch as these residues are not expected to resemble their prey species. In addition, fish and invertebrates would not be affected by the smoke produced during burning.

Given the short duration and limited scope of *in situ* burning, it is unlikely that there would be any permanent or lasting impacts on EFH, particularly at depths below 5 cm in the water column. Although burn residues could float in the water column and then sink to the sea floor, these residues will not be present in large quantities relative to the amount of oil associated with the baseline condition (NOAA OR&R, 2013). Impacts associated with burn residues include the potential smothering of benthic species (e.g., infaunal invertebrate prey items) (NOAA OR&R, 2013). Even if residues were to be consumed by fish or invertebrates in the water column (i.e., buoyant residues) or on the sea floor, residues are essentially non-toxic (NOAA OR&R, 2013) and less toxic than unburned oil (Faksness et al., 2011; Sheppard et al., 1983).

Thus, *in situ* burning would have a negligible impact on pelagic EFH, although low-magnitude, long-term impacts to benthic habitat (e.g., localized smothering of benthic habitat by broadly distributed residues) could occur (NOAA OR&R, 2013).

[17] Specific heat is the amount of energy required to increase the temperature of a volume of material. A material with high specific heat such as water requires more energy to increase in temperature than other materials (e.g., rock).

3.2.3 Bioremediation

Bioremediation is the chemical enhancement of biodegradation (e.g., through the addition of fertilizers) and/or the addition of microbial inoculum. Biodegration is a natural process that involves the partial or complete degradation of oil (or other biodegradable materials) in soil, sediment, or water by microbes (Atlas and Hazen, 2011). Biodegradation is expected to occur to some extent under all spill response actions (including the natural attenuation alternative). The focus of this section is to identify potential impacts to EFH associated with the chemical or biological enhancements of biodegradation. Bioremediation is not currently an approved non-chemical response action for Alaska, but several products have been approved for use at the federal level (i.e., listed on the NCP product schedule).

The most common method of bioremediation is the addition of chemical fertilizers that stimulate microbial growth in order to speed the natural biodegradation process (NOAA, 1994a, b; Prince et al., 2003). By increasing the level of biological activity in the water column, microbes can consume large percentages of the available oxygen supply dissolved in water (or in pore spaces of other media) (Atlas and Hazen, 2011; Kessler et al., 2011), although the testing of bioremediation agents has shown that hypoxia does not result from fertilizer applications (Atlas and Hazen, 2011; NOAA, 1994a). Because hypoxia did not occur as a result of fertilizer application (Atlas and Hazen, 2011; NOAA, 1994a), no significant impacts to fish and invertebrates related to hypoxia (Nebeker et al., 1992; Alabaster, 1988; Lowell and Culp, 1999) would be expected.

Other potential bioremediation agents include foreign microbial inocula (often accompanied by a nutrient source), which provides microbes that are known to biodegrade petroleum products (e.g., crude oil); the application of these agents is sometimes referred to as "seeding" (NOAA, 1994b). The impact of seeding is not well understood, although there is evidence to suggest that this method is not always useful (Prince et al., 2003). Specifically, natural microbial communities (which are adapted to the conditions in which they live) rapidly shift in dominance to species that can metabolize new sources of carbon (e.g., petroleum) after they are introduced into the environment (Hazen et al., 2010; Atlas and Hazen, 2011; Baelum et al., 2012); also, non-native cultures tend to be outcompeted by native cultures, and so are unable to survive for long periods following seeding (Prince et al., 2003). There is little evidence to indicate that seeding is more successful than the stimulation of native cultures (Prince et al., 2003). The ecological impacts of seeding are not well understood (NOAA, 1994b).

3.3 OTHER RESPONSE ACTIONS

For the purpose of this EFH assessment, and consistent with the BA (Windward and ERM, 2014), this category includes a single "action," natural attenuation. The natural attenuation "action" involves taking no action other than spill tracking and monitoring (Section 3.4.1) and is expected to result in impacts consistent with the baseline condition. The selection of natural attenuation as a response action is typically reserved for situations in which sensitive habitat will be incrementally impacted by any mechanical or non-mechanical cleanup response action or because the spill is in a remote location (NMFS, 2003; NOAA, 1994b, a; NRC, 2014). For example, attempts to remove contaminated sediment from coastal wetlands or mudflats could force the contamination deeper into the sediment (NRC, 2005), and the removal of contamination from remote, Arctic regions could result in greater physical damage to shoreline habitats (NRC, 2014).

3.4 Actions Common to All Responses

This section describes the actions that are common to all response actions (including the selection of a natural attenuation alternative). Table 3-1 provides a summary of these actions and their potential effects.

Inland spills of hazardous material that occur away from aquatic habitats would likely have a negligible impact on managed fish or invertebrate species or EFH, and actions common to responses conducted for inland spills (Sections 3.4.1 through 3.4.3) would also have a negligible impact on managed species or EFH.

3.4.1 Spill tracking/monitoring

Spill tracking or monitoring is used to determine the size, shape, and trajectory of a spill, as well as the resources required to appropriately control the spilled material so as to reduce its ecological and economic impacts. Nuka Research (2006) identifies two tracking tactics: plume delineation on land and discharge tracking on the water. Tracking or monitoring actions could involve land transport, boat, or aerial surveillance. The location of a plume can be validated through the use of monitoring equipment (e.g., photo ionization detection). To monitor spills in deep soil, excavation equipment could be required.

Aerial surveillance and the deployment of tracking equipment would not likely have a marked impact on managed fish species. The deployment of equipment on land could result in the compaction of soil and runoff (NMFS, 2003), which could be minimized through the use of existing roads or the establishment and use of identified routes to and from deployment areas. The excavation of soil to monitor spills in upland areas may require some form of stormwater management (e.g., berms, geotextile barriers) in order to limit sedimentation (EPA, 1992). Sedimentation would result in low or negligible impacts to EFH and managed species, with the exception of freshwater spawning streams. The sedimentation of freshwater streams could result in a high-magnitude impact to salmon EFH through the degradation of the quality of spawning habitat. Impacts on individuals could also be of high magnitude if the sedimentation occurred during the egg and larval stages of salmon and eulachon.

The environmental benefit gained through spill monitoring and the timely adaptation to changing spill conditions would likely outweigh any impacts caused by tracking of monitoring efforts.

3.4.2 Mobilization/demobilization

The mobilization and demobilization of equipment, vessels, and personnel in order to implement response actions could result in impacts similar to those identified for tracking or monitoring (Section 3.3.1). Specifically, transport across soil may result in compaction and the erosion of soil into the aquatic environment (i.e., sedimentation) (NMFS, 2003). Sedimentation would result in low or negligible impacts to EFH and managed species, with the exception of freshwater spawning streams, which could result in a high-magnitude impact to salmon EFH through the degradation of the quality of spawning habitat. Impacts on individuals could also be of high magnitude if the sedimentation occurred during the egg and larval stages of salmon and eulachon. These losses could be minimized through the use of existing roads or the establishment and use of identified consistent routes.

Mobilization and demobilization associated with response actions, including the natural attenuation alternative, impacts are not expected to be incrementally greater than the baseline condition. The cumulative ecological benefits associated with tracking/monitoring, as well as mechanical and non-mechanical response actions would likely outweigh minor impacts caused by mobilization/demobilization.

3.4.3 Waste handling, treatment, and disposal

Waste handling, treatment, and disposal are components of almost all spill response actions. The potential impacts that could result from these actions would not likely result in impacts that would be incrementally greater than impacts under the baseline condition. For example, the accidental re-release of crude oil into terrestrial or aquatic environments during handling (including storage), treatment, or disposal would not have a significantly greater effect than allowing the oil to remain in the environment (i.e., baseline condition). In extreme cases, hazardous materials could be collected and removed from a less sensitive environment and then accidentally released into a more sensitive habitat, resulting in a more significant impact; however, such spills are not the intended result of spill response actions. Decanting is a waste handling and treatment action that is used to minimize waste production (NMFS, 2003) and could result in the inadvertent release of relatively small amounts of hazardous material back into the environment without proper monitoring (NMFS, 2003). However, the volume of hazardous material released back into the environment under these circumstances would likely be significantly less than the volume of hazardous material that was originally spilled. Also, decanted water can be discharged into a containment boom to recover any inadvertently re-released hazardous materials.

The storage of hazardous material spill waste prior to disposal could require that temporary, permanent, or semi-permanent storage equipment (e.g., tanks) be placed on soil near aquatic habitats. The placement of this equipment, as well as any associated foot or vehicle traffic to and from the storage areas, could result in the compaction and/or erosion of soil and into aquatic habitats (i.e., sedimentation) (EPA, 1992). Sedimentation is expected to have a negligible or low impact on most aquatic habitats, although the sedimentation of anadromous streams could impact salmon EFH as well as individual salmon and eulachon (in the egg, larval, and/or juvenile life stages) in freshwater streams.

Given that the purpose of removing spilled hazardous materials from the aquatic or terrestrial environment is to minimize impacts related to the baseline condition, waste handling, treatment, and disposal would have a beneficial effect on the environment (including managed species and their EFH) as compared with the baseline condition.

4 Mitigation and Minimization Measures and Recommendations

During an emergency spill response, BMPs are implemented to minimize the impacts of spill response actions. It is ultimately the responsibility of the FOSC to ensure that BMPs are appropriately implemented (EPA et al., 2010). BMPs address the species life stage and habitat sensitivity to disturbance under the actual conditions at the time of the emergency. The specific BMP(s) implemented would depend on the affected resources identified in the SCPs and GRS (ARRT, 2012). GRS are map-based strategies that have been developed by a multi-stakeholder work group and are designed to save time in identifying sensitive areas for priority protection during the critical first hours of a spill response. The GRS show responders where sensitive areas are located and where to implement protective measures, particularly booming or other actions, to control a spill. These site-specific strategies are intended to be flexible and allow for modification by spill responders, as necessary, to fit prevailing conditions at the time of a spill. The strategies developed for the selected sites focus on minimizing environmental damage, creating the smallest footprint possible to support the response operation, and selecting equipment deployment sites that will not cause more damage than the spilled material.

Example BMPs for minimizing the impact of oil spill response actions, as provided in guidance documents (Alaska Clean Seas, 2010; Nuka Research, 2006; Alyeska Pipeline Service, 2008; API et al., 2001; NOAA et al., 2010), a previously published EFH consultation (NMFS, 2003), and the GRS (ARRT, 2012), include the following:

General BMPs

- Consult the GRS for the area of concern to ascertain site-appropriate cleanup actions, materials, deployment methods and locations, and resources relevant to EFH (e.g., spawning habitat).
- Be aware of typical fish migration and/or spawning seasons and plan accordingly to minimize impacts to large numbers of migratory fish.
- Use existing roads, docks, airstrips, or other constructed features (e.g., gravel pad) to access site and mobilize/demobilize equipment (including storage containers), unless otherwise indicated in the GRS.
- Constantly monitor the trajectory of the spill and weather forecast in order to maximize cleanup efficiency.
- Properly deploy, maintain, reconfigure, and redeploy oil containment and retrieval equipment to ensure proper function and efficiency and minimal harm to the local ecosystem.
- Be aware of and minimize (or preclude) contact (to the extent practicable) with EFH and HAPCs.

- Prevent oil from reaching shorelines if possible.
- Consult the spill tactics for Alaska responders (STAR) manual when beaches are in danger of oiling and containment is unlikely.
- If it is determined that oil will come ashore prior to containment, remove as much debris as practicable prior to oiling, leaving larger, structural components (e.g., large woody debris) in place.
- If beaches will be cleaned, allow all oil to come ashore before action.
- Only use approved methods of shoreline cleanup appropriate to the shoreline type, sediment type, tidal zone, and level of protection from wave energy and erosion.
- Commence cleanup operations as soon as feasible in order to minimize the response area and maximize mechanical and/or chemical response effectiveness.
- While conducting cleanup actions, construct or deploy adequate collection materials to ensure that oil remains contained and that sediment transport is minimized.
- Use information gained through surveillance and real-time monitoring (e.g., SMART program approach for non-mechanical countermeasures) to adapt response strategies to a given spill condition (and to continue adapting as conditions change).

Response-Specific BMPs

- Shoreline, nearshore, and freshwater recovery (e.g., skimming, vacuuming, sorbents)
    - Maintain proper storage equipment and area for recovered material, using previously disturbed sites (e.g., paved or cleared ground) when available.
    - Line storage areas with impermeable materials and surround the areas with berms to ensure that recovered material is not released to the environment.
    - Return storage areas to previous conditions after recovery and transport of recovered material to disposal site are complete.
    - Monitor collection devices and adjust response actions based on changing conditions.
    - Use fish screens over collection devices when operating in the nearshore or freshwater environment to mitigate or minimize injuries to shallow-dwelling fish or invertebrates.

- Use proper equipment to minimize waste and wastewater production (e.g., decanting equipment); operate decanting equipment in designated areas with proper containment equipment to mitigate or minimize recontamination; allow enough time for proper decanting when water-oil separation equipment is not available.
- Use appropriate absorbent material to minimize oiling of shorelines: snare booms for persistent oils (e.g., crude oil, Bunker C fuel) and sorbent booms for non-persistent oil (e.g., hydraulic oil, diesel fuel).
- Properly anchor equipment.
- Monitor the effectiveness of sorbent materials and replace periodically, if necessary, to maximize sorbent capabilities during the response.
- Properly dispose of spent sorbent materials.

- Vegetation or woody debris removal
  - To the extent practicable, leave roots of eelgrass and stalks (as well as roots) of kelp intact; similarly, leave roots and stalks of riparian vegetation intact to the extent practicable.
  - Use small and/or lightweight equipment to remove oiled vegetation while minimizing the destruction of non-oiled vegetation, erosion of sediment or soil, smothering of benthic habitat, and introduction of oil into deeper sediment.
  - Leave non-oiled vegetation or woody debris in place, to the extent practicable, on beaches that have become oiled; when possible, remove clean woody debris from beaches that are projected to become oiled (but have not yet been affected) as a means of preventing contamination.
  - Leave large structural components (i.e., large woody debris) in place; instead, clean large components to the extent practicable.
  - Avoid vegetation removal during seasons when vegetation-associated spawning species (e.g., Pacific herring or other potential prey) are present; during spawning seasons, avoid vegetation removal in known areas of spawning.
- Removal and cleaning of shoreline or upland substrate
  - Remove as little sediment or soil as is practicable while still recovering oil; replace removed sediment or soil with clean (i.e., non-toxic) material of a similar grade and composition.
  - Use hand tools rather than heavy machinery when feasible to avoid excessive shoreline or upland soil compaction and erosion.

    - Use small and/or lightweight equipment in order to minimize the introduction of oil into deeper sediment.
    - Avoid substrate removal during seasons when beach-spawning species (e.g., Pacific sand lance) are present; during spawning seasons, avoid known areas of spawning.
- Flushing/flooding of shorelines
    - Regulate water pressure to minimize beach erosion and the destruction of benthic organisms, as well as the forcing of oil deeper into sediment.
    - Use water that is as close to the ambient water temperature as possible in order to minimize heat-related injuries to biota.
    - Properly deploy, maintain, reconfigure, and redeploy oil containment and retrieval equipment to ensure proper containment of remobilized oil.
    - Use flushing/flooding on appropriate sediment grain sizes: flushing/flooding is not appropriate for fine-to-coarse-grained sand beaches or mudflats but may be appropriately used elsewhere.
- Berming, trenching, or underflow damming
    - Use as little local substrate as possible to construct the berm or dam, and be careful to not destroy sensitive habitat (e.g., marsh, tundra [i.e., permafrost], mudflat, eelgrass beds) when constructing earthen barriers.
    - Constantly monitor berm, trench, or dam integrity and replace eroded sediments when necessary.
    - When constructing earthen barriers, use erosion control measures (e.g., silt fences, settling ponds) to minimize the loss of sediment from construction areas to the aquatic environment.
    - Use impervious materials to prevent losses of oil from earthen barriers.
    - When damming, use a culvert with a capacity greater than the stream flow rate.
    - Construct the dam with plastic sheeting or sandbags when local substrate is too porous to contain oil.
    - Ensure the accessibility of upstream and downstream fish passage to the extent practicable, particularly during peak spawning migration; consult with Services to ensure proper construction if engineering expertise is required.
    - Remove earthen barriers once contamination has been removed, and return site to previous conditions (e.g., similar grade, sediment composition) to the extent practicable.

- Culvert blocking
  - Do not place culvert blockage during peak fish migration, and remove blockage prior to peak fish migration to allow for fish passage.
  - When possible, use an adjustable weir or culvert plug to allow some movement of water below an oil slick.
- Nearshore or freshwater deflection, diversion or exclusion booming
  - Properly anchor booms to achieve desired positioning.
  - Use existing anchor points (e.g., pilings) rather than anchoring in sediment when available.
  - Use additional booms to prevent boom entrainment (movement of oil below curtain).
  - Continually monitor and readjust booms to meet changing conditions.
  - Avoid the use of boom curtains that are deep enough to block fish passage into or out of streams (or within freshwater streams), accounting for tidal changes in depth over a 24hour period.
- Marine recovery (including open water booming)
  - Use oleophilic and decanting systems, when appropriate, to minimize waste and wastewater production.
  - Monitor and reposition collection devices (e.g., skimmer, vacuum, sorbent, or boom), as necessary.
  - Constantly monitor equipment efficiency.
  - Be wary of large, submerged rocks or shoals when transporting recovery equipment.
  - Use the proper boom configuration or combinations of configurations to best concentrate and capture oil (and prevent entrainment).
  - Use the proper equipment based on water depth and sea conditions.
  - Develop plan for the transport of oil from collection equipment to transport vessels.
  - Follow GRS guidance and use associated maps for site-specific planning of oil spill recovery.
- Chemical dispersant application
  - Apply dispersants, as determined by the FOSC and with the concurrence of the incident-specific regional response team, within appropriate habitats (Table 2-1), at the prescribed application rate, under appropriate weather conditions (i.e., sufficient wave energy to ensure mixing of dispersants and

oil as well as sufficient to inhibit mechanical means of recovery), and to oils with the appropriate physicochemical properties (e.g., crude oil).

  - Avoid dispersant use in shallow, nearshore habitats where it is not possible to attain a potential dispersal and dilution of oil to 10 m depth. Current guidance specifically requires that dispersion occur in areas over 10 fathoms (~18 m) deep (ARRT, 2014).
  - Avoid dispersant use near sensitive habitat (e.g., eelgrass beds, spawning habitat) to the extent practicable.
  - Use a spotter aircraft when applying dispersant with an airplane to minimize the overspray of chemicals.
  - Apply SMART monitoring as described by the NCP (i.e., gather real-time data to help predict spill conditions, trajectory, and chemistry and inform decision-making).
  - Consult ARRT and the Services prior to dispersant application to ensure safe application.
- *In situ* burning
  - Apply SMART monitoring as described by the NCP (e.g., gather real-time data of spill trajectory, thickness, chemical makeup) in order to assess the feasibility of burning and inform decision-making.
  - Avoid burning in sensitive, shallow aquatic areas (e.g., mudflats, eelgrass or kelp beds) that may be important for fish or invertebrates.
  - Use fire booms or earthen containment (in terrestrial environment), as appropriate, to concentrate oil prior to ignition.
  - Monitor burn constantly and apply additional fuel as needed to maintain burn efficiency.
  - Recover burn residues to the extent practicable.
  - Consult ARRT and the Services prior to *in situ* burning to ensure safe burning.
  - Conduct burning away from human populations to minimize inhalation of smoke.
- Bioremediation
  - Monitor dissolved oxygen concentrations in the area of bioremediation action (i.e., interstitial waters) to ensure that the stimulation of microbes does not result in hypoxia or anoxia
  - Monitor the concentration of fertilizer nutrients in the area of bioremediation to ensure appropriate application rate

- Monitor carbon dioxide evolution during action to ensure that bioremediation is occurring
- Monitor progress of bioremediation over time and adapt response strategies as appropriate to minimize impacts

- Natural attenuation
  - Continually monitor spill trajectory, impacts, and recovery; adapt response strategy, as appropriate.
- Additional actions common to most responses (reconnaissance/ mobilization/ demobilization; waste handling, treatment, and disposal)
  - Take measures to minimize the compaction of shoreline sediment (e.g., laying down plywood to distribute pressure, using paved access roads when available) or upland soil near points of marine access
  - Take measures to control sediment transport to the marine environment during construction in the upland environment.
  - Plan routes of transport to and from the response area; be aware of shallow, submerged rocks or shoals.
  - Plan for the transfer, storage, transport, and disposal of oil as well as decontamination of equipment, personnel, and vessels.
  - Plan for recontamination events (e.g., spills of recovered material).
  - Avoid placing waste containment and transfer points in nearshore or riparian habitat to the extent practicable, or, if impracticable to avoid such placement, minimize the area impacted by the placement of containers, machinery, or vehicles.

5 Action Agencies' View Regarding Effects of Proposed Actions on EFH

The Unified Plan (EPA et al., 2010) has been developed in order to respond in a timely and appropriate manner to a spill of oil or other hazardous material that, under many circumstances, could pose an immediate threat to EFH, managed species of fish and invertebrates, and/or other valued ecological or economic resources. As such, the Unified Plan, as a policy framework for decision-making, is considered by the Action Agencies to be conservative. Any implementation of the Unified Plan (including all potential response actions) is intended to be ecologically and economically beneficial relative to the baseline condition. The baseline condition is the condition of an area after an oil or hazardous materials spill has occurred, which will likely be detrimental to marine EFH, freshwater EFH, or riparian habitats that influence freshwater EFH. The methods of response described in the Unified Plan, although they can potentially cause short-term adverse effects, are intended, over the long term, to be an improvement over the baseline condition.

It is the Action Agencies' view that although the various oil or hazardous material spill response actions approved for use in Alaska have the potential to adversely impact EFH and/or managed fish and invertebrate species (as discussed in Section 3 and summarized in Table 3-1), most spill response actions implemented under the Unified Plan (EPA et al., 2010) are unlikely to result in adverse impacts relative to the baseline condition provided that measures to mitigate or minimize potential adverse effects are appropriately implemented (as discussed in Section 4).

The effects determinations for the response actions identified in the Unified Plan (EPA et al., 2010), which are based on the potential adverse effects outlined in Section 3 as modified by the mitigating (or minimizing) measures recommended in Section 4, are as follows:

- The response actions and components grouped in Table 3-1 under mechanical countermeasures (e.g., booming, flushing or flooding, and cleaning or removal of substrate, debris, or vegetation) are not likely to adversely affect EFH or managed species relative to the baseline condition provided that recommended BMPs are used to mitigate or minimize any potential adverse effects.
- The use of chemical dispersants to treat a spill of crude oil would temporarily adversely affect EFH (e.g., water quality or prey abundance) and could directly and indirectly adversely affect managed species in the vicinity of a dispersant's application.
    - For organisms present in the water column at a depth of between 1 and 10 m, the use of chemical dispersants would adversely affect EFH; impacts would likely be greater than those that would occur under the baseline

condition because untreated oil does not generally mix into the water column at depths greater than 1 m; whereas, dispersed oil is expected to be present at concentrations above hazardous levels to depths of 10 m.

- Hazardous concentrations of chemically dispersed oil would be expected to last no more than 24 hours after application, and impacts to prey species would likely diminish quickly.
- Managed species that are present during early life stages in the water column between depths of 1 and10 m would likely be adversely affected by a chemical dispersant application relative to the baseline condition. Several species that are present throughout their life cycles in waters deeper than 10 m (e.g., sablefish [*Anoplopoma fimbria*]) would not likely be impacted under the baseline condition or by the application of chemical dispersants. Species that are present in shallow waters as late juveniles or adults but not at early life stages could be affected, although adults and relatively large-bodied juveniles tend to be less sensitive to crude or chemically dispersed oils.

- *In situ* burning and bioremediation[18] would not likely adversely affect EFH and managed species as compared with the baseline condition; *in situ* burning has the potential to cause direct effects on EFH managed species (e.g., heat damage to neustonic larvae or prey species); however, the effects would be highly localized and short-term because the heat damage would likely occur in only the upper (13 cm) of the water column directly under an *in situ* burn.
- Effects on EFH and managed species from natural attenuation would be similar to those for the baseline condition; this response action would be reserved for events during which any action would result in greater harm than that anticipated for the baseline condition

The magnitude of impacts on specific EFH and managed species (and at specific life stages) will depend on the seasonality, location, duration, volume, and/or areal extent of the spill and the proximity of responders and response equipment to the oil or hazardous material spill.

The Action Agencies recognize that adverse effects resulting from hazardous materials spill response actions, whether mechanical or chemical and taken independently or in combination, will be shorter in duration relative to the long-term effects on EFH from the spill (baseline condition).

The Action Agencies also recognize that before any hazardous materials spill response actions are implemented, a thorough evaluation of the tradeoffs between the environmental benefits and harm associated with a response action will be undertaken by the ARRT and the FOSC.

[18] Bioremediation is not currently an approved response action.

The analyses and findings of this EFH assessment will be an integral part of the decision-making process and will aid in the selection of appropriate responses to the release of oil and hazardous substances in Alaska waters.

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Appendix A. Dispersant and Dispersed Oil Aquatic Exposure and Toxicity Evaluation

U.S. DEPARTMENT OF
HOMELAND SECURITY

United States Coast Guard

DISPERSANT AND DISPERSED OIL AQUATIC EXPOSURE AND TOXICITY EVALUATION
FINAL

Prepared for:

United States Coast Guard
Seventeenth Coast Guard District
709 W. 9th Street
Juneau, AK 99803

and

United States Environmental protection Agency
Region 10 Alaska Operations Office
222 W. 7th Street, Box 19
Anchorage, AK 99513-7588

18 August 2014

Prepared by:

Windward Environmental LLC
200 West Mercer Street, Suite 401
Seattle, Washington 98119

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Acronyms

ARRT	Alaska Regional Response Team
BA	biological assessment
BMP	best management practice
BSAI	Bering Sea/Aleutian Islands
CAS	Chemical Abstracts Service
DHOS	Deepwater Horizon oil spill
DOR	dispersant-to-oil ratio
DNA	deoxyribonucleic acid
DOSS	dioctyl sulfosuccinate sodium
DPNB	1-(2-butoxy-1-methylethoxy)-2-propanol
EC50	concentration that has an effect on 50% of an exposed sample
EFH	essential fish habitat
EPA	United States Environmental Protection Agency
EROD	ethoxyresorufin-O-deethylase
ESA	Endangered Species Act
EVOS	Exxon Valdez oil spill
FMP	fisheries management plan
GNOME	General NOAA Operational Modeling Environment
GOA	Gulf of Alaska
HC	hazardous concentration (for a given proportion or percentile of a species sensitivity distribution)
IQR	interquartile range
LC50	concentration that is lethal to 50% of an exposed population
LOEC	lowest-observed-effect concentration
LPAH	low- molecular-weight polycyclic aromatic hydrocarbon
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOEC	no-observed-effect concentration
OECD	Organisation for Economic Co-operation and Development
OMA	oil-mineral aggregate
PAH	polycyclic aromatic hydrocarbon
ppb	parts per billion

ppm	parts per million
SSD	species sensitivity distribution
TPH	total petroleum hydrocarbons
USCG	United States Coast Guard
UV	ultraviolet

1 Introduction

1.1 PURPOSE AND THE BASELINE CONDITION

This document is Appendix A to the *Assessment of Essential Fish Habitat for the Alaska Federal/State preparedness plan for Response to Oil & Hazardous Substance Discharges/Releases* (Unified Plan), hereafter referred to in this appendix as the Essential Fish Habitat (EFH) Assessment. The purpose of this appendix is to describe the potential direct adverse impacts of chemical dispersants, alone or in a mixture with oil, on species and habitats (i.e., EFH) managed under the Magnuson-Stevens Fishery Conservation and Management Act (i.e., those fish and invertebrate species included in a fisheries management plan [FMP]).[1] This appendix also addresses direct impacts on reasonably similar surrogates of managed species and indirect impacts on potential prey species (or reasonable surrogates of prey species) for cases when toxicity data for species of interest is not available.[2] These impacts are weighed against the baseline condition: that a hazardous substance (e.g., crude oil) has been spilled, and that a response can be enacted in accordance with the Unified Plan (EPA et al., 2010). Under certain circumstances, such a response may involve the application of chemical dispersants, particularly if a heavy petroleum product such as crude oil is spilled in the marine environment in water of sufficient depth (≥ 10 fathoms [or approximately 18 m])[3] and mixing energy (e.g., waves, wind, moving ice, etc.) to allow for effective dispersion (NOAA et al., 2010).[4] Chemical dispersants are not intended for use in the uplands to treat soils, in bodies of freshwater, or in shallow (< 10 fathoms), nearshore, or shoreline environments (including direct application to sediment) (NOAA et al., 2010; Nuka Research, 2006).

As of the writing of this EFH assessment, dispersants are not pre-authorized for use anywhere in Alaska. A new dispersant use and pre-authorization policy has been drafted (ARRT, 2014), agreed to by all required signatories under the National Contingency Plan (NCP) (40 CFR 300.910), and is in the process of mandatory federal-to-tribal government consultation and State of Alaska public comment, as well as Endangered Species Act (ESA) Section 7 and EFH consultations – all of which are required before the policy can be

[1] "Managed" species, as referred to throughout this appendix, are those managed under FMPs.

[2] The use of surrogate toxicity data is described further in Section 3.6. For several managed species (or groups of species), there is a paucity of data regarding their EFH or habitat preferences, which were used to assign a likelihood that the managed species would be exposed to crude oil, chemical dispersants, and/or dispersed oil in the event of a spill. In those cases, only reasonably similar species with defined EFH were used as surrogates. This is described further in Section 2.4.1.

[3] The requirement for a water depth of 10 fathoms (18 m) in areas where dispersant are being applied has been incorporated into recent chemical dispersant application guidance for Alaska (ARRT, 2014); however, the expected maximum depth of the dispersion of oil droplets is 10 m (NRC, 2005).

[4] Effective dispersion is typically defined as the percent of oil removed from the ocean surface through chemical dispersion into the water column (NRC, 2005).

finalized. The pre-authorization of chemical dispersants does not inherently alter the potential for chemical exposures or the sensitivities of managed fish or invertebrate species or their prey, and so will not affect the conclusions made in this document (Sections 4 and 6). Therefore, the pending approval of the draft pre-authorization plan for chemical dispersant application in Alaska (ARRT, 2014) should not require a re-initiation of the EFH assessment process.

In order for adverse impacts related to chemical dispersants to be considered relevant to this EFH assessment, dispersants must be shown to meet one or more of the following qualifications:

- Dispersants must be inherently more toxic than crude oil.
- Dispersants must increase the exposure concentration and/or duration of exposure of managed fisheries, their prey, or EFH to oil or toxic components of oil (e.g., polycyclic aromatic hydrocarbons [PAHs]).
- Dispersants must increase the toxicity of oil or toxic components of oil to protected species or their prey (thereby impacting EFH when dispersed oil is present).

If the application of dispersants to an oil spill can be shown to mitigate or minimize the expected impacts of an untreated oil spill (i.e., the baseline condition), then the impacts of dispersants as a potential response tool can be considered negligible (or even beneficial by comparison) (Fingas, 2008; NRC, 2005).

In addition to this introduction, Appendix A is presented in the following sections:

- Section 2 provides data regarding the potential exposures of managed fish and invertebrate species (and their prey) to crude oil, dispersants, and chemically dispersed oil.
- Section 3 presents the analyses of the toxicity of crude oil, dispersants, and chemically dispersed oil to managed fish and invertebrate species or reasonable surrogates of those species (and their prey).
- Section 4 provides the synthesis of exposure and toxicity (or "sensitivity") data for managed species (or reasonable surrogates).
- Section 5 provides an analysis of the uncertainties associated with this evaluation.
- Section 6 summarizes the evaluation.

The complete toxicity dataset used for the analyses presented in Section 3 is provided in Attachment B-1 to Appendix B of the *Biological Assessment of the Alaska Federal/State Preparedness Plan for Response to Oil & Hazardous Substance Discharges/Releases (Unified Plan)*, hereafter referred to as the Biological Assessment (BA) (Windward and ERM, 2014), and the complete dataset used in the analyses presented in Sections 2 and 4 are provided in Attachment A1 to this appendix.

1.2 SPECIES CONSIDERED

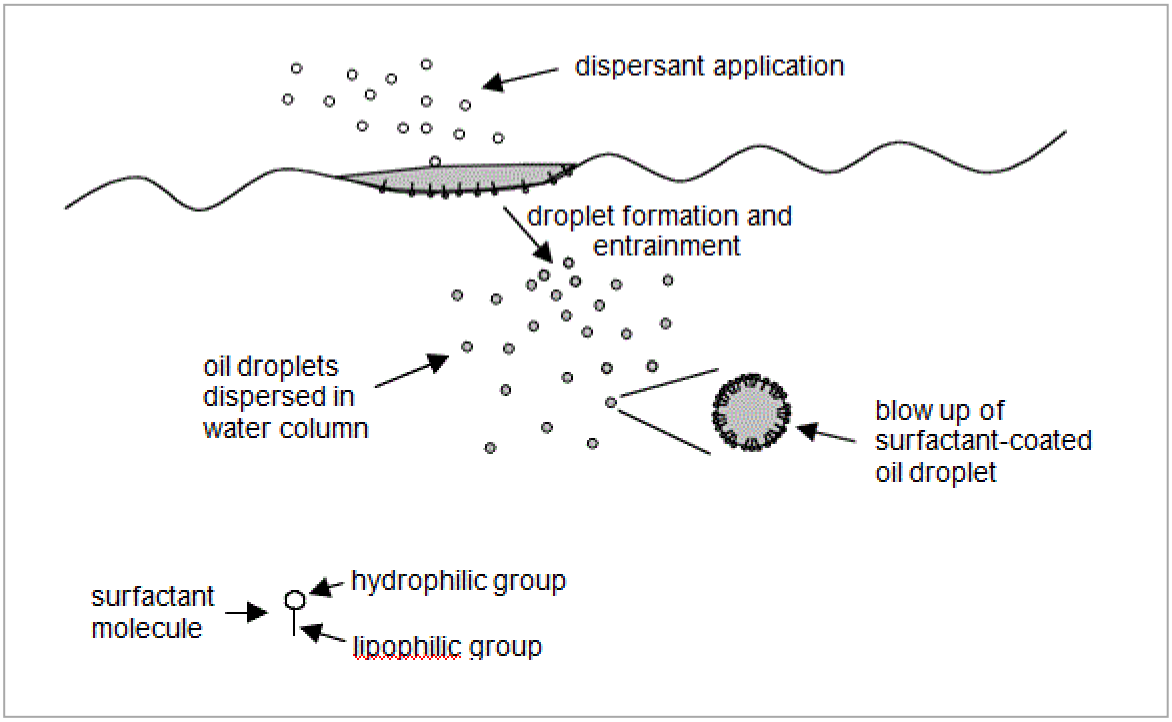
The ecological receptors evaluated in this appendix include the individual species identified in FMPs, rather than the EFH itself. In order for the application of chemical dispersants to have an adverse impact on EFH, the species that inhabit the EFH must be adversely impacted as well. Chemical dispersants and chemically dispersed oil do not pose a threat of irreparable or permanent damage to water or sediment quality in and of themselves (Sections 2.2 through 2.3). Therefore, the immediate threat to EFH posed by chemical dispersant application is considered conceptually interchangeable with the potential for toxicological impacts on managed fish or invertebrate species (or reasonable surrogates).

A comprehensive list of the species which are identified in the six FMPs implemented by the North Pacific Fisheries Management Council is presented in Table 1-1 in the EFH assessment. EFH has been defined for many of these species, although some are managed as part of less clearly defined complexes (e.g., other flatfish, other rockfish, forage species other than capelin [*Mallotus villosus*] and eulachon [*Thaleichthys pacificus*]). No distinction has been made in the evaluation of species covered by more than one FMP (e.g., groundfish in FMPs for both the Gulf of Alaska [GOA] and the Bering Sea/Aleutian Islands [BSAI]), because the potential for toxicological impacts on individual species is assumed to be similar, regardless of geographical location.

In addition to managed fish and invertebrate species, additional species are discussed that may represent the prey of managed species. Indirect impacts (i.e., apparent toxic responses in the prey community) of chemical dispersant application are considered part of the general discussion of the toxicities of oil, chemical dispersants, and dispersed oil. For example, species sensitivity distributions (SSDs) are developed in Section 3.2 of this appendix, and from those SSDs, protective threshold concentrations are calculated that are intended to be protective of 95% of all aquatic fish and invertebrates based on early life stage exposures. This assumedly includes smaller, more sensitive prey of managed species.

1.3 DESCRIPTION OF DISPERSANTS AND CONCEPTUAL MODEL

Chemical dispersants are mixtures of surfactants and hydrocarbon-based solvents that alter the spatial distribution, physical transport, and chemical and biological fate of spilled oil in aquatic environments. The intended purpose of dispersant application is to reduce the concentration of oil at the surface of the ocean by breaking an oil slick into droplets that can be suspended and distributed (and subsequently diluted and biologically degraded) throughout the water column. The presence of suspended sediment (e.g., in nearshore or estuarine habitats) can enhance the formation of droplets (with or without the addition of chemical dispersants) through the creation of oil-mineral aggregates (OMA) (Fingas, 2008; Lee et al., 2008; Khelifa et al., 2008; Zhengkai et al., 2007). The process of the chemical dispersion of oil is portrayed in Figure 1. Dispersant application is also considered a useful tool to reduce the oiling of sensitive shoreline habitats, when applied appropriately and in a timely manner (i.e., prior to migration of the slick into shallow waters [< 10 m], where oil cannot be fully diluted, and prior to significant weathering of the oil), and is expected to substantially reduce the known, long-term impacts of shoreline oiling (Peterson et al., 2003; Cross and Thomson, 1987).



Source: NRC (2005)

Figure 1. Mechanism of chemical dispersion

When released into the aquatic environment, crude oil tends to spread into a thin layer over the surface of the water, < 1 mm thick on average (Lee et al., 2011a) and typically ~0.1 mm thick (NRC, 2005). After oil is spilled, a number of physical, chemical, and biological factors affect its dispersion and ultimate fate (NRC, 2005). Physical factors such as surface tension (a measure of attraction between the molecules of a liquid), density, and viscosity (a measure of resistance to flow) generally cause the oil molecules to stay together, if there are no other forces at work (NRC, 2005). A chemical dispersant can cause an oil slick to either spread rapidly and then disperse, or spread slowly through "herding" (NRC, 2005), after which additional dispersant applications may be required to remove the oil slick from the ocean's surface.

A deep, subsurface release spreads differently than a surface or near-surface release; the presence of natural gas in crude oil makes it buoyant, quickly driving it to the surface as a uniform plume (NRC, 2005). The resulting surface slick may be similar to that of a surface release, particularly when the subsurface release is shallow (NRC, 2005). In the event of deep releases, such as the Deepwater Horizon oil spill (DHOS), density stratification and ambient currents can cause dense oil components to split from gaseous components (i.e., natural gas and methane), resulting in a much slower and less uniform ascent to the surface than a near-surface release (NRC, 2005). The resultant surface slick is expected to be thinner and spread over a larger area (NRC, 2005). Thinner surface slicks are less effectively dispersed (as well as mechanically contained and recovered) (NRC, 2005), which may have prompted the use of chemical dispersants at the wellhead during DHOS instead of a typical surface application. The application of chemical dispersants at the wellhead during DHOS was an unprecedented response action; such a response has never been conducted in Alaska, nor is it approved for use in Alaska. For that reason, subsurface response actions are not being addressed as part of this evaluation; however, as new information and guidance become available in the future, the use of subsurface response actions will be re-evaluated, as appropriate.

Wind, waves, and other physical forces (such as the movement of sea ice) can either enhance dispersion, or mix oil and water to form an emulsion that remains relatively cohesive and does not disperse easily (NRC, 2005; MMS, 2010; Brandvik et al., 2010). Chemical processes (e.g., volatilization and oxidation) can change the chemical composition and density of oil, affecting its fate in the environment (Mackay and McAuliffe, 1988). Biodegradation occurs over time, as fractions of the oil become bioavailable (i.e., dissolved in the water column) (Prince et al., 2013). However, oil thickness, cohesiveness, viscosity, and other factors affect bacterial access to oil molecules (Prince et al., 2003).

2 Fate and Transport of Dispersants and Dispersed Oil

This section expands upon the conceptual model of how dispersed oil behaves in an aquatic environment (Section 1.3) and discusses the factors that affect the toxicity of dispersed oil under field conditions. Oil is assumed to be fresh or slightly weathered crude petroleum, the most likely material for which dispersants would be used (Alaska Clean Seas, 2010; Nuka Research, 2006; NOAA, 2012; ARRT, 2013). Diesel fuel is the most common type of petroleum spilled in Alaska waters, but it is very rarely, if ever, treated with chemical dispersants (see Appendix D to the BA) (Windward and ERM, 2014). The rapid rate at which refined fuels (such as diesel) naturally attenuate (i.e., volatilize, disperse, and degrade) makes dispersant application impractical for such spills.

Factors affecting oil dispersion and dilution are discussed in Section 2.1; dispersants and dispersed oil degradation are discussed in Section 2.2; and transport is discussed in Section 2.3.

2.1 DISPERSION AND DILUTION

Dispersion is a natural process that distributes petroleum at the ocean's surface into the water column, resulting in many small droplets that may or may not resurface and coalesce with the oil slick (NRC, 2005). This process can be very slow under natural conditions, but the addition of chemical dispersants greatly increases the rate of dispersion by lowering the interfacial tension between water and crude oil (NRC, 2005).

The application of dispersants in a typical spill response involves the release of a large tank of undiluted dispersant chemical from a vehicle (e.g., airplane, boat, or helicopter) onto the surface of a spill on open water (Nuka Research, 2006). The volume released depends largely on the vehicles' carrying capacities for liquid dispersants (Nuka Research, 2006). However, the rate of application (i.e., volume of dispersant per unit area of ocean surface) is consistent between application methods over large areas (Nuka Research, 2006), resulting in a more or less uniform input of dispersant chemicals. Ideally, the dispersant droplets come into contact with the oil and mix rapidly, resulting in nearly instantaneous dispersion of oil into the water column. Although chemical dispersant is applied as evenly as possible, because oil slicks tend to be unevenly distributed across the ocean's surface (NRC, 2005), the true dispersant-to-oil ratio (DOR) is expected to vary spatially. The required volume of chemical dispersant is assumed to be that which is needed to coat the surface of an oil slick (with minimal volume allowed for overspray) (Scelfo and Tjeerdema, 1991), and to achieve a recommended DOR, typically between 1:10 and 1:50 (Rico-Martinez et al., 2013). The recommended DOR in Alaska is 1:20 (Alaska Clean Seas, 2010).

The goal of dispersant application is to break the surface tension of the water-oil interface so that droplets of oil form that are small enough to remain suspended in the water column (Brandvik et al., 2010). Dispersant chemical formulations are designed to bind to crude oil specifically, so the individual chemicals in dispersants tend to move through the water column with plumes of dispersed oil (Kujawinski et al., 2011).[5] Once broken into droplets, the oil mixes into the water column, effectively lowering the surface concentration of oil and thus the exposure of aquatic organisms at the ocean's surface (e.g., wildlife). Conversely, pelagic species (e.g., managed fish and invertebrates) may be more exposed to oil after chemical dispersion, because typical concentrations of untreated oil in the water column are very low (i.e., < 1 part per million [ppm]) prior to dispersion, even just below the slick (e.g., 1 to 6 m, depending on wind and wave energy) (Mackay and McAuliffe, 1988; McAuliffe et al., 1981; McAuliffe et al., 1980; Humphrey et al., 1987b).

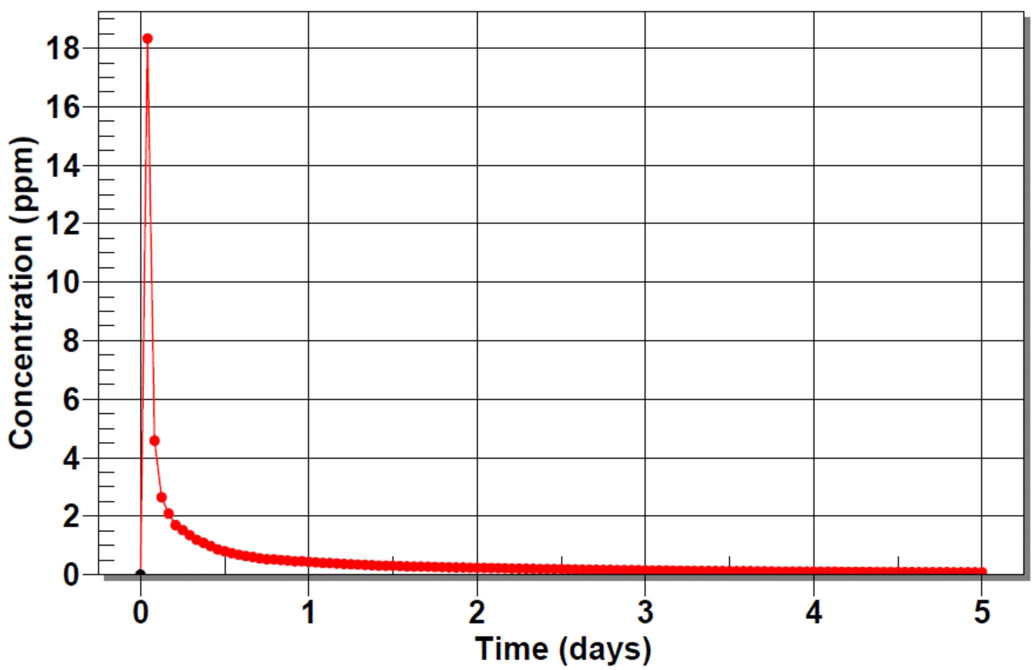
Also, the exposure of species to toxic components of oil (i.e., PAHs) is likely to increase immediately after dispersant application (Yamada et al., 2003; Ramachandran et al., 2004; Milinkovitch et al., 2011), and may result in increased toxicity (Barron, 2003; Barron et al., 2008). PAHs are likely to decrease rapidly in concentration as a result of natural processes (e.g., wave action, wind-driven currents and advection, photo-oxidation, and biodegradation), though toxicity may still occur (French-McCay, 2010).

The rate of oil and chemical dispersant mixing is primarily determined by the energy of the environment in which the dispersant is applied, although some additional factors contribute to effective dispersion (e.g., spill size, dispersant droplet size, penetration of spill upon impact, thickness of spill, extent of weathering, and the formation of less dispersible emulsions) (NRC, 2005). Mixing will occur more slowly in a calm sea than in churning waters, where waves stir the oil and dispersant together. Wind also produces turbulent mixing, facilitating dispersion (NRC, 2005). Both wave action and wind energy act on any oil, regardless of the presence of dispersants, and cause the natural dispersion of oil droplets. In the Arctic, sea ice can dampen the effect of wind and waves, requiring the deliberate addition of turbulence (e.g., propeller wash from a response vessel) (Sørstrøm et al., 2010). Conversely, in some field tests the movement of the ice itself has been shown to sufficiently mix oil and dispersant, such that chemical dispersion is highly effective even in the presence of broken ice (Sørstrøm et al., 2010; Potter et al., 2012). The effectiveness of dispersion at Arctic temperatures is not dissimilar from its effectiveness in warmer waters (Potter et al., 2012; Sørstrøm et al., 2010; Brandvik et al., 2010; MMS, 2010). However, under certain circumstances, it is possible that dispersion will be less effective in areas covered by sea ice due to decreases in surface water salinity (Brandvik et al., 2010;

[5] Therefore, large quantities of freely dissolved dispersant in the water column is unlikely in the presence of oil; overspray into unoiled water, although unlikely, is an exception and would result in partitioning to water. Overspray is minimized by the use of spotter aircraft, which guide the applicator vessel (i.e., airplane, helicopter).

Chandrasekar et al., 2006) or possible sheltering from sea energy (which would also limit mixing caused by the movement of ice) (Sørstrøm et al., 2010).

Gallaway et al. (2012) modeled the expected concentration of dispersant released to the environment assuming an application rate of 5 gal. of Corexit® 9500 per acre, a 10-km^2 area, and a total volume of 5,000 gal. of dispersant. The receiving waters were modeled as having a local, initial concentration of approximately 18 ppm of Corexit® 9500, which diluted rapidly over time (Figure 2).



Source: Gallaway et al. (2012)

Note: Concentration (ppm) refers to Corexit® 9500. The rapid decrease in Corexit® 9500 concentration is driven by dilution. Degradation occurs concurrently, but at a slower rate.

Figure 2. Dilution model of Corexit® 9500 concentration as a function of time after 5,000-gal. application over 10 km^2

The rate of dispersant dilution indicated by the Gallaway et al. (2012) model is similar to that reported by Nedwed (2012), who indicated that concentrations of dispersant decreased to < 1 ppm within a matter of hours (and to the parts per billion [ppb] range within 24 hours). Similar modeling conducted by the National Oceanic and Atmospheric Administration (NOAA) using the General NOAA Operational Modeling Environment (GNOME) provided similar results (NOAA, 2012): dispersion (under ideal conditions) is rapid, and dilution drives concentrations of dispersants to < 1 ppm within 24 hours.[6]

[6] GNOME model inputs used to derive dispersant concentration dilution models assumed idealized conditions for dispersion, such as 100% effectiveness (NOAA, 2012).

Given that chemical dispersants initially partition to oil in the water column (i.e., form droplets with oil rather than dissolve in water) (Fingas, 2008; Kujawinski et al., 2011; NRC, 2005), it can be assumed that crude oil will dilute at a similar rate to chemical dispersants (at least over short time periods) (NRC, 2005; Fingas, 2008); however, local, initial concentrations of chemically-dispersed oil are expected to be far greater than concentrations of chemical dispersants (e.g., 20 times greater at a DOR of 1:20) (Mackay and McAuliffe, 1988; Humphrey et al., 1987b). McAuliffe et al. (1980, 1981) and Mackay and McAuliffe (1988) showed that dispersed oil, although highly concentrated in the water column below an oil slick immediately after dispersion, decreased to below what the authors considered to be protective levels within a matter of hours. Furthermore, the time-averaged concentration of dispersed oil was low (i.e., 0.46 ppm C_1-C_{10} hydrocarbons), even over short time periods immediately following dispersant application (i.e., between 10 and 30 minutes after application) (Mackay and McAuliffe, 1988). Humphrey et al. (1987b), in three simulated dispersant applications, measured a range of dispersed oil concentrations in the water column. Although concentrations of approximately 50 ppm TPH dispersed oil were measured over a period of 12 hours in one area, it was noted that likely concentrations (based on their results and those of several others) were less than 30 to 40 ppm,[7] similar to those measured by McAuliffe et al. (1980, 1981). Within 24 hours, Humphrey et al. (1987b) observed that concentrations had dropped to < 1 ppm TPH, also similar to those measured by McAuliffe et al. (1980, 1981). Based on these studies, it seems likely that exposures to concentrated dispersed oil may persist for up to 24 hours.

Based on the discussion above, it is concluded that, regardless of the sensitivity of managed species to chemical dispersants or chemically dispersed oil (relative to the baseline condition), exposures of fish and invertebrate species in the shallow water column (e.g., larval life stage of many managed species) are expected to increase as a result of chemical dispersion relative to the baseline condition.

2.2 Degradation of Dispersants and Dispersed Oil

This section provides information relevant to the EFH assessment regarding the biological and abiotic degradation of crude oil, dispersants, and chemically dispersed oil. Unlike dilution (Section 2.1), degradation results in the destruction of oil and chemical dispersant components. Dilution is a rapid process that occurs immediately after chemical dispersion, but the rate and extent to which the components of chemical dispersants and oil degrade depend on various environmental factors as well as the individual chemical.

[7] In one exposure scenario, Humphrey et al. (1987b) determined that benthic invertebrates had been exposed to approximately 300 ppm TPH dispersed oil, which the authors noted was an “extreme” circumstance.

2.2.1 Biodegradation

Dispersants, once released into the environment, undergo physical and chemical processes much like spilled oil or other degradable substances. Neff (1988) indicated that, as the volatile components of dispersants evaporate, physical processes initially control the rate of elimination of dispersants from a marine system.[8] After initial evaporation, biological processes determine the rate of removal from the environment.[9]

In a spiked laboratory exposure,[10] Corexit® mixtures[11] were reported to have a 107-minute half-life (i.e., time required for 50% degradation of a chemical) in solution (George-Ares and Clark, 2000), indicating rapid removal from water under certain conditions. Mulkins-Phillips and Stewart (1974) also measured dispersant biodegradation, but only after a microbial lag period in growth; this lag period is likely due to observed shifts in natural microbial communities in response to changing chemical conditions (Hazen et al., 2010; Lu et al., 2011; Baelum et al., 2012). Okpokwasili and Odokuma (1990) observed Corexit® 9527 to biodegrade by 90% or more within 16 days; the half-life of the chemical mixture was approximately 2 to 3 days. Baelum et al. (2012) measured total Corexit® 9500 and individual components, glycols and dioctyl sulfosuccinate sodium (DOSS), in the presence of oil; the authors reported rapid biodegradation of total Corexit® 9500 and DOSS within 5 to 20 days, but the concentration of glycols was largely unchanged after 20 days. Mudge et al. (2011) specifically observed 1-(2-butoxy-1-methylethoxy)-2-propanol (glycol ether DPNB), for which a half-life of approximately 30 days was determined.

Studies by Staples and Davis (2002), Kim and Weber (2005), the US Environmental Protection Agency (EPA) (2005, 2009, 2010), the Organization for Economic Co-operation and Development (OECD) (1997), and West et al. (2007) indicate that the component chemicals of Corexit® 9500 and Corexit® 9527 are marginally or readily biodegradable (as well as abiotically degradable; see Section 2.2.2). Table 1 provides a summary of biodegradation information for Corexit® components. The percent degradation is presented with the duration of microbial exposure. The half life is also provided, if available. The percent loss over time is used in determining biodegradability, such that a > 60% loss of a chemical within 28 days warrants the characterization of a chemical as readily biodegradable.

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[8] Refer to Table 1, which indicates that current Corexit® formulations contain up to two potentially volatile components, petroleum distillates and 2-butoxyethanol; the latter is present in Corexit® 9527 only.

[9] Dilution is also a major factor in determining the concentration of dispersed oil in the water column, although such redistribution of oil does not, in itself, result in removal from the environment.

[10] In a spiked laboratory exposure, a toxicant is added once during the test and allowed to diminish over time through the addition of clean water in renewals or flowing waters (i.e., flow-through exposure).

[11] Corexit® 9500 and Corexit® 9527 are the only two chemical dispersants available for use in Alaska at the time this EFH assessment was prepared. Corexit® 9527 is no longer manufactured and availability is restricted to existing stocks.

Table 1. Biodegradation information for Corexit® component chemicals

CAS No.	Chemical Name (common name)	Biodegradability	Half-Life (days)	Percent Degradation (duration)	Source
57-55-6	1,2-propanediol (propylene glycol)	readily biodegradable	13.6	81 (28 days)	West et al. (2007); Dow AgroSciences (2012)
111-76-2	2-butoxyethanol[a,b]	readily biodegradable	nr	> 60 (28 days)	OECD (1997)
577-11-7	butanedioic acid, 2-sulfo-, 1,4-bis(2-ethylhexyl) ester, sodium salt (1:1) (DOSS)	readily biodegradable[c]	nr	66.4 (28 days)	EPA (2009)
		readily biodegradable	nr	91 to 97.7 (3 to 17 days)	TOXNET (2011)
1338-43-8	sorbitan, mono-(9Z)-9-octadecenoate (Span®80)	readily biodegradable	nr	58 to 62 (14 to 28 days)	EPA (2010, 2005)
9005-65-6	sorbitan, mono-(9Z)-9-octadecenoate, poly(oxy-1,2-ethanediyl) derivs. (Polysorbate 80)	not readily biodegradable	nr	52 (28 days)	Fisher Scientific (2010)
9005-70-3	sorbitan, tri-(9Z)-9-octadecenoate, poly(oxy-1,2-ethanediyl) derivs (Polysorbate 85)	readily biodegradable	nr	60 to 83 (28 days)[d]	EPA (2005)
29911-28-2	1-(2-butoxy-1-methylethoxy)-2-propanol (glycol ether DPNB)	readily biodegradable	10.3 – 28	> 60 (28 days)	Howard et al. (1991); Dow (1993, 1987); Staples and Davis (2002)
64742-47-8	petroleum distillates, hydro-treated, light[a]	readily biodegradable	nr	> 97 (4.7 days)	Rozkov et al. (1998)

[a] Potentially volatile component.

[b] 2-butoxyethanol is present in Corexit® 9527, but not in Corexit® 9500.

[c] EPA states that DOSS did not biodegrade readily; however, the rate at which biodegradation occurred was greater than 60%, above the typical criterion for ready biodegradability (based on standardized OECD methods). Therefore, it has been changed in the table to reflect the more widely accepted criterion.

[d] Values are based on the degradation of chemicals with similar chemical structures and have not been measured directly.

CAS – Chemical Abstracts Service
DOSS – dioctyl sulfosuccinate sodium
DPNB – dipropylene glycol n-butyl ether
EPA – US Environmental Protection Agency
nr – not reported
OECD – Organisation for Economic Co-operation and Development

The biodegradation of dispersed oil is well studied, although results vary among studies (NRC, 2005; Fingas, 2008; Bruheim et al., 1999). In general, biodegradation testing results indicate that oil dispersion increases the rate of oil elimination from the water column under a variety of conditions (Hua, 2006; Lindstrom et al., 1999; Lindstrom and Braddock, 2002; Hazen et al., 2010, as cited in Lee et al., 2011a; McFarlin et al., 2012b; Otitoloju, 2010; MacNaughton et al., 2003; Prince et al., 2003; Zahed et al., 2010; Zahed et al., 2011; Prince et al., 2013; Baelum et al., 2012). Zahed et al. (2011) reported Corexit® 9500-dispersed oil half-lives of 28, 32, 38, and 58 days at oil concentrations of 100, 500, 1,000, and 2,000 ppm TPH, respectively.[12] These half-lives were less than those of untreated oil: 31, 40, 50, and 75 days at the same respective oil concentrations.

Baelum et al. (2012) reported that non-dispersed oil degraded by only 20% within 20 days, whereas dispersed oil degraded by 60%, an increased rate of removal of 40% enhanced by the addition of Corexit® 9500. Prince et al. (2013) reported half-lives for untreated oil and Corexit® 9500-dispersed oil of 13.8 and 11 days, respectively, corroborating results from earlier studies (Zahed et al., 2011; Baelum et al., 2012). The test conditions applied by Prince et al. (2013) and Baelum et al. (2012) (i.e., water temperatures of 8 and 5°C, respectively) are more relevant to Alaska waters than those applied by Zahed et al. (2011) (i.e., water temperature of 27.5°C). McFarlin et al. (2012b) reported that biodegradation increased in response to dispersant application when observing an Arctic microbial community exposed at -1 and 2°C (in two tests).

Biodegradation in the Arctic has been shown to progress rapidly (Lee et al., 2011a), but there have been concerns over temperature limitations on microbial activity (Venosa and Holder, 2007). Rapid biodegradation of crude oil and chemically dispersed oil is expected to occur under Arctic conditions due to the presence of cold-adapted bacterial communities with the ability to biodegrade hydrocarbons (Lee et al., 2011a; McFarlin et al., 2012a).[13]

Increased biodegradation of oil in the presence of dispersant chemicals is significant, but degradation is often incomplete. Biodegradation processes are limited largely to the lighter components of oil, and the addition of dispersants appears to facilitate the mineralization of oil only to a certain extent (McFarlin et al., 2012b). Laboratory studies that investigated changes in the composition of oil over time found that degraded oil contained a larger proportion of the heavier components of oil (Lindstrom and Braddock, 2002; Lindstrom et al., 1999). This has been shown to be true in field observations as well (Hazen et al., 2010; Atlas and Hazen, 2011). Heavier organic components of both untreated and chemically dispersed oils become enriched over time (Lindstrom et al., 1999), so this enrichment does not constitute a negative long-term impact on the natural attenuation of oil relative to the baseline condition. Reductions in the biodegradation of some hydrocarbons may be a result of the inhibition of certain hydrocarbon-degrading bacteria in the marine environment caused by exposure to chemical dispersants (Hamdan and Fulmer, 2011). The results of such tests are not relevant to field conditions, considering the rapid community-level shifts that occur under natural conditions when oil and dispersant

[12] Concentrations of dispersed oil have rarely exceeded 100 ppm during field testing, and have not been shown to exceed 500 ppm TPH (McAuliffe et al., 1980, 1981; Mackay and McAuliffe, 1988; Humphrey et al., 1987b).

[13] Such adaptations are not adequately addressed by testing that uses one community at various temperatures, as was conducted by Venosa and Holder (2007).

are introduced into a diverse microbial community (Hazen et al., 2010; Lu et al., 2011). For example, the inhibition of specific bacteria (Hamdan and Fulmer, 2011) has not been shown to ultimately reduce the rate of biodegradation under field conditions, rather degradation is enhanced after the stimulation of different biodegradative bacteria (Hazen et al., 2010; Lu et al., 2011).

2.2.2 Abiotic degradation

In addition to being biodegraded, it is possible for crude oil, chemical dispersants, and chemically dispersed oil to be abiotically degraded (through physical forces). Lyman et al. (1990) indicate that components of Corexit® 9500 are not expected to be susceptible to photolysis, although hydrolytic degradation may occur in the absence of microbial action. The half-lives indicated for individual components range from 77 days for Polysorbate 85 to 7.7 years for Span®80 (TOXNET, 2011). Rates of hydrolytic degradation vary greatly based on pH. For example, in the absence of microbial degradation, DOSS has a half-life of 240 days at pH 8, but a half-life of 6.7 years at pH 7 (TOXNET, 2011). These chemicals have much shorter half-lives for biodegradation than abiotic degradation (George-Ares and Clark, 2000; Baelum et al., 2012), so it is not expected that abiotic degradation plays a major role in the degradation of Corexit® dispersants in the field.

Many components of oil (e.g., PAHs) are susceptible to abiotic degradation pathways (e.g., photolysis, hydrolysis) (Fathalla, 2007; Shemer and Linden, 2007). Abiotic degradation of crude oil may be an important process for removing certain components of oil from the environment (Fathalla, 2007), although the rate at which abiotic degradation occurs is unclear. It is not clear whether the chemical dispersion of oil will have an influence on the rate of abiotic degradation of oil.

2.3 TRANSPORT OF DISPERSANTS AND DISPERSED OIL

Vertical transport of dispersants and dispersed oil is limited by density gradients within the water column that are controlled by temperature and salinity. Temperature gradients are referred to as thermoclines, and the salinity gradient is referred to as the pycnocline; each represents a density barrier against sea water mixing. Typically, the pycnocline is between 5 and 10 m below the ocean's surface (NOAA, 2012), and thermoclines exist even deeper (i.e., 100 m or more). The presence of density barriers does not hinder the dilution of dispersants and dispersed oil over time, because in addition to being transported vertically to approximately 10 m deep, dispersants and dispersed oil are transported horizontally (both longitudinally with currents and laterally through advection) (NRC, 2005; NOAA, 2012).

Horizontal transport of dispersants and dispersed oil is largely driven by ocean currents. It has been noted that the spread of oil across the ocean's surface can increase rapidly after dispersant application (preceding dispersion into the water column) (NRC, 2005), and that dispersants sprayed at the edge of a slick can cause oil to be herded, somewhat decreasing the slick area (Fingas, 2008). The long-distance transport of dispersants was studied by Kujawinski et al. (2011), who observed DOSS, a component of Corexit® dispersant formulations, after application in deep water (900 to 1,400 m) during DHOS. DOSS was measured within plumes of dispersed oil and gas from the point of application up to 315 km away at a detectable concentration (0.07 ppb) as many as 64 days after application of dispersants ceased. The transport of dispersant components within oil plumes is expected due to the known partitioning characteristics of the surfactant components of Corexit® formulations, as well as the creation of surfactant micelles (Figure 1) (TOXNET, 2011; Nalco, 2005, 2010). It has been noted that at very dilute concentrations of dispersant, surfactants slowly partition into the water column from dispersant-oil micelles (or are degraded) and are lost from the dispersion process (Fingas, 2008). Although long-distance transport was observed after DHOS, that particular event may not be a relevant case study for response actions in Alaska, because the application of chemical dispersants at the Macondo wellhead (during DHOS) represented an atypical response action, one that is not being assessed as part of this evaluation.

The buoyancy of dispersed oil droplets is driven by their size (i.e., diameter), such that smaller droplets disperse deeper and rise to the surface more slowly than larger droplets (NRC, 2005). In the event that a stable suspension of oil droplets in water does not form, which can be common (Fingas, 2008), dispersed oil tends to remain in the water column for between 4 and 24 hours before resurfacing (Fingas, 2008).

Crude or dispersed oils, in the presence of suspended sediment, can form OMA, which are either buoyant (i.e., remain in the water column) or settle out into benthic habitats (Fingas, 2008; Lee et al., 2008; Khelifa et al., 2008; Zhengkai et al., 2007). The formation of OMA is typically greatest in nearshore, estuarine habitats, or other areas with increased suspended sediment (Lee et al., 2008; Khelifa et al., 2008; Zhengkai et al., 2007). Settling of OMA out of the water column may result in increased exposures of demersal fish and benthic or epibenthic invertebrate species or benthic invertebrate prey items. Chemically dispersed oil tends to form smaller OMA particles (than OMA formed with physically dispersed crude oil) (Zhengkai et al., 2007; Lee et al., 2008), which can settle out to a greater extent than crude oil-based OMA particles (Khelifa et al., 2008). Based on recent modeling of OMA settling and the potential risk to benthic species posed by the sedimentation of OMA, it was concluded that OMA formed under natural conditions (i.e., baseline condition) poses no risk to benthic invertebrates,[14] but that the application of chemical dispersants may increase that risk by increasing the rate of sedimentation (Niu and Lee, 2013). For this to occur, chemical dispersants would need to be applied in nearshore habitats, which is not likely to occur (Table 2-1 of the EFH assessment), or in open water, after which the dispersed plume could then move into the nearshore environment where OMA could form.

[14]Risk was evaluated for a simulated oil spill (1000 metric tons), resulting in the natural formation and sedimentation of OMA without the addition of chemical dispersants.

Based on the dilution modeling conducted by Nedwed (2012), Gallaway et al. (2012), and Mackay and McAuliffe (1988) (Section 2.1, Figure 2), 4 to 24 hours is sufficient to greatly dilute the concentrations of dispersant and dispersed oil. Lewis et al. (1995) also showed that subsequent sprayings can increase the effectiveness of dispersion when oil resurfaces quickly. Although the resurfacing of oil may be of concern for aquatic wildlife (e.g., birds and mammals), it may result in reduced exposures of managed fish and invertebrate species in the water column and their EFH. Repeated sprayings would assumedly increase the amount of dispersants and dispersed oil in EFH.

2.4 Potential for Exposure of Managed Species and EFH

2.4.1 Potential for exposure based on EFH information and life history

Based on the discussion provided in Sections 2.1 through 2.3, it is expected that the exposure of managed fish and invertebrate species (and their EFH) to chemical dispersants and chemically dispersed oil will be largely restricted to the upper 10 m of the water column but that exposure to crude oil will be restricted to the upper 1 m of the water column. Thus the application of chemical dispersants to an oil spill will increase aqueous concentrations of petroleum hydrocarbons (in addition to components of chemical dispersants) below an oil spill (i.e., up to 10 m rather than 1 m of the water column); concentrations will diminish with time to < 1 ppm after 24 hours (Humphrey et al., 1987a) or less (i.e., ≤ 4 hours) (Bejarano et al., 2014). It is possible that dispersed oil concentrations will be sufficient to cause adverse impacts in sensitive species and life stages (i.e., small pelagic, epipelagic, and/or neustonic planktonic prey species or eggs or larvae of managed species) over this short period. Although adults and juveniles of some species (e.g., salmon shark [*Lamna ditropis*], cod species) may also be exposed at shallow depths, it is assumed that early life stage individuals are the most sensitive to chemical perturbations (Mohammed, 2013). Therefore, the assessment of early life stages rather than mature life stages is expected to result in a more conservative assessment of potential impacts. Older individuals are assumed to be less sensitive than younger individuals, because older individuals may have more developed detoxification systems and/or greater mobility to avoid contaminated areas (Mohammed, 2013), as well as more pigmentation in external tissues, which will reduce the severity of photo-enhanced toxicity of PAHs (Barron and Ka'aihue, 2001; Barron et al., 2008).

Although chemical dispersants, if used, are applied before an oil plume reaches sensitive shorelines, currents may carry chemically dispersed oil and dispersants into such areas. Therefore, species (at specific life stages) that utilize intertidal/shoreline and nearshore (subtidal) habitat for spawning or rearing may be exposed to dilute concentrations of chemically dispersed oil. Also, the potential exists for demersal and benthic species in those same shallow habitats to be exposed to increased OMA as a result of chemical dispersion (Niu and Lee, 2013).

In order to assess the potential for exposure of managed fisheries to oil, dispersants, and chemically dispersed oil for this EFH assessment, life history, EFH, behavior (e.g., migration), and feeding and reproductive habits data from the literature (including FMPs)[15] were compiled for managed species. Each species was assigned a potential for exposure to chemicals, depending on where and at what life stage each species is found in the water column, as well as the depth to which untreated or dispersed oils are likely to be found in the event of a spill (and subsequent chemical dispersant application). The rationale for assigning potential for exposure was as follows:

- Shallow-dwelling pelagic, epipelagic, and/or neustonic species were assumed to have a **high potential** for exposure (i.e., assumed to be present in the upper 10 m of the water column) to crude oil or dispersed oil.
- Pelagic species in relatively shallow areas (e.g., beaches, bays, estuaries, inner continental shelf, etc.) but unknown if in the top 10 m of the water column were assumed to have the **potential** to be exposed to dispersed oil, but are not expected to have the potential for exposure to crude oil**.**
- Pelagic species that exhibit diel movements (e.g., squid species) were assumed to have a **high potential** for exposure (e.g., during nighttime feeding) to dispersed or crude oils.
- Demersal species in very shallow waters (e.g., intertidal/shorelines or nearshore/subtidal) were assumed to have the **potential** for exposure to dispersed oil, but do not have the potential for exposure to crude oil.
- Demersal species in fairly shallow waters (e.g., inner continental shelf, bays, estuaries, etc.) were assumed to have **no/low potential** for exposure to either dispersed or crude oils. It is improbable but not impossible for these individuals to be exposed to chemically dispersed oil due to their depth, but it is virtually impossible for these individuals to be exposed to crude oil.
- Pelagic species in deeper areas (e.g., mid- to outer continental shelf and other open waters) were assumed to have a **potential** for exposure to dispersed oil (specific to the species, based on available information); there is not expected to have the potential for exposure of these species to crude oil**.**
- Demersal species in deeper areas (e.g., mid- to outer continental shelf and other open waters) were assumed to have **no potential** for exposure to either dispersed or crude oils**.**

[15] Sources include: Campana (1996); Dunn and Matarese (1987); EOL (2014a, b); Gotthardt et al. (2005); ICES/GLOBEC (2005); (NMFS, 2005a); Matta and Anderl (2012); (NMFS, 2005b, c, d, e, 2011, 2012, 2013a, b); NMFS (2014); NOAA (2014); NPFMC (2009); Orr et al. (2000); Orr and Matarese (2000); PFMC (2005); Villanueva et al. (1997); Woodford and Donohue (2007); Young (2013); Zavolokin et al. (2007)

- Egg life stage individuals of ovoviviparous species (e.g., *Sebastes* spp., sharks) were assigned the **same potential for exposure as adult** life stage.
- If little or no data were available for a species at a given life stage, the potential for exposure was stated to be **unclear** (Table 2).[16]
- Only species that are present at a very shallow position in the water column (i.e., < 1 m depth) were expected to be exposed to crude oil under the baseline condition. It was assumed that they have a **high potential** for exposure.

Based on the review of available data, it appears that relative to other life stages, the larvae of many of the managed species have the highest potential to be exposed to crude oil (under the baseline condition), chemical dispersants, and chemically dispersed oil, because larvae tend to be planktonic, pelagic, and, in some cases, neustonic (very shallow in the water column) (NMFS, 2014, 2013b, a, 2012, 2011; NPFMC, 2009); only species or life stages found within the upper 1 m of the water column are expected to be exposed to crude oil (i.e., high potential for exposure). The eggs or embryonic life stages of several managed species may also be exposed; for example, Pacific sand lance [*Ammodytes hexapterus*] spawn in intertidal habitat (Gotthardt et al., 2005) that may be exposed to crude oil (under the baseline condition) or dilute, chemically dispersed oil that washes ashore. Juveniles and adult life stages of many managed species settle into deeper waters (e.g., crabs, scallops, rockfish species, etc.), and several managed species are not expected to move into shallow waters (where they could be exposed to chemically dispersed oil) at any point in their life cycle (e.g., vampire squid [*Vampyroteuthis infernalis*], *Japetella diaphana* [a species of octopus]) (Young, 2013; EOL, 2014b). Conversely, managed salmon species spend their time as eggs/embryos, larvae (i.e., alevin, fry), and early juveniles (i.e., parr) in freshwater streams (where it is not appropriate to apply dispersants), emerging into estuaries and other marine habitats as early to late juveniles (e.g., smolt) (NMFS, 2012). Other species that have a greater potential for exposure as adults include squid (e.g., during diel migration) and Eastern Pacific red octopus (*Octopus rubescens*) (NMFS, 2013a). The potentials for exposure of managed fish and invertebrate species at various life stages are provided in Table 2.

It is important to note that the depth ranges and habitat associations reported in FMPs are broad and encompass areas that might or might not be impacted by crude oil, chemical dispersants, and/or chemically dispersed oil. For example, flatfish larvae tend to be present between depths of 0 and 200 m (NMFS, 2013a, b),[17] including depths

[16] For several species, the potential for exposures to crude or dispersed oils at early life stages (i.e., egg or larvae) was unclear. For the purpose of making a definitive statement regarding the potential for impacts on these species (due to exposures at early life stages) (Section 4), surrogate species information was used to assign an expected potential for exposure. This is discussed in Section 2.4.1.

[17] Possible exceptions include Kamchatka flounder, which are generally found at depths that exceed 200 m during all life stages (NMFS, 2013a)

that would be impacted under the baseline condition (0 to 1 m) or by dispersants and dispersed oil (0 to 10 m) as well as depths in excess of 10 m. Many larval fishes make diel vertical migrations (Busby et al., 2000) so they may move into shallower habitat in search of prey each day. Depending on the species and area from which larvae disperse, depth and habitat associations may vary somewhat, further complicating the determination of the potential for chemical exposure, particularly for broadly distributed larvae. Although there is uncertainty in such determinations (Table 2), the literature provides enough information to make reasonable estimates of exposure following the rationale provided above.

For those managed species lacking sufficient data regarding EFH or habitat associations at specific life stages, information was drawn from other managed species similar enough to be considered surrogates. The potential for the exposure of saffron cod (*Eleginus gracilis*) was uncertain for the larval life stage (NMFS, 2013a; NPFMC, 2009), and the potential for exposure for warty sculpin (*Myoxocephalus verrucosus*) was uncertain for the egg life stage (NMFS, 2013a). Saffron cod are assumed to have a high potential to be exposed as larvae to crude oil or chemically dispersed oil because surrogate species (e.g., Arctic [*Arctogadus glacialis*] and Pacific [*Gadus macrocephalus*] cods) have planktonic (or potentially neustonic) larvae that also have a high potential to be exposed to crude or dispersed oils (NMFS, 2005c, d, 2013a, b; NPFMC, 2009). Warty sculpin are assumed to be similar to other species of the genus *Myoxocephalus*, in that they likely lay their eggs in demersal nests and remain with the eggs until hatching (NMFS, 2013b, a, 2005c, d). The surrogate information noted above is reflected in the potential for exposure of saffron cod and warty sculpin in Table 2.

Table 2. Potential for exposure of managed fisheries based on life history and EFH

Common Name	Species	Potential for Exposure by Life Stage			
		Egg	Larvae	Juvenile	Adult
Alaska plaice	*Pleuronectes quadrituberculatus*	potential	**high potential**[a]	**high potential**	no potential
Alaska skate	*Bathyraja parmifera*	no potential	no potential	no potential	no potential
Aleutian skate	*Bathyraja aleutica*	no potential	no potential	no potential	no potential
Arctic cod	*Arctogadus glacialis*	no potential	**high potential**	potential	**high potential**
Arrowtooth flounder	*Atheresthes stomias*	potential	**high potential**[a]	no/low potential	**high potential**
Atka mackerel	*Pleurogrammus monopterygius*	potential	**high potential**	potential	**high potential**
Bering Sea scallop	*Chlamys behringiana*	no/low potential	potential	no potential	no potential
Bering skate	*Bathyraja interrupta*	no potential	no potential	no potential	no potential
Bigmouth sculpin	*Hemitripterus bolini*	no/low potential	**high potential**	no potential	no potential
Blackspotted rockfish	*Sebastes melanostictus*	no potential	potential	potential	no potential
Blue king crab	*Paralithodes platypus*	no potential	**high potential**	no potential	no potential
Boreal clubhook squid	*Onychoteuthis borealjaponica*	no potential	**high potential**	**high potential**	**high potential**
Butter sole	*Isopsetta isolepis*	potential	**high potential**[a]	**high potential**	no/low potential
Butterfly sculpin	*Hemilepidotus papilio*	no/low potential	**high potential**	no potential	no potential
Canary rockfish	*Sebastes pinniger*	no potential	potential	no potential	no potential
Capelin	*Mallotus villosus*	**high potential**	**high potential**	**high potential**	**high potential**
China rockfish	*Sebastes nebulosus*	no potential	potential	**high potential**	no potential
Chinook salmon	*Oncorhynchus tshawytscha*	no potential	no potential	**high potential**	**high potential**
Chum salmon	*Oncorhynchus keta*	no potential	no potential	**high potential**	**high potential**
Coho salmon	*Oncorhynchus kisutch*	no potential	no potential	**high potential**	**high potential**
Copper rockfish	*Sebastes caurinus*	no potential	potential	**high potential**	no potential
Dover sole	*Microstomus pacificus*	potential	**high potential**[a]	**high potential**	no potential
Dusky rockfish	*Sebastes variabilis*	no potential	potential	no potential	no potential
Eastern Pacific bobtail squid	*Rossia pacifica*	no potential	**high potential**	no/low potential	no/low potential

Common Name	Species	Potential for Exposure by Life Stage			
		Egg	Larvae	Juvenile	Adult
Eastern Pacific red octopus	*Octopus rubescens*	no potential	no potential	**high potential**	**high potential**
English sole	*Parophrys vetulus*	potential	**high potential**[a]	**high potential**	no/low potential
Eulachon	*Thaleichthys pacificus*	no potential	**high potential**	**high potential**	**high potential**
Flapjack octopus	*Opisthoteuthis californiana*	no potential	potential	no potential	no potential
Flathead sole	*Hippoglossoides elassodon*	potential	**high potential**[a]	no/low potential	no potential
Giant or robust clubhook squid	*Moroteuthis robusta*	no potential	**high potential**	no potential	no potential
Giant Pacific octopus	*Enteroctopus dofleini*	no potential	potential	potential	potential
Golden king crab	*Lithodes aequispina*	no potential	**high potential**	no potential	no potential
Great sculpin	*Myoxocephalus polyacanthocephalus*	no potential	**high potential**	**high potential**	no potential
Greenland turbot	*Reinhardtius hippoglossoides*	no/low potential	**high potential**	no potential	no potential
Grooved Tanner crab	*Chionoecetes tanneri*	no potential	**high potential**	no potential	no potential
Kamchatka flounder	*Atheresthes evermanni*	no/low potential	no/low potential[a]	no potential	no potential
Longhead dab	*Pleuronectes proboscidea*	potential	**high potential**[a]	**high potential**	no potential
Longspine thornyhead rockfish	*Sebastolobus altivelis*	potential	potential	no/low potential	no potential
none	*Graneledone boreopacifica*	no potential	no potential	no potential	no potential
none	*Japetella diaphana*	no potential	no potential	no potential	no potential
none	*Octopus* sp. Jorgensen	no potential	no potential	no potential	no potential
none	*Benthoctopus oregonensis*	no potential	no potential	no potential	no potential
North Pacific bigeye octopus	*Octopus californicus*	no potential	no potential	no potential	no potential
Northern rock sole	*Lepidopsetta polyxystra*	no potential	**high potential**[a]	**high potential**	no potential
Northern rockfish	*Sebastes polyspinus*	no potential	potential	no potential	no potential
Pacific cod	*Gadus macrocephalus*	no potential	**high potential**	**high potential**	no potential
Pacific ocean perch	*Sebastes alutus*	no potential	no/low potential	no/low potential	no potential
Pacific sand lance	*Ammodytes hexapterus*	**high potential**	**high potential**	potential	potential
Pacific sleeper shark	*Somniosus pacificus*	no/low potential	na[b]	no/low potential	no/low potential
Pink salmon	*Oncorhynchus gorbuscha*	no potential	no potential	**high potential**	**high potential**

Common Name	Species	Potential for Exposure by Life Stage			
		Egg	Larvae	Juvenile	Adult
Pink scallop	*Chlamys rubida*	no/low potential	potential	no potential	no potential
Plain sculpin	*Myoxocephalus jaok*	no/low potential	**high potential**	**high potential**	potential
Quillback rockfish	*Sebastes maliger*	no potential	potential	**high potential**	improbable
Red Irish lord	*Hemilepidotus hemilepidotus*	**high potential**	**high potential**	**high potential**	no potential
Red king crab	*Paralithodes camtschaticus*	no potential	**high potential**	no potential	no potential
Red or magistrate armhook squid	*Berryteuthis magister*	no potential	no potential	**high potential**	**high potential**
Rex sole	*Glyptocephalus zachirus*	potential	**high potential**[a]	no/low potential	no potential
Rock scallop	*Crassadoma gigantean*	no/low potential	potential	no potential	no potential
Rosethorn rockfish	*Sebastes helvomaculatus*	no potential	potential	no potential	no potential
Rougheye rockfish	*Sebastes aleutianus*	no potential	potential	no potential	no potential
Sablefish	*Anoplopoma fimbria*	no potential	**high potential**	**high potential**	no potential
Saffron cod	*Eleginus gracilis*	no/low potential	**high potential**[c]	**high potential**	**high potential**
Salmon shark	*Lamna ditropis*	potential	na[b]	potential	potential
Sand sole	*Psettichthys melanostictus*	potential	**high potential**[a]	**high potential**	no/low potential
Scarlet king crab	*Lithodes couesi*	no potential	**high potential**	no potential	no potential
Shortraker rockfish	*Sebastes borealis*	no potential	potential	no potential	no potential
Shortspine thornyhead rockfish	*Sebastolobus alascanus*	potential	potential	no/low potential	no potential
Smoothskin octopus	*Benthoctopus leioderma*	no potential	no potential	no potential	no potential
Snow crab	*Chionoecetes opilio*	no potential	**high potential**	no potential	no potential
Sockeye salmon	*Oncorhynchus nerka*	no potential	no potential	**high potential**	**high potential**
Southern rock sole	*Lepidopsetta bilineata*	no potential	**high potential**[a]	**high potential**	no potential
Spiny dogfish	*Squalus acanthias*	potential	na[b]	potential	no/low potential
Spiny scallop	*Chlamys hastata*	no/low potential	potential	no potential	no potential
Starry flounder	*Platichthys stellatus*	**high potential**	**high potential**[a]	**high potential**	no/low potential
Tanner crab	*Chionoecetes bairdi*	no potential	**high potential**	no potential	no potential
Tiger rockfish	*Sebastes nigrocinctus*	no potential	potential	no potential	no potential

Common Name	Species	Potential for Exposure by Life Stage			
		Egg	Larvae	Juvenile	Adult
Triangle Tanner crab	*Chionoecetes angulatus*	no potential	**high potential**	no potential	no potential
Vampire squid	*Vampyroteuthis infernalis*	no potential	no potential	no potential	no potential
Walleye pollock	*Theragra chalcogramma*	potential	potential	**high potential**	no potential
Warty sculpin	*Myoxocephalus verrucosus*	no/low potential[c]	**high potential**	no potential	no potential
Weathervane scallop	*Patinopecten caurinus*	no/low potential	potential	no potential	no potential
White scallop	*Chlamys albida*	no/low potential	potential	no potential	no potential
Yellow Irish lord	*Hemilepidotus jordani*	potential	**high potential**	no potential	no potential
Yelloweye rockfish	*Sebastes ruberrimus*	no potential	potential	no potential	no potential
Yellowfin sole	*Limanda aspera*	potential	**high potential**[a]	**high potential**	no/low potential

Sources: Campana (1996); Dunn and Matarese (1987); EOL (2014a, b); Gotthardt et al. (2005); ICES/GLOBEC (2005); NMFS (2005a); Matta and Anderl (2012); NMFS (2005b, c, d, e, 2011, 2012, 2013a, b, 2014); NOAA (2014); NPFMC (2009); Orr et al. (2000); Orr and Matarese (2000); PFMC (2005); Villanueva et al. (1997); Woodford and Donohue (2007); Young (2013); Zavolokin et al. (2007); Johnson et al. (2012); Abookire et al. (2000); Abookire and Piatt (2005); Busby et al. (2000); Alton et al. (1988); Brodeur and Rugen (1994)

[a] Based on available data, the distributions of larval flatfish (see sources above) are expected to overlap substantially and vary significantly depending on season, location, and time of day (i.e., diel movement). The potential for the chemical exposure of all flatfish species during an oil spill response action has been assumed to be similar (high potential for exposure), except for Kamchatka flounder, which are present below 200 m during all life stages (NMFS, 2013a).

[b] Shark species do not have a larval life stage.

[c] Saffron cod larvae are assumed to have a high potential for exposure based on other similar species of cod (e.g., Arctic cod, Pacific cod), which tend to be found near the ocean surface. Warty sculpin eggs are assumed to have a no or low potential for exposure based on other sculpin species (e.g., plain, great, and bigmouth sculpin), which lay eggs in demersal nests.

EFH – essential fish habitat

na – not applicable

Bold identifies the only relevant exposures for the evaluation of crude oil due to the shallow depth to which crude oil mixes into the water column (i.e., < 1 m) (NRC, 2005).

2.4.2 Potential for exposure and uncertainty regarding seasonality

There are several uncertainties associated with the potentials for exposure provided in Table 2. First, the potential for exposure for a species assumes that it is at a specific life stage during a spill event (and response action); the seasonality of fish life stages is not addressed in the potential for exposure evaluation (Table 2), possibly overestimating the potential for exposure. For example, Greenland turbot [*Reinhardtius hippoglossoides*] eggs in BSAI are laid primarily in fall and hatch to the larval life stage in spring (NMFS, 2013a). The embryonic and larval life stages each last a matter of months, after which juveniles settle out and become demersal. Conversely, salmon species are not present in the marine environment (where chemical dispersant could be applied) during early life stages (excluding juveniles [smolt]). Given the short time frame during which eggs or larvae would be exposed, seasonality is an important consideration for specific fisheries and EFH. However, based on the spawning seasons presented in the various FMPs or their appendices (NMFS, 2011, 2012, 2013a, b, 2014; NPFMC, 2009), it is reasonable to assume that at least one managed species at an early life stage will be present in Alaskan waters during any given season. Therefore, adverse impacts may occur for at least one managed fishery at any given time as a result of an oil spill (i.e., baseline condition) and subsequent chemical dispersant application.

Based on the investigation of historical oil spill data from January 1995 to August 2012 (including an evaluation of seasonal trends) presented in Appendix D to the BA (Windward and ERM, 2014), it was determined that non-crude oil (e.g., diesel fuel) is spilled in the marine environment primarily during summer in the Aleutian Islands and southeast Alaska. Although crude oil is spilled very infrequently in the marine environment, it is spilled most often during fall and winter in Cook Inlet. Spills in western Alaska (e.g., Bering Sea) are infrequent during all seasons, as are spills along the North Slope into Arctic waters. Non-crude oil is spilled in the GOA somewhat more often off Kodiak Island than in the North Slope or Bering Sea, mostly occurring in January but also in August and September.

Historically, the largest spills of petroleum to aquatic environments in Alaska include the Exxon Valdez oil spill (EVOS) in 1989, which impacted PWS, Cook Inlet, GOA, and Kodiak Island, and the M/V *Selendang Ayu* incident in 2004, which occurred in the Aleutian Islands (i.e., Unalaska Island).

3 Toxicity and Sensitivity

The purpose of this section is to evaluate the sensitivities of managed species (or reasonable surrogates for managed species) of fish and invertebrates, as well as species that could be considered prey items (e.g., plankton), to crude oil, chemical dispersants, and chemically dispersed oil. In Section 3.1, the available toxicity data for fish and invertebrates (as well as aquatic plants, as available) is discussed; the data are provided in Attachment B-1 to Appendix B of the BA (Windward and ERM, 2014).

In Section 3.2, the acute toxicological data are organized into SSDs, which are a common way of evaluating and graphically showing the relative sensitivity of different species to the same chemical (Figures 3 through 7) and/or to multiple chemicals (Figures 8 and 9); SSDs are also used to establish protective short-term exposure thresholds called hazardous concentrations (HCs), typically reported as the 5th percentile of the SSD (or the HC5) (Posthuma et al., 2002). For the purposes of this evaluation of oil, dispersants, and chemically dispersed oil, the SSDs are primarily used to compare the acute toxicities of the various chemical mixtures (Section 3.3), and to establish a concentration for each mixture above which adverse impacts may be expected in the most sensitive, early life stage and/or planktonic species, which is intended to represent sensitive prey species, in general.

Additional discussion of the various uncertainties associated with the use of SSDs and the HC5 for assessing the potential for adverse impacts on managed species or the community as a whole is provided in Sections 3.4 and 3.5.

Conclusions specifically regarding the sensitivities of managed species of fish and invertebrates to oil, dispersants, and chemically dispersed oil are provided in Section 3.6. The information provided in that section omits toxicological data regarding unrelated species; these are included in the discussions in Section 3.1 and in the development of SSDs and HC5s in Section 3.2. Conclusions regarding the potential for adverse impacts are not included in Section 3, which deals entirely with toxicity data without incorporating essential information about the potential for exposures presented in Section 2. The synthesis of exposure and effects data is provided in Section 4.

3.1 Toxicity Data

Many of the toxicological studies from which data were compiled for this analysis were conducted with established test species (e.g., mysids, daphnids, and inland silverside [*Menidia beryllina*]), which are sensitive to chemical perturbation and are relatively short-lived (e.g., compared to *Sebastes* spp.). The majority of test species were exposed at an early life stage, the goal being to observe the response in each species at its most sensitive stage of development. Such studies are conducted to determine the relative toxicity of a chemical (or a mixture) compared to other chemicals, or to address the relative sensitivities of many species or groups of species (i.e., genera) to a single chemical. Of the species included in the SSDs, only the following are managed under an FMP: saffron cod, tanner crab (*Chionoecetes bairdi*), red king crab (*Paralithodes camtschaticus*), great sculpin (*Myoxocephalus polyacanthocephalus*), starry flounder (*Platichthys stellatus*), walleye pollock (*Theragra chalcogramma*), and pink, coho, sockeye, and Chinook salmon (*Oncorhynchus gorbushca, O. kisutch, O. nerka*, and *O. tshawytscha*, respectively). Among these, only Chinook salmon had directly comparable oil and dispersed oil toxicity data.[18] Many other test species are considered reasonable surrogates for managed species or prey of managed species, and food web interactions are discussed in this EFH assessment as applicable; for example, HC5s are considered applicable to the entire community of early life stage and planktonic species, any of which could be prey (or reasonable surrogates for prey) for managed species.

3.1.1 Toxicity data acceptability criteria for developing SSDs

Acute aquatic toxicity values were compiled from the literature available for dispersants and dispersed oil, as summarized in Attachment B-1 to Appendix B of the BA (Windward and ERM, 2014). SSDs for each mixture were developed using the median lethal concentrations (i.e., concentrations that are lethal to 50% of an exposed population) (LC50s) for exposure durations of between 48 and 96 hours for all species, with either constant concentration (i.e., static, static renewal, and flow-through) or spiked exposures.[19] Only 96-hour exposures were included for larval or juvenile fish, but 48-hour exposures were included for embryonic or embryo-larval fish; only 4 48-hour LC50 values were included for 3 fish species (i.e., Atlantic menhaden [*Brevoortia tyrannus*], spot croaker [*Leiostomus xanthurus*], and red drum [*Sciaenops ocellatus*]). Although the embryo-larval red drum toxicity data suggests that the test species were relatively insensitive to Corexit® 9500 after 48 hours in comparison to other species, red drum were relatively moderately sensitive to Corexit® 9527, crude oil, and the mixtures of Corexit® 9500 with oil.[20] Neither embryo-larval spot croaker nor embryo-larval Atlantic menhaden appeared to be less sensitive to Corexit® 9527 relative to other species based on a 48-hour exposure.

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[18] Median lethal concentrations were directly comparable, in that the endpoints and exposure durations were the same, the species were the same, and the exposure scenarios were the same. Dispersed oil was less toxic than oil alone to Chinook salmon (Lin et al., 2009; Moles et al., 1979 as cited in Barron et al., 2013; Van Scoy et al., 2010).

[19] Spiked exposures are similar to static renewal exposures or flow-through exposures (depending on the particular method) (Rhoton et al., 2001; Singer et al., 1990; Wetzel and Van Fleet, 2001), except that, in spiked exposures, a toxicant is added once during the test and allowed to diminish over time through the addition of clean water in renewals or flowing waters (i.e., flow-through exposure). In standardized static renewal and flow-through tests, one does not typically use clean water for renewals or flowing water, but rather adds water similar to the initial exposure medium in order to maintain an approximately stable concentration over the entire exposure duration.

[20] Data were not available for exposures of red drum to Corexit® 9527-dispersed oil.

Spiked exposures, which simulate dilution over time, are typically considered most applicable for evaluating the toxicity of a chemical dispersant as used in the field (Clark et al., 2001), although they were not the most frequently used exposure method in the literature (Attachment B-1 to Appendix B of the BA). Static exposures may also result in realistic exposure scenarios applicable to a chemical dispersant application of oil, although that exposure method does not simulate dilution over time. Repeated application of chemical dispersants (to ensure effective dispersion) may be mimicked during toxicity testing by static renewal or flow-through exposure scenarios rather than static or spiked exposures. Toxicity data using any of these exposure scenarios was considered valid for the development of SSDs. The inclusion of static, static renewal, or flow-through exposure data is expected to result in more protective HC5 values, because spiked exposures often result in much higher LC50 values than constant concentration exposure tests.

Aquatic plant and algae bioassays were included if they satisfied the other test criteria for inclusion noted above (e.g., duration and measured endpoint). Plants were not more or less sensitive to dispersants than other species, so their inclusion in the SSD did not apparently bias the SSDs.[21]

Both freshwater and saltwater species were used, particularly because of the availability of freshwater rainbow trout (*Oncorhynchus mykiss*) data, a useful surrogate for other salmon species. The inclusion of both types of species did not apparently affect the HC5 values.[22]

Although unbounded toxicity values (reported as inequalities, either "less than" or "greater than" the lowest or highest exposure concentration, respectively) are reported in the following sections, such values were not included in the development of the SSDs. Unbounded values provide useful information regarding the potential range of species' sensitivities; however, unbounded values cannot be ranked and, therefore, cannot be used to develop SSDs.

3.1.2 Acute lethality data

3.1.2.1 Corexit® 9527

Acute toxicity data for 48- and 96-hour exposures to Corexit® 9527 were compiled from 48 tests on 34 species within 31 different genera. Specifically, for invertebrates and aquatic plants, toxicity tests that lasted only 48 hours were included, because these

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[21] Exclusion of the plant species would not have resulted in the selection of a different best-fit model. Neither plant species was at the lower end of the distribution, and therefore did not affect the selection of the HC5.

[22] To test this bias, the HC5s were calculated using both freshwater and saltwater species, and then again omitting freshwater species. The calculated HC5 did not change, because the freshwater species tended to be less sensitive to dispersants and dispersed oil. The lower end of the SSD was composed of sensitive saltwater species.

species tend to have shorter periods of development than fish. Only 96-hour toxicity test data were included for fish species, with the exception of embryo-larval tests using Atlantic menhaden, red drum, and spot croaker (Fucik et al., 1995; Slade, 1982). Of the tests conducted, 2 used plants, 28 used invertebrates, and 18 used fish species. The observed LC50s were between 2.4 and 840 ppm. Only bounded data were included in the calculation of HC5s; unbounded values (i.e., LC50s reported as greater than the highest concentration tested or less than lowest concentration tested) were omitted. Tests were carried out under various water temperatures, each assumedly appropriate to the test species; therefore, not all tests are entirely applicable to Alaska waters. As applicable, Arctic and sub-Arctic Alaska species are identified and discussed below. Concentrations reported in this section are given as ppm Corexit® 9527.

Invertebrate species had more varied LC50s than did fish or plants. Green hydra (*Hydra viridissima*) and grass shrimp (*Palaemonetes pugio*) were the least sensitive invertebrate species and least sensitive species overall. Various crustaceans (*Allorchestes compressa, Pseudocalanus minutus,* and *Penaeus setiferus*) and Pacific oyster (*Crassostrea gigas*) were the most sensitive invertebrates and most sensitive species overall. The invertebrate species most similar to decapods covered under FMPs (i.e., tanner, king, and snow [*Chionoecetes opilio*] crabs) were blue crab (*Callinectes sapidus)*, ghost shrimp (*Palaemon serenus*), grass shrimp, and other shrimps/prawns (*Penaeus* spp.); LC50s ranged from 11.9 to 840 ppm for those decapods (Bussarawit, 1994; Fucik et al., 1995; Gulec and Holdway, 2000; NRC, 1989). The invertebrate species most similar to managed scallops, which are covered under their own FMP, were Pacific oyster and Pacific littleneck clam (*Protothaca staminea*); the LC50 values for those species were between 3.1 and 100 ppm, the clam being least sensitive (Clark et al., 2001; George-Ares and Clark, 2000; Hartwick et al., 1982). There are no useful toxicity data for Corexit® 9527 for squid or octopus species.

Generally, fish were less sensitive than invertebrates and as sensitive as plant species. Of the fish tested, European flounder (*Platichthys flesus*) were the most similar to managed flatfish (e.g., flounder, dab, sole, plaice, and turbot species); the LC50 for European flounder was 100 ppm (Baklien et al., 1986). Tests with rainbow trout, which are reasonable surrogates for managed salmon species, resulted in LC50s of 96 and 260 ppm (Doe and Wells, 1978; Wells and Doe, 1976). Smaller fish species (i.e., topsmelt [*Atherinops affinis],* inland silverside, Atlantic menhaden, fathead minnow *[Pimephales promelas],* and common mummichog *[Fundulus heteroclitus]*) (Bricino et al., 1992; Clark et al., 2001; Fucik et al., 1995; George-Ares and Clark, 2000; Nalco, 2010; Pace and Clark, 1993; Singer et al., 1990; Singer et al., 1991), which are functionally similar to managed forage fish such as capelin, eulachon, and Pacific sand lance, had a wide range of LC50 values, between 14.6 and 201 ppm. There are no useful toxicity data for Corexit® 9527 for skate, shark, sculpin, cod or sablefish, or rockfish species.

Two aquatic plant species were tested: a brown alga (*Phyllospora comosa)* and turtle grass (*Thalassia testudinum*). The 48-hour LC50 for the brown alga was 30 ppm (Burridge and Shir, 1995), and the 96-hour LC50 for turtle grass was 200 ppm (Baca and Getter, 1984). Algae and sea grasses contribute to fish and invertebrate habitat complexity (e.g., refuge or forage habitat, spawning substrate), and are also directly consumed by herbivorous and omnivorous species.

3.1.2.2 Corexit® 9500

Acute toxicity data for 48- to 96-hour exposures to Corexit® 9500 were compiled from 48 tests with 26 species and 24 genera. Of the tests conducted, 26 used invertebrates and 22 used fish. The observed range of 48- to 96-hour LC50s was between 3.5 and 1,038 ppm, the highest values being for spiked exposures.

Invertebrates that were less sensitive to Corexit® 9527 included green hydra and Eastern oyster (*Crassostrea virginica*). Sensitive species included the amphipod *A. compressa*, copepods (*Eurytemora affinis* and *Tigriopus japonicus*), and red abalone (*Haliotis rufescens*). Of the invertebrates covered by FMPs, toxicity data were available for only tanner crab, which was used as a surrogate for other managed crabs; the LC50 values for tanner crab were 5.6 and 355 ppm from 96-hour static (daily) renewal and 96-hour spiked exposures, respectively (Rhoton et al., 2001). Bivalve toxicity data were available for Eastern oyster, which was used as a surrogate for managed scallops; the LC50 value for Eastern oyster was 167 ppm (Liu, 2003). There were no useful toxicity data for Corexit® 9527 for squid or octopus species.

Fish were generally less sensitive to Corexit® 9500 than to Corexit® 9527. Of the fish tested, rainbow trout and red drum were the least sensitive; rainbow trout had a 96-hour LC50[23] of 354 ppm (George-Ares and Clark, 2000), and red drum had a 96-hour spiked LC50 of 744 ppm. Other relatively insensitive species included the sheepshead minnow (*Cyprinodon variegatus*) and gulf killifish (*Fundulus grandis*). In addition, some tests, but not all, indicated inland silverside to be relatively insensitive. Toxicity data for rainbow trout and turbot (*Scophthalmus maximus*) were considered surrogate information for managed salmon and flatfish species, respectively; the LC50 for turbot was 74.7 ppm (George-Ares and Clark, 2000), and the LC50 for rainbow trout was 354 ppm. The data from various forage fish (e.g., small-mouthed hardyhead [*Atherinosoma microstoma],* sheepshead minnow, gulf killifish, mummichog, and inland silverside) were used as surrogates for functionally similar species of forage fish (i.e., eulachon, capelin, and Pacific sand lance); LC50s for small forage fish ranged from 7.6 to 593 ppm (Edwards et al., 2003; Fuller et al., 2004; Fuller and Bonner, 2001; Hemmer et al., 2011, 2010; Inchcape, 1995; Liu, 2003; Marine and Freshwater Resources Institute, 1998; Rhoton et al., 2001; Wetzel and Van Fleet, 2001).

[23] The exposure type was not reported (George-Ares and Clark, 2000), although it is assumed to not be a spiked exposure; spiked exposures were specifically reported for other species, but not for rainbow trout (George-Ares and Clark, 2000)

Most laboratory toxicity tests use temperate or warm-water species, warm exposure conditions (i.e., 20 to 25°C), and variable exposure scenarios or test types. There is a paucity of data representing conditions similar to Alaska waters. Recent tests by McFarlin et al. (2011) were conducted under conditions that would be observed during an oil spill response in Alaska. These tests incorporated cold-water temperatures, spiked exposures, and Arctic test species.

An earlier study, conducted by Ordzie and Garofalo (1981) with Corexit® 9527, reported 6-hour LC50s between 200 ppm at 20°C and 2,500 ppm at 2°C. This toxicity test was conducted using temperatures similar to those in Alaska waters and an appropriate exposure duration, but using a test species (a scallop [*Argopecten irradians*]) not present in Alaska.[24]

The following studies used species that may be present in Alaska, or tested species under conditions approximating the application of dispersant under Arctic field conditions:

- Clark et al. (2001) reported an LC50 of 13.9 ppm Corexit® 9527 for larval Pacific oyster using a 48-hour spiked exposure system. The Pacific oyster is found in Alaska, although it is a non-native species primarily valued for aquaculture.
- Clark et al. (2001) determined a spiked 48-hour LC50 of > 1,055 ppm Corexit® 9500 for turbot, a fish present in the North Atlantic. This value is unbounded, and was therefore not included in the SSD.
- Nalco (2005, 2010) determined 96-hour LC50s of 75 ppm Corexit® 9500 and 50 ppm Corexit® 9527 for turbot.
- Rhoton et al. (2001) reported a 96-hour LC50 of 355 ppm Corexit® 9500 for larval tanner crab in a spiked exposure scenario.
- Duval et al. (1982; cited in NRC, 2005) reported a 96-hour exposure LC50 of > 1,000 ppm Corexit® 9527 for the isopod *Gnorimosphaeroma oregonensis*, which can be found in intertidal areas of Alaska. This value is unbounded, and therefore was not included in SSD.
- Hartwick et al. (1982; cited in NRC, 2005) reported a 96-hour LC50 of 100 ppm Corexit® 9527 for Pacific littleneck clam, an important aquaculture species that is present throughout nearshore and intertidal areas of GOA and the Aleutian Islands.
- Foy (1982; cited in NRC, 2005) reported 96-hour LC50s[25] for four Arctic amphipod species—*Anonyx laticoxae, Anonyx nugax*, *Boeckosimus edwardsi*, and *Onisimus litoralis*—as well as an unidentified species within the genus

[24] The result may be useful for assessing the toxicity to managed scallops, which are in the same family as *A. irradians* (i.e., Pectinidae).
[25] None of the exposures were spiked exposures (Foy, 1982).

Boeckosimus. The LC50s were as follows: > 140 ppm for *A. laticoxae*, 97 to 111 ppm for *A. nugax*, > 80 ppm for *B. edwardsi*, > 175 ppm for *Boeckosimus* spp., and 80 to 160 ppm for *O. litoralis*. The same study reported 96-hour LC50s of < 40 and > 80 ppm Corexit® 9527 for fourhorn sculpin (*Myoxocephalus quadricornis*) and a copepod (*Gammarus oceanicus)*, respectively. Unbounded values were not included in the SSD.

- Rainbow trout 96-hour LC50 toxicity values were reported by Wells and Doe (1976; cited in NRC, 2005) and by Doe and Wells (1978; cited in NRC, 2005) as being between 96 and 293 ppm Corexit® 9527.
- George-Ares and Clark (2000) reported a 96-hour LC50 of 354 ppm Corexit® 9500 for rainbow trout.

Not all studies listed herein report the temperatures at which exposures were conducted. It can be assumed that all studies were conducted under conditions appropriate to the test species, such that temperatures were not outside the species' tolerable limits.[26] Exposures of Alaska species using temperatures higher than those typically observed in Alaska could result in the overestimation of toxicity, based on the findings of Ordzie and Garofalo (1981), rather than an underestimate. Therefore, it is expected that the SSDs, which include both warm- and cold-water species, result in protective estimates of the HC5s (i.e., lower values).

3.1.2.3 Crude oil

In order for a definitive statement to be made regarding the change in toxicity due to the application of dispersants, it is important to establish the toxicity of crude oil relative to that of dispersants and dispersed oil.

A number of studies were compiled to characterize the toxicity of oil alone in an aquatic system. Oil toxicity data represent exposure durations between 48 and 96 hours with established test species. The same assumptions and limitations that applied to the dispersant toxicity data (Section 3.1.3) apply to this dataset. However, the interpretation of this dataset is less straightforward, because additional variables exist when dealing with oil, which is a complex mixture (and more variable than Corexit® formulations).

Lacking a singular source or composition, oil is expected to elicit variable acute responses in ecological receptors. More specifically, different types of oil have different fractions of toxic components, such as PAHs (Ramachandran et al., 2004). Each type of oil can be either fresh or weathered, depending on the time the oil has spent exposed to natural conditions (e.g., ultraviolet [UV] radiation, wind and water, biodegradation, and evaporation). Weathered oil tends to have fewer bioavailable

[26] This assumption is based on the use of a negative control treatment in each study that indicated the health or condition of the test species under the given test conditions.

components due to the volatilization and biodegradation of its lighter (and typically more acutely toxic) constituents (NRC, 2005; 2003b as cited in NRC, 2005; 2003a). This was a point of study by Barron et al. (2013), who developed SSDs and reported HC5 values for different oil types; HC5 values ranged from 0.285 to 3.53 ppm TPH, depending on the type of oil (Barron et al., 2013).

Unlike the toxicity datasets for dispersants or dispersed oil, the majority (56%) of species tested with oil alone were cold-water species. A total of 134 tests were conducted; 73 tests on invertebrates, and 61 tests on fish. A total of 59 species were tested, of which 34 were invertebrates and 25 were fish. A total of 45 genera were tested, of which 27 were invertebrates and 18 were fish. Approximately half of the species tested (as well as the groups of species or genera) are found in cold-water environments. Not all tests with cold-water species were conducted under cold-water conditions, but it is assumed that the exposure conditions were appropriate (i.e., tolerable range of temperatures) for the species.[27]

Two warm-water invertebrates (ghost shrimp and *A. compressa*) and one warm-water fish (Australian bass [*Macquaria novemaculeata*]) were found to have 96-hour LC50 values between 258,000 and 465,000 ppm TPH; these three LC50 values are more than three orders of magnitude greater than the fourth-least sensitive species (*T. japonicus*), and more than four orders of magnitude greater than the fifth-least sensitive genus (*Platichthys*). The four highest LC50 values (i.e., ghost shrimp, *A. compressa,* Australian bass, and *T. japonicus*) were confirmed as outliers using the interquartile range (IQR) method.[28]

When developing the SSD for crude oil (Section 3.2), two distributions were fit using the entire dataset, excluding the upper three and four data points.[29] The removal of the three (or four) highest data points resulted in the selection of a distribution that fit the entire dataset better, both visually and statistically (based on the Anderson-Darling statistic), than did a distribution using all data points. The statistical distribution was fit to the empirical SSD with the three highest LC50 values omitted to minimize (i.e., improve) the best-fit statistic and more realistically predict values at the lower end of the SSD. It is unclear, based on the studies available (Gulec and Holdway, 2000; Gulec et al., 1997), why the LC50 values for the removed outliers are substantially higher than those of other similar exposures.

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[27] This assumption is validated by the use of a negative control during toxicity testing. The control indicated the condition of the test species under the given exposure conditions.

[28] According to the range, outliers are defined between the 25th and 75th percentiles of the dataset (or the IQR), such that values greater than 1.5 or 3 times the IQR plus the 75th percentile value are considered outliers. The method also applies to low outliers that are less than 1.5 or 3 times the IQR below the 25th percentile.

[29] Removal of the fourth-highest data point resulted in no change in the best-fit distribution selected or the calculated HC5. The fourth-highest data point was left in the dataset to provide a more accurate calculation of the HC5 for crude oil.

After removing the three highest LC50 values, the least sensitive invertebrates were the copepod *T. japonicus* and a polychaete worm, *Platynereis dumerilli*. Relatively insensitive fish included starry and European flounder and topsmelt. Relatively sensitive invertebrates included pale octopus (*Octopus pallidus*), black chiton (*Katharina tunicate*), Alaska shrimp (*Crangon alaskensis*), and green hydra. The range of LC50 values at the genus level was between 0.39 and 124.3 ppm TPH (excluding the values between 258,000 and 465,000 ppm TPH). These values (i.e., 0.39 to 124.3 ppm TPH) are somewhat similar to those reported for dispersed oils (Section 3.3), although the SSDs and HC5s calculated in this appendix indicate that oil is slightly more acutely toxic (i.e., lethal) than dispersed oil. This finding is consistent with much of the literature, although contrary to what has been suggested in past literature reviews (Fingas, 2008; NRC, 2005) and many toxicity studies (Attachment B-1 to Appendix B of the BA) (Windward and ERM, 2014).

LC50 data for crude oil is specifically available for the following managed fish and invertebrate species:

- Saffron cod (2.2 ppm TPH) (Malins, 1977)
- Great sculpin (1.31 and 3.82 ppm TPH) (Rice et al., 1979)
- Red king crab (between 0.81 and 3.69 ppm TPH) (Malins, 1977; Rice et al., 1979; Moles et al., 1979)
- Starry flounder (1.8 ppm TPH) (Moles et al., 1979)
- Walleye pollock (1.73 ppm TPH) (Rice et al., 1979)
- Pink, coho, sockeye, and Chinook salmon (between 0.54 and 7.46 ppm TPH) (Lin et al., 2009; Malins, 1977; Moles et al., 1979; Rice et al., 1979; Van Scoy et al., 2010)

Reasonable surrogate data were available for managed cod species (e.g., Arctic cod) using Arctic cod (*Boreogadus saida*), or walleye pollock; the LC50 value for Arctic cod (*B. saida*) is 1.2 ppm (McFarlin et al., 2011) (or between 1.2 and 2.2 ppm TPH, based on the potential surrogate cod species). Starry flounder was considered a reasonable surrogate for other managed flatfish. Great sculpin and *Myoxocephalus* spp. were used as surrogates for other species of sculpin (e.g., red [*Hemilepidotus hemilepidotus*] and yellow [*Hemilepidotus jordani*] Irish lords and butterfly [*Hemilepidotus papilio*] and bigmouth [*Hemitripterus bolini*] sculpins); the LC50 value for *Myoxocephalus* spp. was 1.6 ppm TPH (McFarlin et al., 2011), which is within the range of LC50 values for great sculpin, noted above. Although fairly different taxonomically, *Myoxocephalus* spp. are the closest to rockfish species (e.g., *Sebastes* and *Sebastolobus* spp.) and sablefish (*Anoplopoma fimbria*) in terms of taxonomy;[30] *Myoxocephalus* spp. were used as

[30] Cottid sculpins and rockfish are both members of the order Scorpaeniformes. This group is fairly diverse and includes fish of varying sizes that inhabit various water bodies.

surrogates, but with great uncertainty. Data for a smaller forage fish surrogate, Pacific herring (*Clupea pallasii*), were used for estimating the sensitivity of early life stage Pacific sand lance, eulachon, and capelin; the LC50 value for Pacific herring was 1.22 ppm TPH.

Pale octopus was used as a surrogate for other octopus species (e.g., smoothskin [*Benthoctopus leioderm*], giant Pacific [*Enteroctopus dofleini*], North Pacific bigeye [*Octopus californicus*], and flapjack octopuses [*Opisthoteuthis californiana*], as well as the octopodiform *Vampiroteuthis infernalis*); the LC50 value for pale octopus was 0.39 ppm TPH (Long and Holdway, 2002). Red king crab data were used as a reasonable surrogate for other managed crabs (e.g., tanner, king, and snow crabs).

3.1.2.4 Corexit® 9527-dispersed oil

A number of studies were compiled to characterize the toxicity of dispersed oil in an aquatic system. Dispersed oil data represent exposure durations between 48 and 96 hours with established test species. The same assumptions and limitations that applied to dispersant toxicity data (Section 3.1.3) apply to this dataset. However, the interpretation of this dataset is less straightforward due to the complex nature of oil (Section 3.1.4), as well as the varied interaction of dispersant chemicals with different types of oil (Fingas, 2008).

Acute values that were used in the calculation of the SSD for Corexit® 9527-dispersed oil were based on the minimum calculated 48- to 96-hour LC50 value that was reported in each study. In other words, if a study reported several LC50 values after repeated tests, the lowest, most protective LC50 value was included in the SSD. Corexit® 9527-dispersed oil data were available from 29 tests with 13 different species, each from a different genus. This dataset is the smallest of those presented in this appendix, particularly due to the small number of species represented, of which only 2 are considered to be cold-water species. Of the tests performed, 8 were conducted with fish (5 different species), and 21 were conducted with invertebrates (8 different renewal tests[31] were available, with LC50s ranging from 0.74 to 28.5 ppm. Constant exposure 48- to 96-hour LC50s ranged from 0.11 to 75 ppm; excluding the maximum value for this exposure type (75 ppm), all other values were ≤ 1.09 ppm.

Although data for managed species were not available, surrogate data for several species were available. European flounder data were used as a surrogate for other flatfish, sole, and turbot species; the LC50 for European flounder was 75 ppm (Baklien et al., 1986). Pacific oyster was used as a surrogate for managed scallops; the LC50 values for Pacific oyster were between 0.5 and 2.28 ppm, with spiked exposures

[31] Static renewal is similar to a static exposure, in that the chemical is premixed with the exposure solution prior to testing. In a renewal test, the solution is periodically replaced with fresh solution (e.g., every 24 or 48 hours); the result is an exposure scenario whereby the chemical is maintained at a more constant concentration than under completely static conditions but is allowed to degrade for a period of time.

resulting in higher LC50 values (Clark et al., 2001). Although fairly different taxonomically, ghost shrimp was used as a surrogate for managed decapods (e.g., tanner, king, and snow crabs); the 96-hour LC50 for ghost shrimp was 8.1 ppm (Gulec and Holdway, 2000). For octopus, pale octopus was used as a surrogate; the 48-hour LC50 for pale octopus was 1.8 ppm (Long and Holdway, 2002). Although fairly different taxonomically, topsmelt, Australian rainbowfish (*Melanotaenia fluviatilis*), and inland silverside were used as surrogates for managed forage fish (e.g., capelin, eulachon, and Pacific sand lance); the LC50 values for topsmelt, Australian rainbowfish, and inland silverside ranged from 0.55 to 28.6 ppm, with spiked exposures resulting in higher LC50 values than static renewal or flow-through exposures. No surrogate data were available for sharks or skates, salmon, cod, sablefish, mackerel, pollock, rockfish, or sculpins.

3.1.2.5 Corexit® 9500-dispersed oil

Corexit® 9500-dispersed oil data were available for 51 tests with 18 different species, each from a different genus. Of these, 28 tests were conducted with fish (9 different species) and 23 with invertebrates (9 different species). LC50s ranged from 0.186 to 155.9 ppm as TPH. The geometric mean LC50s used to develop the SSD were between 1.37 and 76.0 ppm. Concentrations reported in this section represent the ppm of oil as TPH, modified in solution by Corexit® 9500.

LC50s from 27 spiked tests conducted with Corexit® 9500-dispersed oil ranged from 2.84 to 72.6 ppm. Clark et al. (2001) reported LC50s between 0.81 and 3.99 ppm dispersed oil for spiked exposures of Pacific oyster; a single LC50 of 48.6 ppm dispersed oil was reported for turbot under the same exposure conditions.

LC50s from 24 tests using static, static renewal, and flow-through exposure scenarios to Corexit® 9500-dispersed oil ranged from 0.19 to 155.9 ppm, the highest value being for Chinook salmon, a managed salmonid.

Five cold-water species or genera are represented in the dataset, three fish (sculpin [*Myoxocephalus* spp.], Arctic cod [*B. saida*], and Chinook salmon) and two invertebrates (Pacific oyster and *Calanus glacialis*). Cold-water species were the most insensitive to Corexit® 9500-dispersed oil, with the exception of Pacific oyster, which was relatively sensitive. McFarlin et al. (2011) reported LC50 values for three of the four relatively insensitive cold-water species (sculpin, *C. glacialis,* and Arctic cod (*B. saida*), indicating that different methodologies may have resulted in relatively lower toxicity. All three species were exposed to a spiked dispersed oil scenario in cold water (2 °C), whereas Pacific oyster was exposed in warmer water (Clark et al., 2001; as cited in NRC, 2005).

The geometric mean 96-hour LC50 value for Chinook salmon exposed to Corexit® 9500-dispersed oil under constant conditions was approximately 76.0 ppm TPH. This is the only managed species for which toxicity data are available. Reasonable surrogates are available for other species covered under FMPs.

Cod species and walleye pollock are fairly similar to Arctic cod (*B. saida*), which had an LC50 of 45 ppm (McFarlin et al., 2011). *Myoxocephalus* spp. was used as a surrogate for sculpins, Atka mackerel (*Pleurogrammus monopterygiu*), sablefish, and rockfish species; the LC50 for *Myxocephalus* spp. was 17 ppm (McFarlin et al., 2011). Chinook salmon was used as a surrogate for other managed salmon species (e.g., pink, chum [*Oncorhynchus keta*], coho, and sockeye salmon); the geomean LC50 value for Chinook salmon was 76 ppm. Although fairly different taxonomically, the decapods *Palaemon serenus* and *Litopenaeus setiferus* were used as potential surrogates for managed crab species; the LC50 values for these potential surrogates were 3.6 and 7.5 ppm, respectively (Gulec and Holdway, 2000; Liu et al., 2006). Pacific oyster was used as a surrogate for managed scallops; the LC50 values for Pacific oyster were 0.81 and 3.99 ppm for constant and spiked exposures, respectively (Clark et al., 2001), and the geomean LC50 value was 1.8 ppm TPH. Small-bodied forage fish (e.g., sheepshead minnow, inland silverside, topsmelt, and Australian rainbowfish) were used as surrogates for functionally similar, managed forage fish (i.e., eulachon, capelin, and Pacific sand lance); the LC50 values for the potential surrogates were between 0.49 and 32.47 ppm, with spiked exposures resulting in much higher LC50 values. No surrogate data were available for flatfish species (e.g., sole, plaice, dab, turbot, or flounder), sharks or skates, or octopus or squid species.

3.1.3 Sublethal or chronic toxicity data

3.1.3.1 Corexit® 9527 and Corexit® 9500

Although sublethal and chronic toxicity data were not included in the calculation of HC5s, some data have been compiled in Attachment B-1 to Appendix B of the BA (Windward and ERM, 2014); these data are summarized here for comparison to acutely lethal concentrations, as well as to identify known sublethal effects. In a small number of studies, exposures to chemical dispersants have been shown to cause sublethal or chronic[32] toxic responses. Singer et al. (1991) reported an EC50 (concentration that has an effect on 50% of the exposed organisms) of 13.6 ppm Corexit® 9527, based on abnormal growth in red abalone after a 48-hour exposure to spiked concentrations. Nalco (2010) reported a 72-hour reduced biomass EC50 of 9.4 ppm Corexit® 9527 for a culture of the diatom *Skeletonema costatum*. A culture of the bioluminescent marine bacterium *Vibrio fischeri* was determined to have a reduced bioluminescence EC50 of 104 ppm Corexit® 9500 (NRC, 2005) after a 15-minute exposure; reduced bioluminescence is an indication of lowered metabolic activity. The 15-minute *V. fischeri* bioassay is considered a chronic test because of the bacterium's very short life span. Mitchell and Holdway (2000) reported chronic, 7-day no-

[32] Chronic responses are those following exposure of a duration that includes a notable portion of a species' entire life cycle or early life stages. The duration is characteristically longer than acute exposures, and endpoints often include sublethal effects that are slow to manifest and continual (e.g., abnormal growth).

observed-effect concentration (NOEC) values (based on the population growth rate) of 13 and < 15 ppm for green hydra exposed (static, daily renewal) to Corexit® 9527 and Corexit® 9500, respectively; the lowest-observed-effect concentration (LOEC) for Corexit® 9527 and Corexit® 9500 were 15 and 43 ppm, respectively. Other studies found that dispersants inhibited reproduction (Singer et al., 1991), growth, development (Singer et al., 1991; Wells et al., 1982), and other endpoints (Gulec et al., 1997; Norwegian Institute for Water Research, 1994; Burridge and Shir, 1995; all cited in NRC, 2005) in various species (e.g., giant kelp [*Macrocsytis pyrifera*], amphipods, diatoms, mysids, and red abalone) when these species were exposed over a long period of time relative to the species' life spans.

Delayed development has also been observed at high concentrations of Corexit® 9527 (100 ppm) (Falk-Petersen et al., 1983; Lonning and Falk-Petersen, 1978), but this is not an ecologically-relevant concentration.

3.1.3.2 Crude oil

Sublethal impacts of crude oil (and PAHs in particular) on fish and invertebrates are well documented (Douben, 2003). Potential impacts include deoxyribonucleic acid (DNA) damage, impaired growth or reproductive capabilities, abnormal development, generalized oxidative stress, and impaired immune function (Bravo et al., 2011; Carls and Meador, 2009; Incardona et al., 2014; Incardona et al., 2013; Incardona et al., 2011; Meador, 2003; Payne et al., 2003). Sublethal effects of PAH exposures may result in disease or otherwise reduced fitness, leading to death.

Smit et al. (2009) synthesized chronic exposure data and developed an SSD of chronic or sublethal endpoints (i.e., DNA damage; oxidative stress [biomarkers]; and reduced survival, growth, and reproduction ["whole-organism" responses]. Smit et al. (2009) found that the species most sensitive for the DNA damage endpoint were blue mussel (*Mytilus edulis*) and green sea urchin (*Strongylocentrotus droebachiensis*), with chronic 210-day LOECs of 2.8 and 4 ppb TPH, respectively. Iceland scallop (*Chlamys islandicus*) was the most sensitive for the oxidative stress endpoint, with a chronic 30-day LOEC of 2.3 ppb TPH. Blue mussel was the most sensitive for whole-organism responses, with a 33-day chronic NOEC for reproduction of 30 ppb TPH.

Sheepshead minnow was the least sensitive for the DNA damage endpoint, with a 21-day chronic LOEC of 100 ppb TPH; blue mussel and Atlantic cod (*Gadus morhua*) were the least sensitive for the oxidative stress endpoint, with a chronic 30-day LOEC for reproduction of 63.4 ppb TPH and sublethal 3-day LOEC of 69.4 ppb TPH. Longnose killifish (*Fundulus similis*) was the least sensitive to whole-organism responses, with a chronic 8-day NOEC of 9,900 ppb TPH.

HC5 values for different groups of endpoints were between 1.4 and 70.5 ppb TPH; based on various fish and invertebrates, 70.5 ppb TPH, the HC5 for whole-organism responses, was identified as the maximum allowable threshold for chronic exposures of aquatic life. That chronic threshold was approximately 15% of the HC5 calculated for this EFH assessment for oil alone, based on acute toxicity (Section 3.3).

3.1.3.3 Chemically dispersed oil

The chronic and sublethal effects of dispersed oil have not been studied extensively. A study by Lee et al. (2011b) reported hatchability (equivalent to mortality endpoint) of Atlantic herring (*Clupea harengus*) embryos exposed to Corexit® 9500-dispersed oil over a period of 2.4 to 336 hours. The chronic 336-hour LC50s for Corexit® 9500-dispersed oil were 1.75 and 1.94 ppm TPH for Pacific herring, and 2.03 and 4.33 ppm TPH for Atlantic herring. In the same study, Lee et al. tested normal development in Atlantic herring after 366-hour exposures; EC50s were below the lowest tested concentrations of chemically dispersed oil (< 0.25 and < 0.37 ppm TPH, using two oil types). Given the rate at which chemical dispersants and oil are expected to dilute and biodegrade over a period of one week (Gallaway et al., 2012; Carretta et al., 2013; Nedwed, 2012; Mackay and McAuliffe, 1988), such impacts are somewhat unlikely to occur.

In short-term (2.4-hour to 24-hour) sublethal exposures of Atlantic herring to Corexit® 9500-dispersed oil, Lee et al. (2011b) calculated time-dependant abnormal growth EC50 values of between 0.49 and 18.0 ppm TPH. Although herring are not currently managed under any FMP in Alaska, they may be similar in sensitivity to other small forage fish species that are covered, such as eulachon, capelin, and Pacific sand lance.

3.2 SSDs and Calculation of HC5s for Dispersants, Oil, and Dispersed Oil

In order to assess the potential risk to invertebrates and fish associated with dispersant application, SSDs were developed for simplified scenarios of exposure to crude oil (including all oil types, weathered or fresh), Corexit® 9500 and Corexit® 9527, and oil dispersed by the Corexit® products. This approach has been applied recently to similar datasets for crude oil, dispersants alone (Barron et al., 2013; Smit et al., 2009; de Hoop et al., 2011), and dispersed oil (Gardiner et al., 2012). The SSDs were developed using toxicological data from the literature, and HC5s were calculated from the lower (i.e., more sensitive) ends of each SSD. The HC5 was chosen to represent a concentration that was protective of approximately 95% of aquatic species (Barron et al., 2013; Posthuma et al., 2002).

LC50s for each species were ranked according to increasing acute 48- to 96-hour LC50s[33] (Tables 3, 4, and 5) and plotted on a logarithmic scale (Figures 3 through 7).

[33] The dataset of LC50 values was limited to exposure durations between 48 and 96 hours for invertebrates and 96 hours for fish; only juvenile or other early life stages of fish were acceptable, although adult life stages of small, short-lived invertebrates (e.g., kelp forest mysid [*Holmesimysis costata*]) were also deemed acceptable. All exposure types (e.g., static, flow-through, etc.) were included in the calculation of HC5 values.

The geometric mean LC50 value of each species was used when multiple valid tests were available for a single species, and the geometric mean of a genus was used when data existed for multiple species within the same genus. If a single test was replicated for a single species in a single study, only the lowest LC50 (i.e., the most protective value) was selected in order to produce the most protective SSDs.

The distribution of empirical toxicity data (i.e., LC50 values) was estimated using @Risk® software (palisade Decision Tools, version 6.1.1) as a Microsoft Excel® add-in. As distributions can take a number of theoretical forms (e.g., normal, logarithmic, etc.), the distribution that best fit the empirical data was selected using the Anderson-Darling statistic. The Anderson-Darling statistic is useful for describing the goodness-of-fit of a distribution, particularly the low and high ends of a distribution.

When fitting distributions with @Risk®, it was assumed that the LC50 values predicted by @Risk® could not be less than 0 ppm. This assumption defined the list of distributions that could be fit to the empirical dataset. For crude oil and Corexit® 9500, a Pearson 6 distribution best described the empirical toxicity data. A log-logistic distribution best fit Corexit® 9527- and Corexit® 9500-dispersed oil toxicity data, and a lognormal distribution best fit Corexit® 9527-dispersed oil toxicity data.

Latin Hypercube sampling, a method for creating large, hypothetical datasets from a smaller empirical dataset, was used to simulate 5,000 iterations of hypothetical data points (i.e., LC50 values) from the selected distributions; these data points were then plotted and compared to the empirical datasets (Figures 3 through 7). The hypothetical dataset simulated by @Risk® for each distribution was ranked from low to high, and the 250th value of the 5,000 (i.e., the 5th percentile) was selected as the HC5. The calculated HC5 values were not extrapolated beyond the empirical LC50 datasets except in the case of Corexit® 9527-dispersed oil. In the latter case, only 13 genus geometric mean LC50 values were available, resulting in the calculation of an HC5 less than the minimum genus geometric mean LC50 among empirical data. Although uncertain (due to extrapolation of this value), the use of extrapolated HC5 values is acceptable (Posthuma et al., 2002).

Figures 8 and 9 provide a comparison of the different SSDs, which provides an indication of the relative toxicities of crude oil, dispersants, and chemically dispersed oil. A summary of the calculated HC5 values for the different chemical mixtures is provided in Table 6.

Table 3. Summary of geometric mean LC50 values for crude oil

Genus	Cold Water?	Genus Geomean LC50 (ppm TPH)	Rank
Crude Oil			
Octopus	no	0.39	1
Katharina	yes	0.44	2

Genus	Cold Water?	Genus Geomean LC50 (ppm TPH)	Rank
Crangon	yes	0.56	3
Hydra	no	0.7	4
Sciaenops	no	0.85	5
Holmesimysis	no	1.11	6
Pagurus	yes	1.14	7
Boreogadus	yes	1.2	8
Clupea	yes	1.22	9
Cryptochiton	yes	1.24	10
Melanotaenia	no	1.28	11
Pandalus	yes	1.29	12
Eualus	yes	1.32	13
Capitella	yes	1.44	14
Salvelinus	yes	1.49	15
Oncorhynchus	yes	1.68	16
Theragra	yes	1.73	17
Aulorhynchus	yes	1.85	18
Myoxocephalus	yes	1.89	19
Farfantepenaeus	no	1.9	20
Chlamys	yes	1.90	21
Americamysis	no	1.91	22
Thymallus	yes	2.04	23
Paralithodes	yes	2.22	24
Eleginus	yes	2.28	25
Xenacanthomysis	yes	2.31	26
Calanus	yes	2.4	27
Cottus	yes	3	28
Menidia	no	4.02	29
Palaemonetes	no	4.60	30
Neanthes	yes	4.82	31
Spiochaetopterus	no	4.92	32
Notoacmea	yes	5.32	33
Leander	no	6	34
Cyprinodon	no	6.21	35
Fundulus	no	6.22	36
Daphnia	yes	6.32	37
Litopenaeus	no	6.54	38

Genus	Cold Water?	Genus Geomean LC50 (ppm TPH)	Rank
Atherinops	no	9.35	39
Platynereis	no	9.5	40
Platichthys	yes	11.62	41
Tigriopus	no	124.3	42
Palaemon	no	258,000[a]	43
Allorchestes	no	311,000[a]	44
Macquaria	no	465,000[a]	45

Note: The best fit distribution for crude oil selected using the risk analysis software @Risk® was the Pearson 6 distribution.

[a] Value was removed from the final SSD, because it was a statistical outlier that negatively influenced the fitting of statistical distributions (i.e., resulted in lower Anderson-Darling statistics).

LC50 – concentration that is lethal to 50% of an exposed population
ppm – parts per million
SSD – species sensitivity distribution
TPH – total petroleum hydrocarbons

Table 4. Summary of geometric mean LC50 values for Corexit® 9500 and Corexit® 9527

Genus	Cold Water?	Genus Geomean LC50 (ppm)	Rank
Corexit® 9500[a]			
Allorchestes	no	3.5	1
Eurytemora	no	5.2	2
Tigriopus	no	10	3
Haliotis	no	12.8	4
Macquaria	no	19.8	5
Artemia	no	20.8	6
Litopenaeus	no	31.1	7
Acartia	yes	34	8
Chionoecetes	yes	44.6	9
Penaeus	no	48	10
Atherinosoma	no	50	11
Americamysis	no	50.4	12
Menidia	no	51.1	13
Scophthalmus	yes	74.7	14
Palaemon	no	83.1	15
Lates	no	143	16
Sarotherodon	no	150	17
Fundulus	no	155.4	18

Genus	Cold Water?	Genus Geomean LC50 (ppm)	Rank
Holmesimysis	no	158	19
Hydra	no	160	20
Crassostrea	yes	167	21
Cyprinodon	no	262.8	22
Oncorhynchus	yes	354	23
Sciaenops	no	744	24
Corexit® 9527[b]			
Allorchestes	no	3	1
Pseudocalanus	yes	5	2
Crassostrea	yes	6.6	3
Macquaria	no	14.3	4
Penaeus[c]	no	20.0	5
Holmesimysis	no	20.6	6
Acartia	yes	23	7
Americamysis	no	23.7	8
Litopenaeus	no	24.1	9
Phyllospora	no	30	10
Menidia	no	35.4	11
Atherinops	no	38.9	12
Leiostomus	no	40.9	13
Brevoortia	no	42.4	14
Artemia	no	46.0	15
Palaemon	no	49.4	16
Scophthalmus	yes	50	17
Sciaenops	no	52.6	18
Cyprinodon	no	74	19
Daphnia	yes	75	20
Callinectes	no	77.9	21
Onisimus	yes	80	22
Fundulus	no	89.5	23
Anonyx	yes	97	24
Platichthys	yes	100	25
Protothaca	yes	100	26
Oncorhynchus	yes	158.0	27
Corophium	no	159	28
Thalassia	no	200	29
Pimephales	no	201	30

Genus	Cold Water?	Genus Geomean LC50 (ppm)	Rank
Hydra	no	230	31
Palaemonetes	no	840	32

[a] The best fit distribution for Corexit® 9500 selected using the risk analysis software @Risk® was the Pearson 6 distribution.

[b] The best fit distribution for Corexit® 9527 selected using the risk analysis software @Risk® was the log-logistic distribution.

[c] *Penaeus* spp. data were mistakenly excluded from the Corexit® 9527 SSD as presented in Appendix B to the BA (Windward and ERM, 2014). The inclusion of the *Penaeus* spp. data results in the selection of a log-logistic distribution (rather than a Pearson 6 distribution) and a slightly increased HC5 value (i.e., 8.01 ppm rather than 7.12 ppm).

BA – biological assessment
LC50 – concentration that is lethal to 50% of an exposed population
ppm – parts per million
SSD – species sensitivity distribution

Table 5. Summary of geometric mean LC50 values for Corexit® 9500- and Corexit® 9527-dispersed oil

Species	Cold Water?	Species Geomean LC50 (ppm TPH)	Rank
Corexit® 9500-Dispersed Oil[a]			
Melanotaenia fluviatilis	no	1.37	1
Crassostrea gigas	yes	1.8	2
Palaemon serenus	no	3.6	3
Americamysis bahia	no	3.7	4
Sciaenops ocellatus	no	4.23	5
Menidia beryllina	no	6.2	6
Hydra viridissima	no	7.2	7
Holmesimysis costata	no	7.4	8
Litopenaeus setiferus	no	7.5	9
Tigriopus japonicus	no	10.7	10
Atherinops affinis	no	11.1	11
Macquaria novemaculeata	no	14.1	12
Allorchestes compressa	no	14.8	13
Myoxocephalus spp.	yes	17	14
Cyprinodon variegatus	no	18.6	15
Calanus glacialis	yes	20.5	16
Boreogadus saida	yes	45	17
Oncorhynchus tshawytscha	yes	76.0	18

Species	Cold Water?	Species Geomean LC50 (ppm TPH)	Rank
Corexit® 9527-Dispersed Oil[b]			
Melanotaenia fluviatilis	no	0.74	1
Crassostrea gigas	yes	1.03	2
Octopus pallidus	no	1.8	3
Holmesimysis costata	no	2.35	4
Menidia beryllina	no	2.55	5
Americamysis bahia	no	3.65	6
Palaemon serenus	no	8.1	7
Hydra viridissima	no	9	8
Daphnia magna	yes	15.28	9
Allorchestes compressa	no	16.2	10
Macquaria novemaculeata	no	28.5	11
Atherinops affinis	no	28.6	12
Platichthys flesus	no	75	13

a The best fit distribution for Corexit® 9500 + oil selected using the risk analysis software @Risk® was the log-logistic distribution.

b The best fit distribution for Corexit® 9527 + oil selected using the risk analysis software @Risk® was the log-normal distribution.

LC50 – concentration that is lethal to 50% of an exposed population TPH – total petroleum hydrocarbons

ppm – parts per million

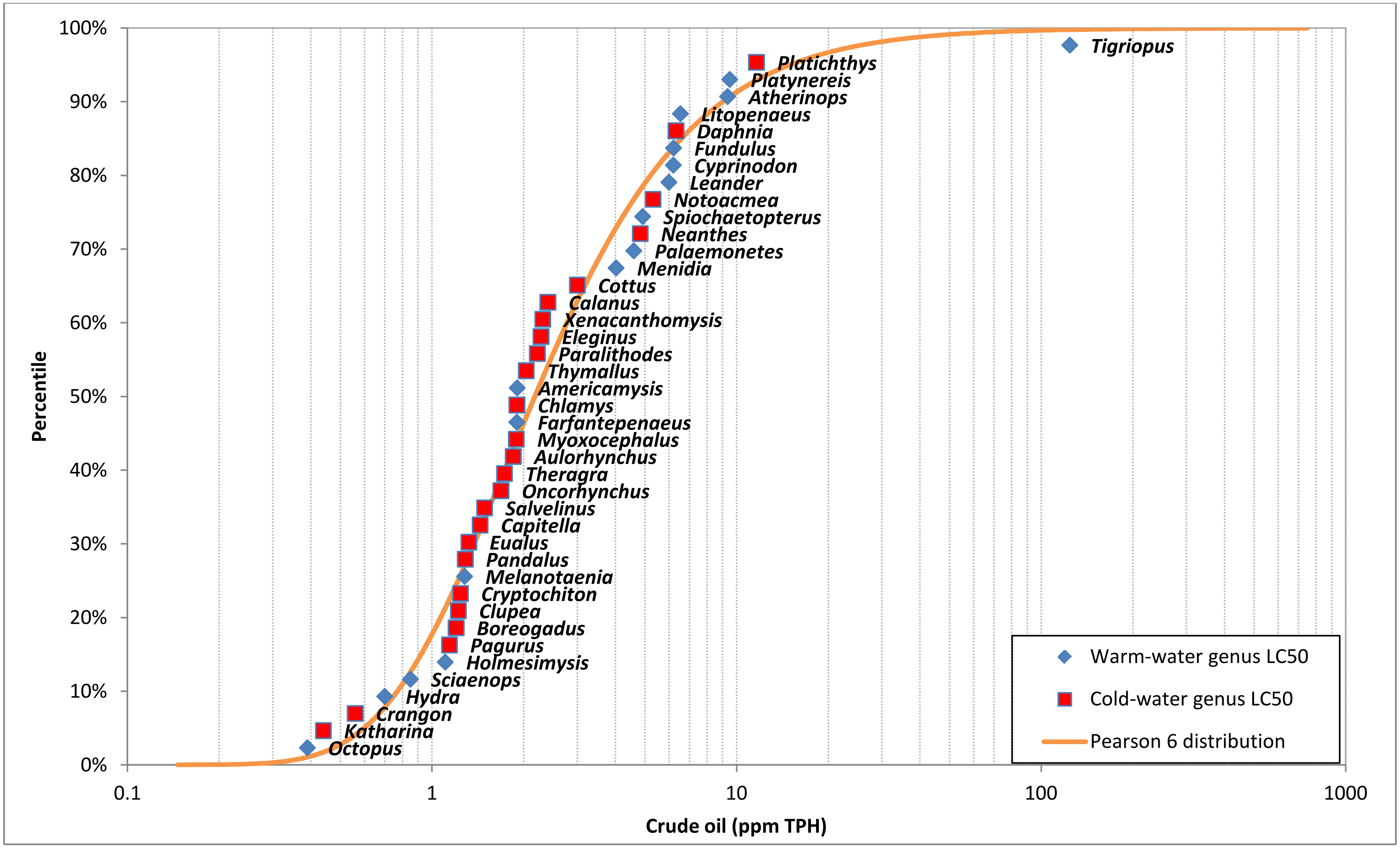
Note: Species geometric mean LC50 values were used for chemically dispersed oil SSDs, because chemically dispersed oil toxicity data for multiple species within a single genus were not available; therefore species and genus geometric mean LC50 values were equivalent.

Table 6. Comparison of HC5 values

Material	HC5 (ppm)
Corexit® 9500	5.53
Corexit® 9527	8.01
Crude oil	0.46
Corexit® 9500-dispersed oil	1.71
Corexit® 9527-dispersed oil	0.69

HC5 – hazardous concentration, 5th percentile

ppm – parts per million



Note: The three highest LC50 values were removed, and the distribution was fit to the remaining points. This resulted in a much better fitting distribution, both visually and based on the Anderson-Darling statistic.

Figure 3. SSD for water-accommodated fraction of crude oil with the selected distribution fit to empirical toxicity data

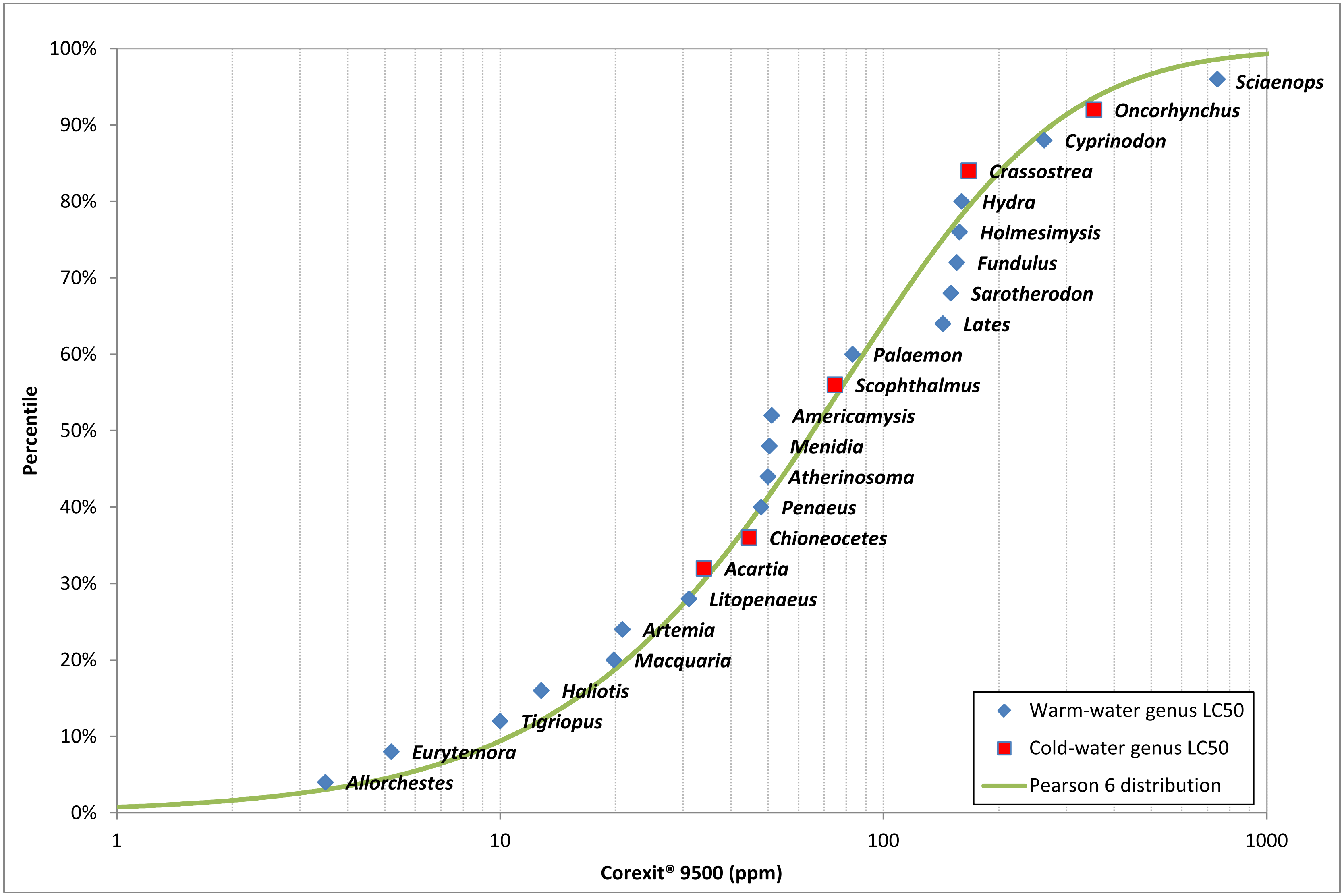
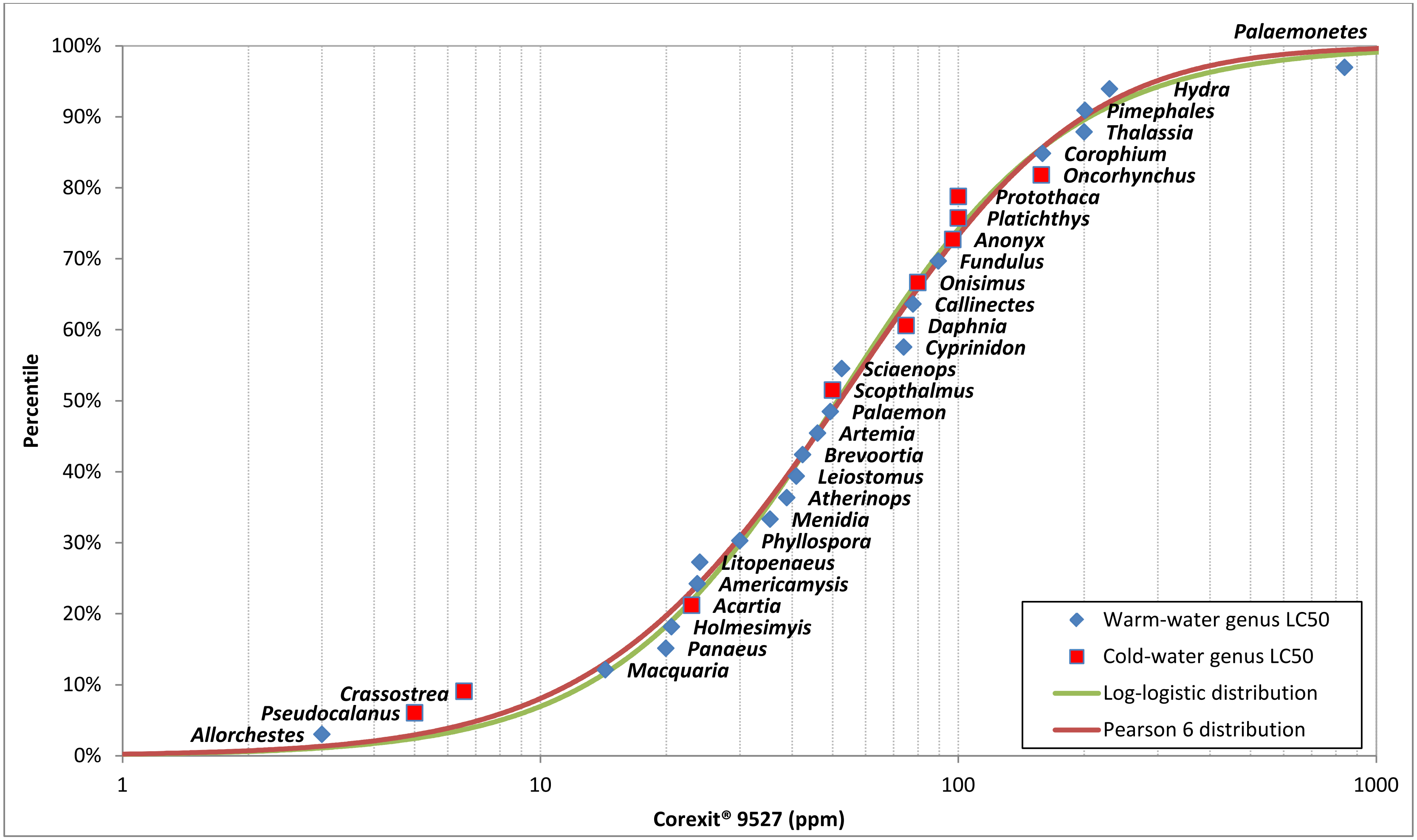


Figure 4. SSD for Corexit® 9500 with the selected distribution fit to empirical toxicity data



Note: The inclusion of LC50 data for the genus *Penaeus* resulted in the selection of a log-logistic distribution, which had a marginally better fit than a Pearson 6 distribution based on the Anderson-Darling statistic. The Pearson 6 distribution was selected for use in Appendix B to the BA (Windward and ERM, 2014), wherein *Penaus* LC50 data was not included. Both distributions are provided in the figure for visual comparison, although the reported HC5 (Table 3) is based on the log-logistic distribution. There was a marginal impact on the reported HC5 for Corexit® 9527 (Table 3), but the difference does not influence conclusions made in this assessment or alter those made in the BA (Windward and ERM, 2014).

Figure 5. SSDs for Corexit® 9527 with the selected distribution fit to empirical toxicity data

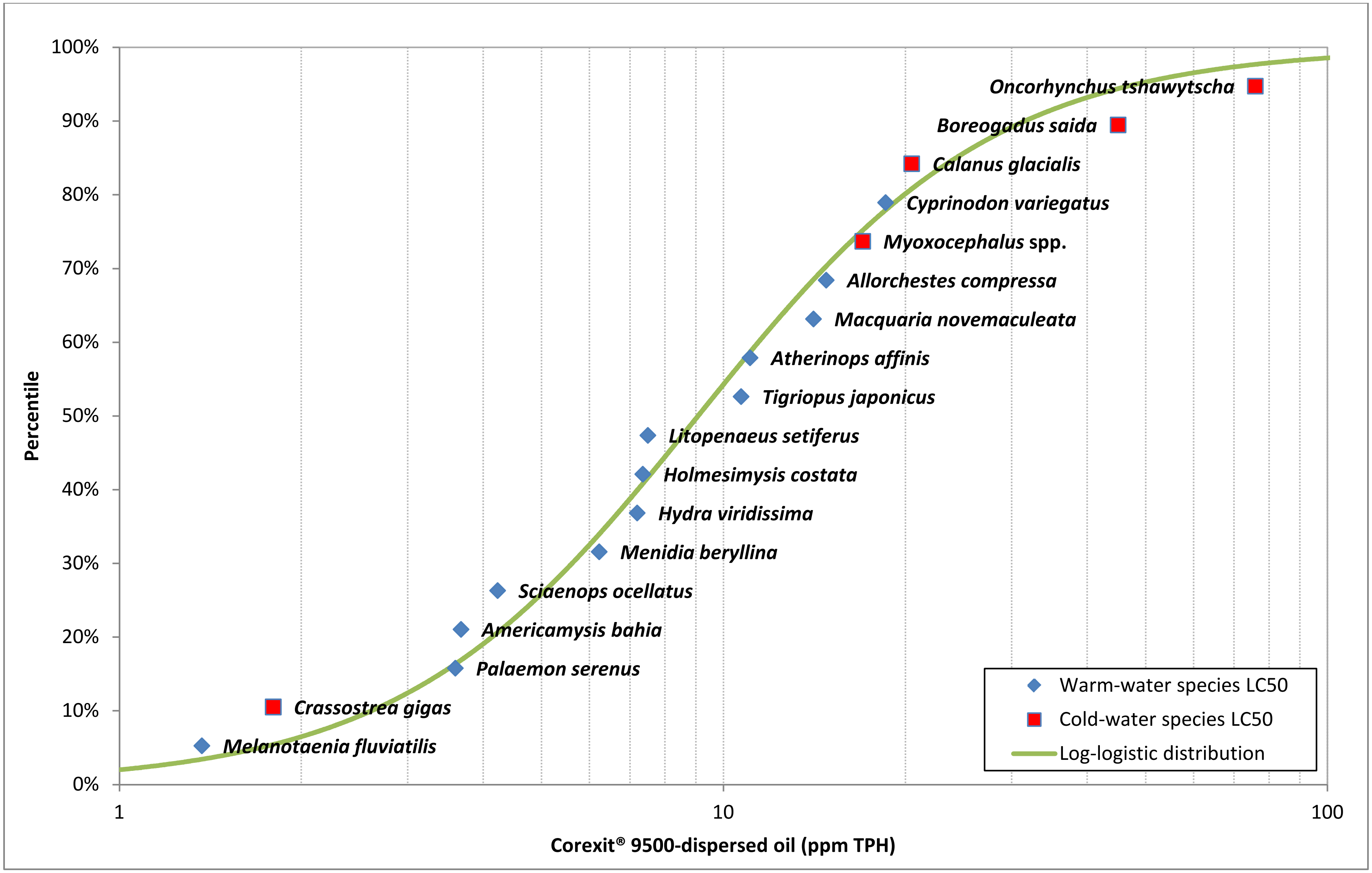
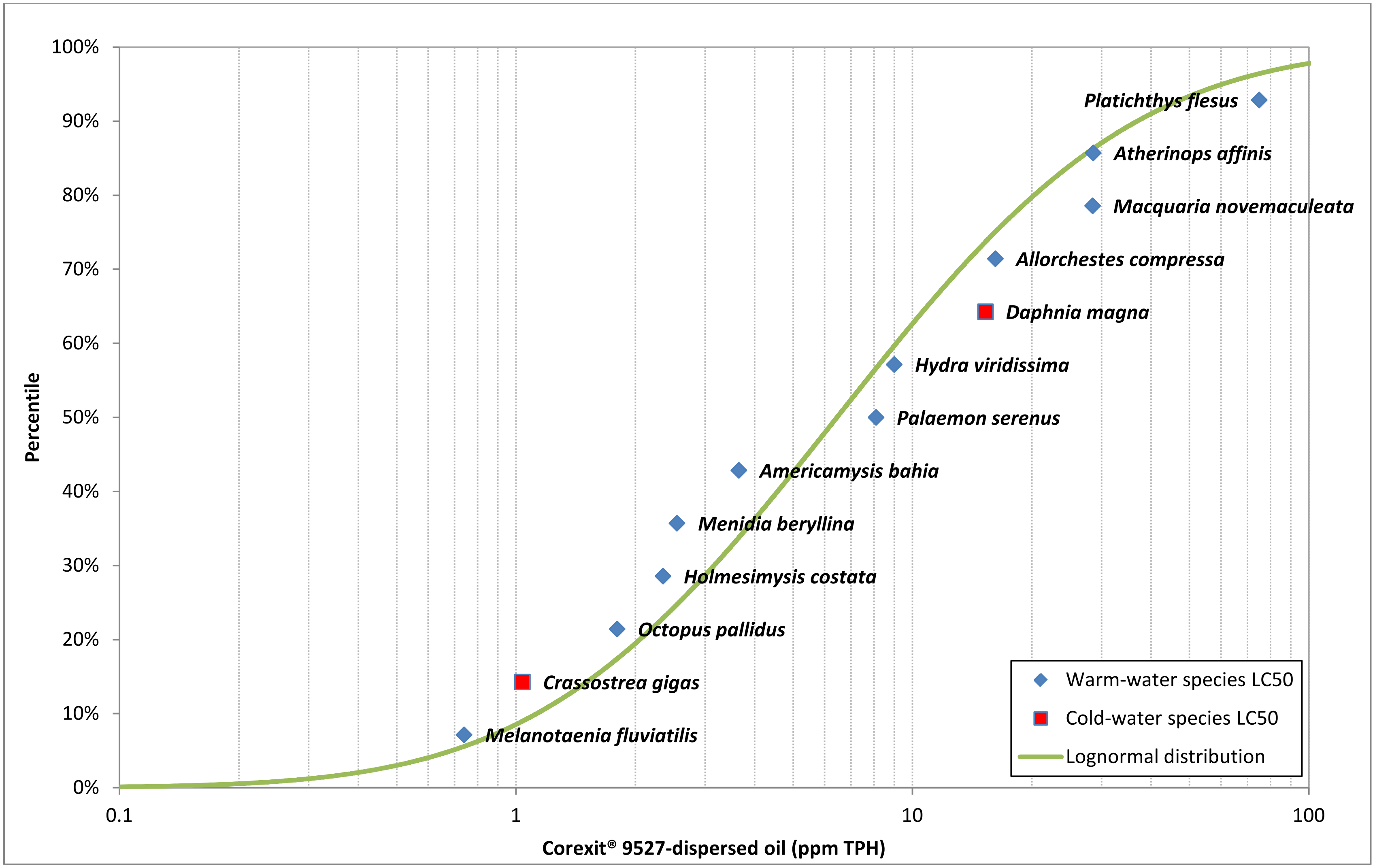


Figure 6. **SSD for Corexit® 9500-dispersed oil with the selected distribution fit to empirical toxicity data**



Note: The HC5 for Corexit® 9527-dispersed oil (based on the lognormal distribution) was below the minimum species geomean LC50 value (0.74 ppm TPH).

Figure 7. SSD for Corexit® 9527-dispersed oil with the selected distribution fit to empirical toxicity data

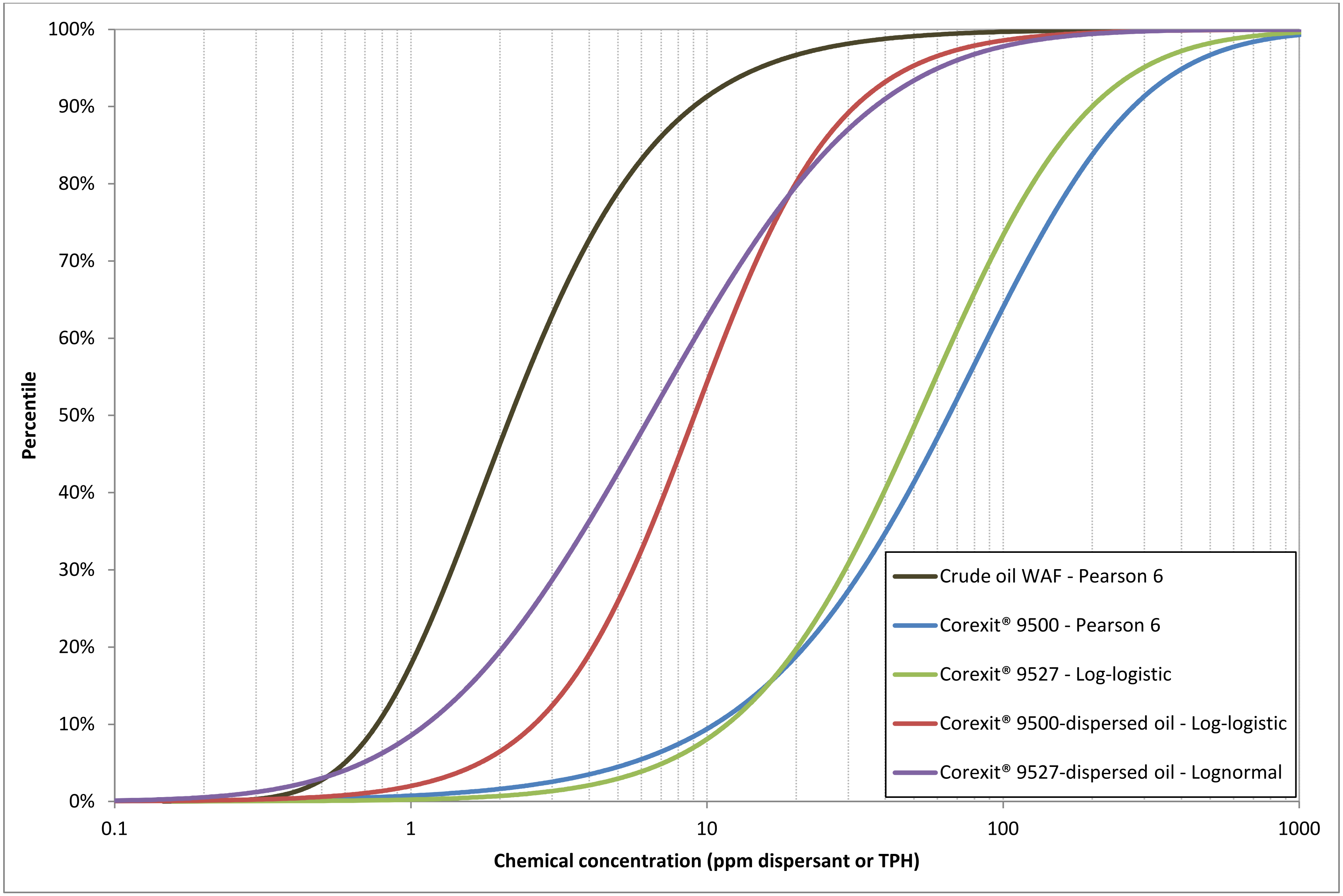


Figure 8. Comparison of SSDs for multiple toxicity datasets

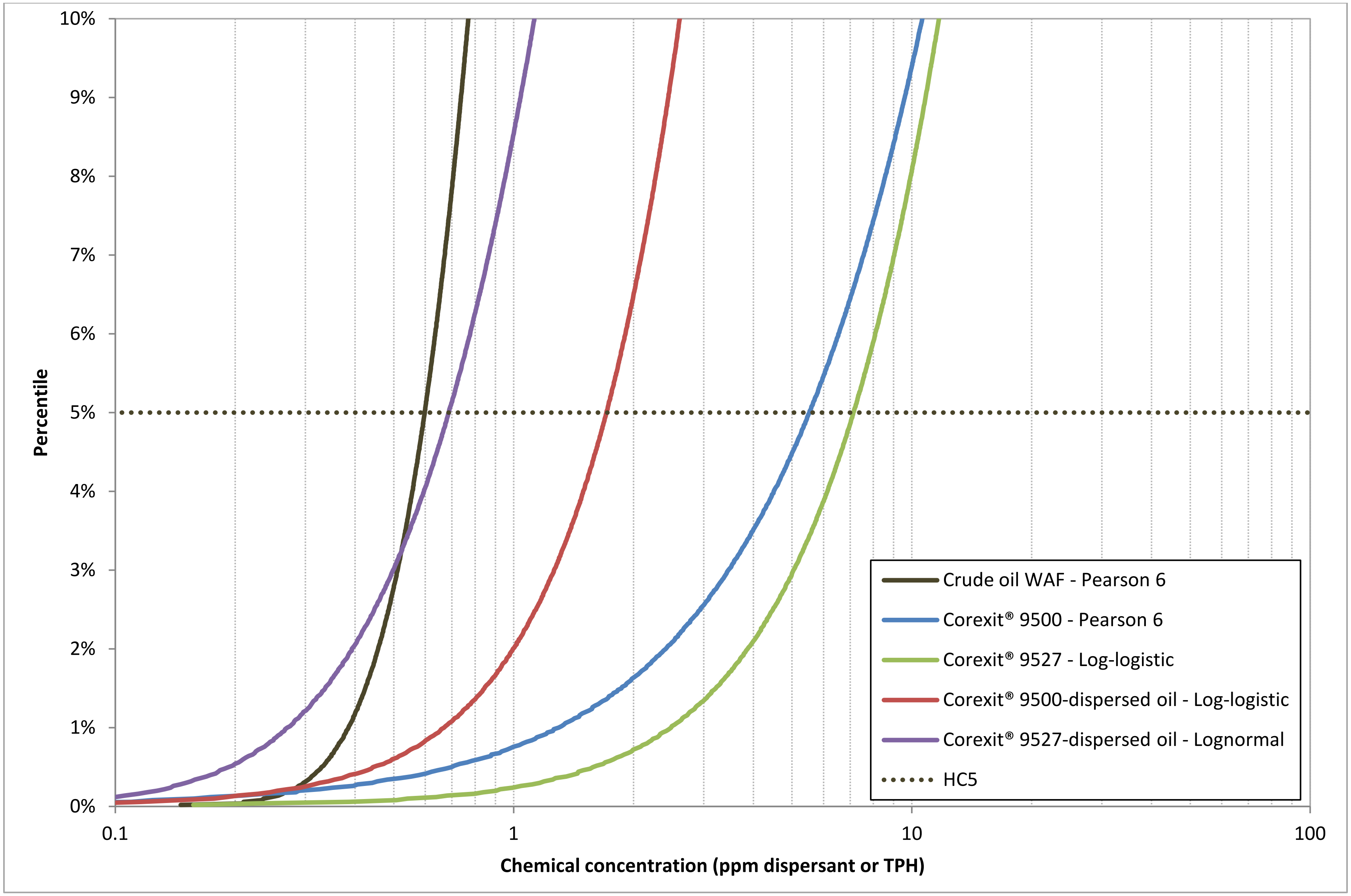


Figure 9. Comparison of SSDs for multiple toxicity datasets, lower end with HC5 shown

Based on the SSD method for calculating HC5 values presented above, the HC5 for oil treated with Corexit® 9500 and Corexit® 9527 were approximately 3.7 and 1.5 times higher than the HC5s for crude oil alone, respectively, indicating only a slight decrease in toxicity after chemical dispersion. Although the toxicity of oil may decrease slightly as a result of chemical dispersant application (Section 3.2), it is expected that increased exposures to chemically dispersed oil in the water column (relative to exposure to crude oil under the baseline condition) will have a greater influence on the likelihood of impacts to managed species (or their prey). A recent study by Adams et al. (2014) showed that, although measureable concentrations of hydrocarbons dissolving in test solution were far greater for chemically dispersed oil than for crude oil, the inherent toxicity of chemically dispersed oil was equal to crude oil. Although hatchability of Atlantic herring was reduced after a 19-day exposure to chemically dispersed oil (relative to exposure to crude oil), it was concluded that increased exposure to hydrocarbons partitioning from dispersed oil droplets caused the measured effects rather than increased toxicity from the dispersant or interaction between dispersant and oil.

It has been noted that concentrations of crude oil naturally dispersed under an oil slick (> 1 m depth) are negligible, whereas concentrations of chemically dispersed oil can be approximately 50 ppm TPH for up to 24 hours under certain conditions (Mackay and McAuliffe, 1988; McAuliffe et al., 1981; McAuliffe et al., 1980; Humphrey et al., 1987b).; this concentration and exposure duration may be sufficient to cause adverse impacts in managed species between a depth of 1 and 10 m that would not occur (under the baseline condition) but for the application of chemical dispersants. The potential for such impacts occurring within 24 hours of exposure is unclear, as the analysis conducted in this appendix (Section 3.2) focuses on toxicity data from 48 and 96-hour exposures.

In general, the acute HC5s reported in Table 6 were within a factor of three of the acute HC5s reported by others for the same chemical mixtures (Barron et al., 2013; de Hoop et al., 2011; Gardiner et al., 2012), and within a factor of seven of the chronic HC5 reported by Smit et al. (2009) (for crude oil only). The only exception was the HC5 for South Louisiana Crude oil reported by Barron et al. (2013), which was approximately eight times higher than the crude oil HC5 calculated for this EFH assessment.

Variability in the calculated HC5 values for crude oil can be explained by variability in oil types used (Barron et al., 2013) and species included in SSDs (Gardiner et al., 2012; de Hoop et al., 2011). Although both de Hoop et al. (2011) and Gardiner et al. (2012) report slightly lower crude oil HC5 values for polar or Arctic species than for temperate or non-Arctic species, the differences were slight, within a factor of two for both studies, indicating that cold-water species are of a similar sensitivity to crude oil as warm-water species.

3.3 RELATIVE ACUTE TOXICITY OF OIL VERSUS DISPERSED OIL

The purpose of this section is to place the discussion of dispersed oil toxicity in the context appropriate for this EFH assessment. The toxicity of dispersed oil relative to the toxicity of oil alone must be considered in order to evaluate the potential risk to EFH and managed species. Exposure to and the toxicity of crude oil, alone, represents the baseline condition against which the toxicity of dispersed oil and exposure must be compared. Neither the toxicity of dispersants compared to that of natural seawater (or laboratory negative control data) nor the toxicity of oil alone compared to that of natural seawater (or laboratory negative control data) are considered appropriate discussions for the EFH assessment.

Although many laboratory studies have shown that oil is more acutely toxic than or similarly toxic to chemically dispersed oil (Section 3.2; Attachment B-1 to the BA Appendix B) (Windward and ERM, 2014), chemically dispersed oil is generally considered to be more toxic than oil alone (McFarlin et al., 2011; Ramachandran et al., 2004; Singer et al., 1998), because dispersants tend to increase the solubility of the toxic components of oil (e.g., PAHs) and the exposure of aquatic species to those components (Couillard et al., 2005; Faksness et al., 2011; Milinkovitch et al., 2011; Ramachandran et al., 2004; Wolfe et al, 1998, 2001; Yamada et al., 2003). Similarly, Carls et al. (2008) showed that the toxicity of oil droplets is due to the level of toxic PAHs in solution (that dissolve from the droplets) rather than the amount of droplets. Therefore, by effectively increasing the surface area of the oil-water interface (by dispersing oil into smaller droplets), chemical dispersants increase the exposures of managed species to PAHs in the water column.

In contrast to those that have reported increased toxicity of oil as a result of chemical dispersion, some have reported a decrease in exposure and impacts of oil as a result of chemical dispersion. For example, in some cases the retention or net uptake of oil in tissue decreased (relative to crude oil alone) when oil was chemically dispersed (Wolfe et al., 2001; Mageau et al., 1987; Lin et al., 2009; Chase et al., 2013). Wolfe et al. (1998) showed a non-significant increase in the uptake of a chemically dispersed low-molecular-weight polycyclic aromatic hydrocarbon (LPAH) in fish tissues over time, and Milinkovitch et al. (2012) showed a lack of effects after PAH uptake in fish increased as a result of chemical dispersion. LPAHs and other light components of oil are more soluble (NRC, 2005), more easily degraded, and more rapidly depurated than HPAHs (Logan, 2007; Meador, 2003), which could account for the reduced uptake or retention in tissues (Mageau et al., 1987; Wolfe et al., 2001).

Bejarano et al. (2014) showed that the majority of acute toxicity values (89%) from studies during which oil concentrations were actually measured (rather than reported as a nominal concentration) were lower (i.e., more toxic) for crude oil than for chemically dispersed oil. The discrepancy between measured and nominal reporting methods was also described by Adams et al. (2014), although in this study, crude and chemically dispersed oils were shown to be nearly equally toxic.

Other possible mitigating factors of acute toxicity include temperature (i.e., exposure decreases as temperatures decrease) (Lyons et al., 2011) and salinity (i.e., exposure decreases as salinity increases) (Ramachandran et al., 2006). Lin et al. (2009) note that dispersed oil droplets may be unavailable due to the creation of bulky, stable micelles (see "surfactant-coated oil droplet" in Figure 1) that encapsulate oil and render PAHs and other oil components less bioavailable. This effect has been verified by others in biodegradation experiments (using microbes rather than larger organisms) with surfactants and PAHs (Guha et al., 1998; Kim and Weber, 2003; Liu et al., 1995; Volkering et al., 1995). PAHs have also been shown to partition to non-aqueous phases (i.e., solid or organic phases) upon microbial degradation of non-ionic surfactants, again resulting in less bioavailable forms of PAHs (Kim and Weber, 2003). Although possible under certain circumstances, a reduction in the bioavailability of PAHs in the water column after chemical dispersion appears unlikely based on the larger body of literature that reports increased exposures (Wolfe et al, 1998, 2001; Ramachandran et al., 2004; Yamada et al., 2003; Milinkovitch et al., 2011; Couillard et al., 2005; Faksness et al., 2011).

Based on the SSD method for calculating HC5 values presented above, the HC5s for oil treated with Corexit® 9500 and Corexit® 9527 were approximately 3.7 and 1.5 times higher than the HC5 for crude oil alone, respectively, indicating only a slight decrease in toxicity after chemical dispersion. Although the toxicity of oil may decrease slightly as a result of chemical dispersant application (Section 3.2), it is expected that increased exposures to chemically dispersed oil in the water column (relative to exposures to crude oil under the baseline condition) will have a greater influence (than inherent toxicity) on the likelihood of impacts to managed species (or their prey). It has been noted that concentrations of crude oil naturally dispersed under an oil slick (> 1 m depth) are negligible, whereas concentrations of chemically dispersed oil can be approximately 50 ppm TPH for up to 24 hours under certain conditions (Humphrey et al., 1987b; Mackay and McAuliffe, 1988; McAuliffe et al., 1980; McAuliffe et al., 1981); this concentration and exposure duration may be sufficient to cause adverse impacts in managed species between a depth of 1 and 10 m that would not occur (under the baseline condition) but for the application of chemical dispersants. The potential for such impacts occurring within 24 hours of exposure is unclear, as the analysis conducted in this appendix (Section 3.2) focuses on toxicity data from 48 and 96-hour exposures.

3.4 RELATIVE SUBLETHAL TOXICITY OF OIL VERSUS DISPERSED OIL

Comparable toxicity test data for sublethal endpoints are limited. Three tests with Corexit® 9500-dispersed oil were available for a single species, rainbow trout (Ramachandran et al., 2004). Dispersants increased the exposure of rainbow trout in the three tests, as indicated by the induction of cytochrome P4501A and measured using the ethoxyresorufin-O-deethylase (EROD) enzyme activity bioassay (Ramachandran et al., 2004). After oil was treated with Corexit® 9500, EC50s decreased by factors of 5.91 to 1,116. It should be noted that these tests were conducted under laboratory conditions with closed systems and a static-renewal exposure scenario, and so may overestimate the exposure of test species to dispersed oil expected under field conditions.[34] More importantly, EROD activity is a highly sensitive biomarker of exposure but is not directly related to adverse effects.

Sublethal toxicity data from four tests comparing Corexit® 9527-dispersed oil and oil alone were available. A study by Singer et al. (1998) evaluated sublethal toxicity of Corexit® 9527 to red abalone (i.e., larval shell development endpoint) and to topsmelt and kelp forest mysid (*Holmesimysis costata*) (short-term narcosis endpoint). In the larval development assay, EC50s for dispersed oil (ranging from 17.81 to 32.70 ppm TPH) were lower (i.e., more toxic) than EC50s for crude oil alone (more than the highest concentrations tested, which ranged from 33.58 to 46.99 ppm TPH). However, oil alone was had a greater effect on initial narcosis in topsmelt and kelp forest mysid than Corexit® 9527-dispersed oil. Narcosis, although measured after a brief exposure period (not resulting in mortality), is considered to be the general mode of PAH toxicity leading to acute mortality in fish and invertebrates (Logan, 2007; den Besten et al., 2003; Ankley et al., 2003); the noted decrease in initial narcosis after chemical dispersion (Singer et al., 1998) may explain the decrease in acute toxicity noted in Section 3.2. A second study (Mitchell and Holdway, 2000) showed changes in the modeled population growth rate of green hydra. Over a period of 168 hours, the toxicity of the oil increased after dispersant had been added. The mortality endpoint for green hydra measured during the same study indicated that oil alone was more acutely toxic than dispersed oil. Recent study has shown that crude oil and dispersed oil are nearly equal to one another in sublethal and chronic toxicity to fish (in tests with Atlantic herring and rainbow trout, respectively) (Adams et al., 2014) when evaluating the concentration of hydrocarbons in water (Adams et al., 2014).

The results of sublethal toxicity testing suggest that long-term exposures resulting in sublethal and/or chronic impacts (e.g., impaired development and altered population dynamics) may be enhanced by the application of chemical dispersants, whereas the results of acute mortality testing suggest that short-term exposures (resulting in mortality through a general narcosis mode of action) are slightly decreased by the application of chemical dispersants (Sections 3.2 and 3.3). As with acute toxicity (Section 3.3), the major implication of sublethal and chronic testing with crude oil and chemically dispersed oil is that the use of chemical dispersants increases the potential for impacts on fish and invertebrate species by increasing the potential for exposures to toxic components of oil (e.g., PAHs).

[34] This statement assumes that exposed species are mobile rather than held within a plume. The assumption is relevant for the test species in question, rainbow trout, but the latter condition is relevant for many planktonic species. In that case, exposures can be expected to increase, as observed by Ramachandran et al. (2004).

3.5 UNCERTAINTIES ASSOCIATED WITH THE APPLICATION OF HC5S

The data presented in Section 3.2 uses standardized toxicity test results to evaluate the relative sensitivities of aquatic species. Standardized tests may not incorporate ecologically-relevant exposure durations or conditions, resulting in uncertainty when extrapolating results to field conditions. However, most data available for developing SSDs and calculating HC5 values is derived from laboratory tests it is typical to rely on laboratory data for these purposes (Posthuma et al., 2002).

The use of spiked exposures is perhaps the most relevant exposure scenario for mimicking a surface application of chemical dispersants in the field, as discussed in Section 3.1.2; these tests were specifically investigated by Gardiner et al. (2012), who noted that dispersed oil was approximately 5 to 10 times less toxic than oil alone, and that Arctic species were less sensitive than non-Arctic species. The inclusion of standardized static, static renewal, and flow-through exposure methods, which are more prevalent in the literature, for the development of SSDs and calculation of HC5s is also typical (Posthuma et al., 2002).

Real-world oil spill scenarios are expected to differ from laboratory exposure scenarios because of several factors. Crude oil changes over time due to weathering, natural dispersion, and degradation. Sea and wind energy is not constant, nor will it be consistent between spills. Spills are not the same size (i.e., volume of oil or areal extent of slick), the same type of oil, or in the same location or proximity to response equipment. Response actions may not proceed at the same rate from spill to spill; for example, inclement weather may slow mobility to and from a spill. Also, the effectiveness of the chemical dispersant may change from spill to spill depending on the environment in which it is applied; for example, effectiveness can be hindered by low mixing energies of wind and water (NRC, 2005), as well as salinity (Blondina et al., 1999; Chandrasekar et al., 2006; Fingas, 2004; Moles et al., 2001) and the state of the oil (as noted above) (Moles et al., 2001; NRC, 2005).

Other important uncertainties regarding the HC5s include the variety of treatment parameters used in their development. Exposure temperatures, salinities, oil conditions (i.e., weathered or fresh), oil types (e.g., Alaska North Slope, Prudhoe Bay crude oil, etc.), and species life stages all potentially contribute to variability in the toxicity dataset. For example, tests using different species exposed at different temperatures or salinities could result in different rates of ingestion, respiration, and depuration; an indirect example is provided by Venosa and Holder (2007), who observed that microbial activity in a single consortium slowed at colder temperatures. Fresh oils characteristically contain higher concentrations of small, volatile, and more bioavailable hydrocarbons than weathered oil (Bobra et al., 1989; Rhoton, 1999; Singer et al., 2001; Rhoton et al., 2001). Similarly, different oil types have different chemical compositions, and may elicit varying toxicity (Barron et al., 2013). Species life stages are known to affect the results of toxicity testing, such that earlier life stages (particularly embryonic or larval life stages) tend to be much more susceptible to chemical intoxication. Attachment B-1 to Appendix B of the BA (Windward and ERM, 2014) includes a small amount of data from various literature reviews (i.e., compilations of toxicity data) that did not explicitly state the life stage of the tested species, so the HC5 calculations may have inadvertently included a small number of mature life stage LC50s.

The HC5 for Corexit® 9527-dispersed oil was extrapolated beyond the range of available LC50 data due to the small sample size for that particular SSD (n < 20). Although extrapolating such a value results in a somewhat uncertain HC5 value, it remains a protective estimate of the HC5; this approach is consistent with approved methods for determining HC5 values (Posthuma et al., 2002).

3.6 Predicted Sensitivities of Managed Fish and Invertebrates

The sensitivities of managed fish and invertebrate species have been assessed in several ways in this appendix. Of particular interest for the determination of potential adverse impacts on managed species are the species-specific acute LC50 values and potential surrogate toxicity data, which were provided in Sections 3.1.2.1 through 3.1.2.3 of this appendix as well as in Attachment B-1 to Appendix B of the BA (Windward and ERM, 2014).

The following approaches were used for assessing the sensitivities of managed species:[35]

- Sensitivities of managed species (or reasonable surrogates) to either crude oil or chemically dispersed oils (based on LC50 values)
- Relative sensitivities of individual species (or reasonable surrogates) to crude oil and chemically dispersed oil (i.e., comparison of chemicals)

The full analysis of available data (for all chemicals) is presented in Attachment A1, and a summary of the most relevant information (e.g., relating crude oil to Corexit® 9500-dispersed oil toxicity data and SSDs) is presented in Table 7. A discussion of the table is provided below.

The sensitivities of managed species (or reasonable surrogates) ranged from 0.39 to 12 ppm TPH crude oil and from 1.8 to 76 ppm TPH Corexit® 9500-dispersed oil. Octopus, cod, and sockeye salmon (or reasonable surrogates) were most sensitive to crude oil, and flatfish were least sensitive (although starry flounder was moderately sensitive based on species geomean LC50 values). Scallops (based on a surrogate oyster species) are expected to be most sensitive to dispersed oil, and salmon and cod species are expected to be least sensitive to dispersed oil.

[35] Rather than the sensitivity of the entire community of aquatic species (including prey), which was addressed by calculating protective HC5 values

Crude oil and dispersed oil LC50 values for managed species (or reasonable surrogates) were higher for dispersed oil than for crude oil for species in Table 7, with the exception of scallop species. The LC50 values for scallop species were essentially the same for both crude oil and chemically dispersed oil (i.e., 1.9 and 1.8 ppm TPH, respectively). Of the species compared in this way, only two were directly comparable species or surrogates (i.e., toxicity data for dispersed oil and crude oil exposures were available from single species):[36] Chinook salmon and Arctic cod (*B. saida*).[37]

In Table 7, a nominal sensitivity is assigned to each managed species based on the sensitivity of the species relative to the sensitivities of other species to the same chemical. The LC50 data for each species were associated with a percentile of the total dataset in the SSD, and that percentile was used to assign the nominal sensitivity value. Each percentile is within a quartile of the SSD data (e.g., 0 to 25%, 25 to 50%, 50 to 75%, or 75 to 100% of the LC50 values from various species). The assignment of nominal sensitivities was as follows:

- Sensitive species were those in the lower quartile of LC50 values.
- Moderately sensitive species were in the second quartile of LC50 values.
- Moderately insensitive species were in the third quartile of LC50 values.
- Insensitive species were in the upper quartile of LC50 values.

These values are used in a qualitative way in Section 4.1 to assess the potential for adverse impacts on managed fish or invertebrates.[38]

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[36] Both the Chinook salmon and Arctic cod toxicity tests were based on the same exposure regimes (and conducted in the same laboratories), so the notable decrease in toxicity for chemically dispersed oil relative to crude oil was not caused by obvious methodological differences.

[37] Chinook salmon data were used as surrogate information regarding other salmon species (in addition to being specific to Chinook salmon), and Arctic cod (*B. saida*) was used as a surrogate for other cod species.

[38] The assessment presented in Section 4 is primarily based on the likelihood of exposures, rather than the sensitivity of fish and invertebrates. As noted in Sections 3.3 and 3.4, the toxicities of crude oil and chemically dispersed oil are generally less important for predicting impacts than the likelihood of exposure to oil or chemically dispersed oil, because the toxicities of oil and chemically dispersed oil are relatively similar.

Table 7. Predicted sensitivities of managed fish and invertebrates based on available toxicity data

Species	Common Name	Crude Oil[a]				Corexit® 9500 – Dispersed Oil[b]			
		Species or Surrogate(s) (see table note for color designation)	Based on Crude Oil SSD		Geomean LC50 (ppm TPH)	Species or Surrogate(s) (see table note for color designation)	Based on Dispersed Oil SSD		Geomean LC50 (ppm TPH)
			Percentile[c]	Sensitivity[d]			Percentile[c]	Sensitivity[d]	
Octopus rubescens	Eastern Pacific red octopus	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Opisthoteuthis californiana	flapjack octopus	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Enteroctopus dofleini	giant Pacific octopus	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Graneledone boreopacifica	none	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Japetella diaphana	none	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Octopus sp. Jorgensen	none	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Benthoctopus oregonensis	none	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Octopus californicus	north Pacific bigeye octopus	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Benthoctopus leioderma	smoothskin octopus	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Vampyroteuthis infernalis	vampire squid	*Octopus pallidus*	2%	sensitive	0.39	none	no data	no data	no data
Oncorhynchus nerka	sockeye salmon	*Oncorhynchus nerka*	16%[f]	sensitive	1.1[f]	*Oncorhynchus tshawytscha*	95%	insensitive	76
Arctogadus glacialis	Arctic cod	*Boreogadus saida*	19%	sensitive	1.2	*Boreogadus saida*	89%	insensitive	45
Gadus macrocephalus	Pacific cod	*Boreogadus saida*	19%	sensitive	1.2	*Boreogadus saida*	89%	insensitive	45
Oncorhynchus gorbuscha	pink salmon	*Oncorhynchus gorbuscha*	30%[f]	moderately sensitive	1.3[f]	*Oncorhynchus tshawytscha*	95%	insensitive	76
Oncorhynchus kisutch	coho salmon	*Oncorhynchus kisutch*	35%[f]	moderately sensitive	1.5[f]	*Oncorhynchus tshawytscha*	95%	insensitive	76
Oncorhynchus keta	chum salmon	*Oncorhynchus* spp.	37%	moderately sensitive	1.7	*Oncorhynchus tshawytscha*	95%	insensitive	76
Theragra chalcogramma	walleye pollock	*Theragra chalcogramma*	44%[f]	moderately sensitive	1.7[f]	*Boreogadus saida*	89%	insensitive	45
Platichthys stellatus	starry flounder	*Platichthys stellatus*	46%[f]	moderately sensitive	1.8[f]	none	no data	no data	no data
Myoxocephalus jaok	plain sculpin	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp.	44%	moderately sensitive	1.9	*Myoxocephalus* spp.	74%	moderately insensitive	17
Myoxocephalus verrucosus	warty sculpin	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp.	44%	moderately sensitive	1.9	*Myoxocephalus* spp.	74%	moderately insensitive	17
Chlamys behringiana	Bering Sea scallop	*Chlamys* spp.	49%	moderately sensitive	1.9	*Crassostrea gigas*	11%	sensitive	1.8
Chlamys rubida	pink scallop	*Chlamys* spp.	49%	moderately sensitive	1.9	*Crassostrea gigas*	11%	sensitive	1.8
Crassadoma gigantean	rock scallop	*Chlamys* spp.	49%	moderately sensitive	1.9	*Crassostrea gigas*	11%	sensitive	1.8
Chlamys hastata	spiny scallop	*Chlamys* spp.	49%	moderately sensitive	1.9	*Crassostrea gigas*	11%	sensitive	1.8
Patinopecten caurinus	weathervane scallop	*Chlamys* spp.	49%	moderately sensitive	1.9	*Crassostrea gigas*	11%	sensitive	1.8
Chlamys albida	white scallop	*Chlamys* spp.	49%	moderately sensitive	1.9	*Crassostrea gigas*	11%	sensitive	1.8
Paralithodes platypus	blue king crab	*Paralithodes camtschaticus*	56%	moderately insensitive	2.2	*Palaemon serenus*, *Litopenaeus setiferus*	16 – 47% (32%)[e]	moderately sensitive	3.6 – 7.5 (5.2)[e]
Lithodes aequispiba	golden king crab	*Paralithodes camtschaticus*	56%	moderately insensitive	2.2	*none*	no data	no data	no data
Chionoecetes tanneri	grooved tanner crab	*Paralithodes camtschaticus*	56%	moderately insensitive	2.2	*Palaemon serenus*, *Litopenaeus setiferus*	16 – 47% (32%)[e]	moderately sensitive	3.6 – 7.5 (5.2)[e]
Lithodes couesi	scarlet king crab	*Paralithodes camtschaticus*	56%	moderately insensitive	2.2	*Palaemon serenus*, *Litopenaeus setiferus*	16 – 47% (32%)[e]	moderately sensitive	3.6 – 7.5 (5.2)[e]

Species	Common Name	Crude Oil[a]				Corexit® 9500 – Dispersed Oil[b]			
		Species or Surrogate(s) (see table note for color designation)	Based on Crude Oil SSD		Geomean LC50 (ppm TPH)	Species or Surrogate(s) (see table note for color designation)	Based on Dispersed Oil SSD		Geomean LC50 (ppm TPH)
			Percentile[c]	Sensitivity[d]			Percentile[c]	Sensitivity[d]	
Chionoecetes opilio	snow crab	*Paralithodes camtschaticus*	56%	moderately insensitive	2.2	*Palaemon serenus, Litopenaeus setiferus*	16 – 47% (32%)[e]	moderately sensitive	3.6 – 7.5 (5.2)[e]
Chionoecetes bairdi	tanner crab	*Paralithodes camtschaticus*	56%	moderately insensitive	2.2	*Palaemon serenus, Litopenaeus setiferus*	16 – 47% (32%)[e]	moderately sensitive	3.6 – 7.5 (5.2)[e]
Chionoecetes angulatus	triangle tanner crab	*Paralithodes camtschaticus*	56%	moderately insensitive	2.2	*Palaemon serenus, Litopenaeus setiferus*	16 – 47% (32%)[e]	moderately sensitive	3.6 – 7.5 (5.2)[e]
Paralithodes camtschaticus	red king crab	*Paralithodes camtschaticus*	58%[f]	moderately insensitive	2.2[f]	*Palaemon serenus, Litopenaeus setiferus*	16 – 47% (32%)[e]	moderately sensitive	3.6 – 7.5 (5.2)[e]
Myoxocephalus polyacanthocephalus	great sculpin	*Myoxocephalus polyacanthocephalus*	60%[f]	moderately insensitive	2.2[f]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Eleginus gracilis	saffron cod	*Eleginus gracilis*	61%[f]	moderately insensitive	2.3[f]	*Boreogadus saida*	89%	insensitive	45
Sebastes alutus	Pacific ocean perch	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Pleurogrammus monopterygius	Atka mackerel	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Hemitripterus bolini	bigmouth sculpin	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes melanostictus	blackspotted rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Hemilepidotus papilio	butterfly sculpin	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes pinniger	canary rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes nebulosus	China rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes caurinus	copper rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes variabilis	dusky rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastolobus altivelis	longspine thornyhead rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes polyspinus	northern rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes maliger	quillback rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Hemilepidotus hemilepidotus	red Irish lord	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes helvomaculatus	rosethorn rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes aleutianus	rougheye rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17

Species	Common Name	Crude Oil[a]				Corexit® 9500 – Dispersed Oil[b]			
		Species or Surrogate(s) (see table note for color designation)	Based on Crude Oil SSD		Geomean LC50 (ppm TPH)	Species or Surrogate(s) (see table note for color designation)	Based on Dispersed Oil SSD		Geomean LC50 (ppm TPH)
			Percentile[c]	Sensitivity[d]			Percentile[c]	Sensitivity[d]	
Anoplopoma fimbria	sablefish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Boreogadus saida*	89%	insensitive	45
Sebastes borealis	shortraker rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastolobus alascanus	shortspine thornyhead rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes nigrocinctus	tiger rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Hemilepidotus jordani	yellow Irish lord	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Sebastes ruberrimus	yelloweye rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus* spp., *Cottus cognatus*	44 – 65% (55%)[e]	moderately insensitive	1.9 – 3 (2.4)[e]	*Myoxocephalus* spp.	74%	moderately insensitive	17
Mallotus villosus	capelin	*Clupea pallasii, Atherinops affinis, Aulorhynchus flavidus, Fundulus similis, Cyprinidon variegatus, Menidia beryllina, Melanotaenia fluviatilis* (small forage fish)	21 – 91% (59%)[e]	moderately insensitive	1.2 – 9.4 (3.3)[e]	*Atherinops affinis, Menidia beryllina, Cypridon variegatus, Melanotaenia fluviatilis* (similar functionally)	32 – 79% (56%)[e]	moderately insensitive	1.4 – 19 (6.5)[e]
Thaleichthys pacificus	eulachon	*Clupea pallasii, Atherinops affinis, Aulorhynchus flavidus, Fundulus similis, Cyprinidon variegatus, Menidia beryllina, Melanotaenia fluviatilis* (small forage fish)	21 – 91% (59%)[e]	moderately insensitive	1.2 – 9.4 (3.3)[e]	*Atherinops affinis, Menidia beryllina, Cypridon variegatus, Melanotaenia fluviatilis* (similar functionally)	32 – 79% (56%)[e]	moderately insensitive	1.4 – 19 (6.5)[e]
Ammodytes hexapterus	Pacific sand lance	*Clupea pallasii, Atherinops affinis, Aulorhynchus flavidus, Fundulus similis, Cyprinidon variegatus, Menidia beryllina, Melanotaenia fluviatilis* (small forage fish)	21 – 91% (59%)[e]	moderately insensitive	1.2 – 9.4 (3.3)[e]	*Atherinops affinis, Menidia beryllina, Cypridon variegatus, Melanotaenia fluviatilis* (similar functionally)	32 – 79% (56%)[e]	moderately insensitive	1.4 – 19 (6.5)[e]
Oncorhynchus tshawytscha	Chinook salmon	*Oncorhynchus tshawytscha*	74%[f]	moderately insensitive	4.1[f]	*Oncorhynchus tshawytscha*	95%[f]	insensitive	76[f]
Pleuronectes quadrituberculatus	Alaska plaice	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Atheresthes stomias	arrowtooth flounder	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Isopsetta isolepis	butter sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Microstomus pacificus	Dover sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Parophrys vetulus	English sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Hippoglossoides elassodon	flathead sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Reinhardtius hippoglossoides	Greenland turbot	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Atheresthes evermanni	Kamchatka flounder	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Pleuronectes proboscidea	longhead dab	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Lepidopsetta polyxystra	northern rock sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Glyptocephalus zachirus	rex sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Psettichthys melanostictus	sand sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data
Lepidopsetta bilineata	southern rock sole	*Platichthys stellatus*, *P. flesus*	95%	insensitive	12	none	no data	no data	no data

Species	Common Name	Crude Oil[a]				Corexit® 9500 – Dispersed Oil[b]			
		Species or Surrogate(s) (see table note for color designation)	Based on Crude Oil SSD		Geomean LC50 (ppm TPH)	Species or Surrogate(s) (see table note for color designation)	Based on Dispersed Oil SSD		Geomean LC50 (ppm TPH)
			Percentile[c]	Sensitivity[d]			Percentile[c]	Sensitivity[d]	
Limanda aspera	yellowfin sole	*Platichthys stellatus,* P. *flesus*	95%	insensitive	12	none	no data	no data	no data
Bathyraja parmifera	Alaska skate	none	no data	no data	no data	none	no data	no data	no data
Bathyraja aleutica	Aleutian skate	none	no data	no data	no data	none	no data	no data	no data
Bathyraja interrupta	Bering skate	none	no data	no data	no data	none	no data	no data	no data
Onychoteuthis borealjaponica	boreal clubhook squid	none	no data	no data	no data	none	no data	no data	no data
Rossia pacifica	Eastern Pacific bobtail squid	none	no data	no data	no data	none	no data	no data	no data
Moroteuthis robusta	giant or robust clubhook squid	none	no data	no data	no data	none	no data	no data	no data
Somniosus pacificus	Pacific sleeper shark	none	no data	no data	no data	none	no data	no data	no data
Berryteuthis magister	red or magister armhook squid	none	no data	no data	no data	none	no data	no data	no data
Lamna ditropis	salmon shark	none	no data	no data	no data	none	no data	no data	no data
Squalus acanthias	spiny dogfish	none	no data	no data	no data	none	no data	no data	no data

Note: The color applied to species listed in the species or surrogate(s) column include the level of uncertainty associated with the surrogate data applied to managed species. Purple indicates the most certainty (species-specific rather than surrogate data). Blue indicates less certainty (surrogate data are from similar genus or family). Orange indicates fair uncertainty (based on same taxonomic order). Green indicates the most uncertainty (based on functionally similar rather than taxonomically similar species).

[a] Crude oil includes all types of oil at all stages of weathering.

[b] Corexit® 9500-dispersed oil is the most likely exposure scenario to be encountered in Alaska waters; stockpiles of Corexit® 9527 are mostly exhausted, but Corexit® 9500, the only other approved chemical dispersant for use in Alaska, is still stockpiled for future use.

[c] Percentiles, unless otherwise noted, are based on the SSDs of genus geomean LC50 values and may include multiple species LC50 values.

[d] Sensitivity is based on the quartile into which the given percentile (based on the SSDs of LC50 values) falls: "Insensitive" are in the fourth quartile, "moderately insensitive" are in the third quartile, "moderately sensitive" are in the second quartile, and "sensitive" are in the first quartile. Values are relative to other species.

[e] Range of values based on several potential surrogate genus geomean LC50 values with the arithmetic mean percentile or geometric mean LC50 value in parentheses.

[f] Percentile is based on the SSD of species geomean LC50s, because there were toxicological data available for the target species specifically. Value may differ from the percentile of the SSD of genus geomean LC50s based on the same species (used elsewhere as a surrogate).

LC50 – concentration that is lethal to 50% of an exposed population ppm – parts per million SSD – species sensitivity distribution TPH – total petroleum hydrocarbons

4 Synthesis of Potential Exposures and Species Sensitivities

The purpose of this section is to qualify the information provided in Section 2 regarding the potential for exposure for each species and EFH managed under the various FMPs (Table 2) with the information provided in Section 3 regarding the sensitivities of managed fish and invertebrate species or reasonable surrogates (Table 7). The process for combining sensitivity and exposure data is described in Section 4.1, the analysis is provided in its entirety in Attachment A1, and the results are summarized in Section 4.2.

By combining sensitivity and exposure information without addressing seasonal or geographic aspects of early-life-stage individuals from specific fisheries, the results should be considered predictive of a worst-case-scenario; that is to say that an oil spill has occurred, chemical dispersants are used to treat the oil, and individuals are present in the life stage that is most vulnerable and/or sensitive to exposure.

4.1 SYNTHESIS METHODS

The data presented in Tables 2 (Section 2.4.1) and 7 (Section 3.6) were combined using the matrix in Table 8. The matrix was developed based on the following rationale:

- The potential likelihood for exposure in Table 8 (as defined in Section 2.4.1) assume that oil has been chemically dispersed; exposures to crude oil are limited to the upper 1 m of the water column (NRC, 2005), so the potential for impacts of crude oil exposures (i.e., baseline condition) to managed species are relevant only to those species with a "high potential" for exposure (i.e., present in the upper 1 m of the water column).
- The potential likelihood for exposure to dispersed oil (as defined in Section 2.4.1) assumes that exposure will occur in the top 10 m of the water column.
- The potential likelihood for exposure is more important than relative sensitivity for predicting effects.
    - A sensitive individual that has no potential or a no/low potential for exposure to dispersed oil will not likely be impacted, whereas an insensitive individual that has the potential or high potential to be exposed to dispersed or crude oils may be affected.
    - If there is the potential for exposure, there may be an effect.[39]

[39] As measured by several researchers (Humphrey et al., 1987b), chemically dispersed oil concentrations could reach 50 ppm TPH for nearly 24 hours (within the upper 10 m). Others (Bejarano et al. 2014) have measured dilutions from 54 ppm TPH to 1 ppm TPH or less within 4 hours. Although the current analysis is based on 48- and 96-hour exposures, the LC50 values for chemically dispersed oil

- The likelihood of an impact occurring as a result of a potential exposure is qualified by the relative sensitivity of the individual.
    - Sensitive individuals are assumed to be more likely to be impacted than insensitive ones, although insensitive individuals may still be impacted.

Table 8. Potential for adverse impact based on sensitivity and likelihood for exposure

Exposure Likelihood	Adverse Impact Determination				
	Insensitive	Moderately Insensitive	Moderately Sensitive	Sensitive	No Data
No potential	effect unlikely	effect unlikely	effect unlikely	effect unlikely	effect unlikely
No/low potential	effect unlikely	effect unlikely	effect unlikely	effect unlikely	effect unlikely
Potential	may affect	may affect	may affect	may affect	uncertain
High potential	may affect	may affect	most likely to affect	most likely to affect	uncertain

Note: Expected impacts of crude oil on managed species apply only to species that are "likely" to be exposed, because oil does not mix into the water column beyond approximately 1 m (NRC, 2005). Species present in the upper water column (e.g., neuston or shallow-dwelling nekton) are assumed "likely" to be exposed.

In two instances where the potential for exposure of a particular species (i.e., saffron cod and warty sculpin) could not be determined due to a lack of available data regarding habitat use, surrogate species were used to infer the potential for exposure. These are noted in Table 9, which summarizes the results from the analysis conducted in Attachment A1. Table 9 includes those species for which there is a potential for adverse impacts from either crude oil or Corexit® 9500-dispersed oil; the application of Corexit® 9500 represents the most likely exposure scenario in the event of a chemical dispersant application response action because Corexit® 9527 is no longer being manufactured and no substantial stockpiles of that formulation are available. The potential for adverse impacts for all species is presented in Attachment A1, including assessments for Corexit® 9500 and Corexit® 9527, both alone and mixed with oil.

(attributed to managed species) tended to be less than 50 ppm TPH. Therefore, it is possible that mortalities will result from a chemical dispersant action within the first 24 hours of the action. Any extrapolation of toxicological data from 48- or 96-hour exposures to exposures between 0 and 24 hours in duration is highly uncertain. In general, short durations of exposure to crude and chemically dispersed oils result in increased toxicity values (less toxic) (Bejarano et al., 2014). Therefore, the method outlined in Section 4.1 is considered to be conservative.

Table 9. Summary of species that may be impacted at early life stages by crude and/or Corexit® 9500-dispersed oil

Common Name	Species	Maximum Potential for Exposure[a]	Adverse Impact Determination[b]	
			Crude Oil[c,d]	Corexit® 9500-Dispersed Oil
Alaska plaice	*Pleuronectes quadrituberculatus*	high potential	may affect	may affect/sensitivity unknown
Arctic cod	*Arctogadus glacialis*	high potential	**most likely to affect**	may affect
Arrowtooth flounder	*Atheresthes stomias*	high potential	may affect	may affect/sensitivity unknown
Atka mackerel	*Pleurogrammus monopterygius*	high potential	may affect	may affect
Bering Sea scallop	*Chlamys behringiana*	potential	effect unlikely	may affect
Bigmouth sculpin	*Hemitripterus bolini*	high potential	may affect	may affect
Blackspotted rockfish	*Sebastes melanostictus*	potential	effect unlikely	may affect
Blue king crab	*Paralithodes platypus*	high potential	may affect	**most likely to affect**
Boreal clubhook squid	*Onychoteuthis borealjaponica*	high potential	may affect/sensitivity unknown	may affect/sensitivity unknown
Butter sole	*Isopsetta isolepis*	high potential	may affect	may affect/sensitivity unknown
Butterfly sculpin	*Hemilepidotus papilio*	high potential	may affect	may affect
Canary rockfish	*Sebastes pinniger*	potential	effect unlikely	may affect
Capelin	*Mallotus villosus*	high potential	may affect	may affect
China rockfish	*Sebastes nebulosus*	potential	effect unlikely	may affect
Chinook salmon[e]	*Oncorhynchus tshawytscha*	no potential	effect unlikely	effect unlikely
Chum salmon[e]	*Oncorhynchus keta*	no potential	effect unlikely	effect unlikely
Coho salmon[e]	*Oncorhynchus kisutch*	no potential	effect unlikely	effect unlikely
Copper rockfish	*Sebastes caurinus*	potential	effect unlikely	may affect
Dover sole	*Microstomus pacificus*	high potential	may affect	may affect/sensitivity unknown
Dusky rockfish	*Sebastes variabilis*	potential	effect unlikely	may affect
Eastern Pacific bobtail squid	*Rossia pacifica*	high potential	may affect/ sensitivity unknown	may affect/sensitivity unknown
Eastern Pacific red octopus[e]	*Octopus rubescens*	no potential	effect unlikely	effect unlikely
English sole	*Parophrys vetulus*	high potential	may affect	may affect/sensitivity unknown
Eulachon	*Thaleichthys pacificus*	high potential	may affect	may affect
Flapjack octopus	*Opisthoteuthis californiana*	potential	effect unlikely	may affect/sensitivity unknown
Flathead sole	*Hippoglossoides elassodon*	high potential	may affect	may affect/sensitivity unknown

Common Name	Species	Maximum Potential for Exposure[a]	Adverse Impact Determination[b]	
			Crude Oil[c,d]	Corexit® 9500-Dispersed Oil
Giant or robust clubhook squid	*Moroteuthis robusta*	high potential	may affect/sensitivity unknown	may affect/sensitivity unknown
Giant Pacific octopus	*Enteroctopus dofleini*	potential	effect unlikely	may affect/sensitivity unknown
Golden king crab	*Lithodes aequispiba*	high potential	may affect	**most likely to affect**
Great sculpin	*Myoxocephalus polyacanthocephalus*	high potential	may affect	may affect
Greenland turbot	*Reinhardtius hippoglossoides*	high potential	may affect	may affect/sensitivity unknown
Grooved Tanner crab	*Chionoecetes tanneri*	high potential	may affect	**most likely to affect**
Longhead dab	*Pleuronectes proboscidea*	high potential	may affect	may affect/sensitivity unknown
Longspine thornyhead rockfish	*Sebastolobus altivelis*	potential	effect unlikely	may affect
Northern rock sole	*Lepidopsetta polyxystra*	high potential	may affect	may affect/sensitivity unknown
Northern rockfish	*Sebastes polyspinus*	potential	effect unlikely	may affect
Pacific cod	*Gadus macrocephalus*	high potential	**most likely to affect**	may affect
Pacific sand lance	*Ammodytes hexapterus*	high potential	may affect	may affect
Pink salmon[e]	*Oncorhynchus gorbuscha*	no potential	effect unlikely	effect unlikely
Pink scallop	*Chlamys rubida*	potential	effect unlikely	may affect
Plain sculpin	*Myoxocephalus jaok*	high potential	**most likely to affect**	may affect
Quillback rockfish	*Sebastes maliger*	potential	effect unlikely	may affect
Red Irish lord	*Hemilepidotus hemilepidotus*	high potential	may affect	may affect
Red king crab	*Paralithodes camtschaticus*	high potential	may affect	**most likely to affect**
Red or magistrate armhook squid[e]	*Berryteuthis magister*	no potential	effect unlikely	effect unlikely
Rex sole	*Glyptocephalus zachirus*	high potential	may affect	may affect/sensitivity unknown
Rock scallop	*Crassadoma gigantean*	potential	effect unlikely	may affect
Rosethorn rockfish	*Sebastes helvomaculatus*	potential	effect unlikely	may affect
Rougheye rockfish	*Sebastes aleutianus*	potential	effect unlikely	may affect
Sablefish	*Anoplopoma fimbria*	high potential	may affect	may affect
Saffron cod	*Eleginus gracilis*	high potential[f]	may affect	may affect
Salmon shark	*Lamna ditropis*	potential	effect unlikely	may affect/sensitivity unknown
Sand sole	*Psettichthys melanostictus*	high potential	may affect	may affect/sensitivity unknown
Scarlet king crab	*Lithodes couesi*	high potential	may affect	**most likely to affect**
Shortraker rockfish	*Sebastes borealis*	potential	effect unlikely	may affect

Common Name	Species	Maximum Potential for Exposure[a]	Adverse Impact Determination[b]	
			Crude Oil[c,d]	Corexit® 9500-Dispersed Oil
Shortspine thornyhead rockfish	*Sebastolobus alascanus*	potential	effect unlikely	may affect
Snow crab	*Chionoecetes opilio*	high potential	may affect	**most likely to affect**
Sockeye salmon[e]	*Oncorhynchus nerka*	no potential	effect unlikely	effect unlikely
Southern rock sole	*Lepidopsetta bilineata*	high potential	may affect	may affect/sensitivity unknown
Spiny dogfish	*Squalus acanthias*	potential	effect unlikely	may affect/sensitivity unknown
Spiny scallop	*Chlamys hastata*	potential	effect unlikely	may affect
Starry flounder	*Platichthys stellatus*	high potential	**most likely to affect**	may affect/sensitivity unknown
Tanner crab	*Chionoecetes bairdi*	high potential	may affect	**most likely to affect**
Tiger rockfish	*Sebastes nigrocinctus*	potential	effect unlikely	may affect
Triangle Tanner crab	*Chionoecetes angulatus*	high potential	may affect	**most likely to affect**
Walleye pollock	*Theragra chalcogramma*	potential	effect unlikely	may affect
Warty sculpin	*Myoxocephalus verrucosus*	high potential	**most likely to affect**	may affect
Weathervane scallop	*Patinopecten caurinus*	potential	effect unlikely	may affect
White scallop	*Chlamys albida*	potential	effect unlikely	may affect
Yellow Irish lord	*Hemilepidotus jordani*	high potential	may affect	may affect
Yelloweye rockfish	*Sebastes ruberrimus*	potential	effect unlikely	may affect
Yellowfin sole	*Limanda aspera*	high potential	may affect	may affect/sensitivity unknown

[a] The potential for exposure reported in this table is based on the highest exposure likelihood among egg and larval life stages as presented in Table 2.

[b] The determination of adverse impacts is based on the matrix presented in Table 8, which combines information from Tables 2 and 7; if no toxicological data were available (Table 7), but the potential for exposure exists (Table 2), then it is concluded that chemical dispersion "may affect" but that the species' sensitivity is "unknown."

[c] Crude oil is provided here as an indication of the baseline condition. The likelihood of impacts caused by crude oil is not being assessed in this appendix or the main text of the EFH assessment. Impacts resulting from crude oil exposures are only expected for species with a high potential for exposure (i.e., those present in the very shallow portion of the the water column).

[d] Unless a species is present in the very shallow portion of the water column (i.e., "high potential" likelihood for exposure), then it is assumed that exposures to crude oil are negligible. This is based on the fact that oil tends to naturally mix into the upper water column to only 1 m depth (NRC, 2005).

[e] Although the maximum potential for egg or larval life stages is negligible for this species, individuals may be exposed at early or late juvenile life stages. Individuals, if exposed as juveniles, could be adversely impacted, although the magnitude of such impacts would likely decrease in individuals of advanced age and increased body size. This species has been included in this table because adverse impacts in these species are not discountable.

[f] Maximum exposure likelihood is based on similar surrogate species; saffron cod is based on Arctic and Pacific cods.

Bold is used for emphasis.

In the event that concentrations of chemically dispersed oil similar to those measured in the field (e.g., up to 50 ppm TPH) (McAuliffe et al., 1981; McAuliffe et al., 1980; Humphrey et al., 1987b), which exceeded the LC50 values of most managed species (or reasonable surrogates), persist for a matter of hours (i.e., up to 24 hours), impacts on the majority of managed species (in shallow water, at early life stages) may occur regardless of their nominal sensitivities.

4.2 Synthesis Results

The results of the synthesis of exposure and sensitivity data presented in Tables 2 and 7 are summarized in Table 9. Species listed in Table 9 include those that may be impacted by the application of dispersants (72of the 85 species identified in FMPs, 65 of which have the potential to be impacted as larvae or eggs and 7 of which have the potential to be impacted as juveniles). There was insufficient toxicological data to qualify the potential impacts for several species (e.g., sharks and squid), but, because the potential exists for some of these species to be exposed to crude oil, chemical dispersants, or chemically dispersed oil, they are included in Table 9. The majority of impacts are expected to occur in larvae, because it is common for fish and invertebrate larvae to exist as pelagic, epipelagic, or neustonic plankton, assumed to be quite shallow in the water column (NMFS, 2014, 2013b, a, 2012, 2011) where exposures will increase as a result of chemical dispersion (NRC, 2005). Early life stages tend to be most sensitive to chemical perturbations (Mohammed, 2013). Also, early life stage fish and invertebrate species are often translucent, resulting in a greater potential for photo-enhanced PAH toxicity after internalizing oil droplets (Barron and Ka'aihue, 2001; Barron et al., 2008; Almeda et al., 2013). In addition to the acute impacts of PAH exposures in fish, delayed responses may occur (e.g., abnormal growth, genetic damage, reduced metabolic and cardiac function, and reduced immune function) (Carls and Meador, 2009; Carls et al., 2008; Carls et al., 1999; Carls and Rice, 1989; Hicken et al., 2011; Incardona et al., 2014; Incardona et al., 2013; Incardona et al., 2011; Logan, 2007; Payne et al., 2003), which may significantly reduce their ability to survive natural stress (e.g., evasion of predators and successful reproduction) (Claireaux et al., 2013). Species that have the potential to be exposed as early to late juveniles but not as eggs or larvae (e.g., salmon) have been included in Table 9; adverse impacts in these species are not entirely discountable, although juveniles are assumed to be less sensitive to crude and chemically dispersed oils than are eggs or larvae (Mohammed, 2013; Barron et al., 2008; Barron and Ka'aihue, 2001).

By focusing on the larval life stages of fish and invertebrates (many of which exist as plankton) to conduct the analysis of exposure and sensitivities, the results of the synthesis are also representative of the prey of managed species (e.g., plankton). Using the HC5 values calculated in Section 3.2 (based on acute toxicological data) as they relate to potential exposure concentrations measured in field studies (i.e., up to 50 ppm) (McAuliffe et al., 1981; McAuliffe et al., 1980; Humphrey et al., 1987b), it is possible that significant mortality may occur within the planktonic (prey) community within the first 24 hours. Although impacts on the planktonic (prey) community may be immediately apparent (Almeda et al., 2013), case studies have shown that planktonic (prey) communities are not greatly affected over time after chemical dispersion of oil (Abbriano et al., 2011; Varela et al., 2006). Prey resources are likely to recover quickly from a chemical dispersant application. Benthic and deeper pelagic prey items are less likely to be exposed to chemically dispersed oil, particularly at high concentrations (e.g., within 24 hours of a chemical dispersant application). It is possible that a dilute dispersed oil plume could move into shallow areas (e.g., intertidal and subtidal habitats), resulting in exposures of benthic prey items to dispersed oil. Exposures of such habitats to chemically dispersed oil is expected to be greater over a short time period due to the increased dissolution of oil components (e.g., PAHs) in the water column (Mageau et al., 1987; Humphrey et al., 1987a), but long-term exposures (e.g., > 1 year) may be reduced (Humphrey et al., 1987a; Peterson et al., 2003). For example, heavy oiling of sediments with untreated oil has been shown to result in prolonged exposures of benthic invertebrate species to oil (Peterson et al., 2003; Humphrey et al., 1987a), as well as ambient concentrations of oil seeping into the water column (Humphrey et al., 1987b). Dispersants have been shown to increase the rate of microbial biodegradation of oil in marine sediments (Hua, 2006). The formation of smaller, buoyant OMA in nearshore areas as a result of chemical dispersion (applied in open water then moving into the nearshore) could increase benthic exposures to dispersed oil (Niu and Lee, 2013).

5 Uncertainty Analysis

The various points of uncertainty been stated throughout this appendix are summarized in this section.

5.1 Sea Conditions, Spill Conditions, and Expected Spill Responses

No two spills are expected to be alike, considering the complex nature of the environment into which oil is spilled, the expansive area of the State of Alaska, and the various potential sources of oil (e.g., oil tanker, oil platform, marine fueling station, etc.). Therefore, it is impossible to accurately predict the response actions that will be applied and the efficacy of those actions. The use of dispersants would not be effective under many conditions, nor would it be practical under all conditions (Nedwed, 2012).

Assuming that conditions are such that dispersants are approved for use on a given spill, it is impossible to know in advance the effectiveness of the dispersant due to changing sea conditions (e.g., wind and wave energy and tides), the presence of sea ice, salinity differences, and various other conditions. It is also impossible to know in advance whether best management practices (BMPs) will be entirely successful in mitigating damages to EFH, although the intended purpose of the chemical dispersion of oil (i.e., to mix oil droplets into the water column) has the potential to impact EFH under ideal dispersion conditions.

5.2 Calculation of the HC5

The HC5s derived for use in this assessment of EFH are representative of only Corexit® 9500 or Corexit® 9527, the only two dispersants currently available for use (i.e., stockpiled) in Alaska. However, Corexit® 9527 is no longer being manufactured, so the model created here will become obsolete once those stockpiles are exhausted. It is assumed that Corexit® 9500 will be used once Corexit® 9527 ceases to be available for emergency responses. Few toxicity data are available to evaluate other dispersant formulations that could be approved for use by the Alaska Regional Response Team (ARRT) in the future.

The majority of studies used to derive the HC5s were based on constant (i.e., static, static renewal, and flow through) exposure scenarios. As discussed, the resulting LC50s were generally lower than those derived from spiked exposures. Because a geometric mean LC50 was used to represent a given species or genera, spiked data were, in some cases, combined with constant concentration exposure data. Although spiked exposures are expected to provide a more realistic simulation of dispersants in the field (i.e., surface application), the HC5s derived are more representative of constant concentration exposures. For these reasons, the HC5s may overestimate toxicity as it relates to a field application, and can thus be seen as protective (over a short time period).

Although only early life stage fish species were used in developing the SSDs, there were various invertebrates included in the SSDs for which the life stage was not reported in literature reviews (George-Ares and Clark, 2000; NRC, 2005). Because life stage is important in driving the sensitivity of invertebrates (as well as most species in general), the sensitivity of certain taxa may be slightly underestimated.

The toxicity data largely represent either temperate or warm-water species (as opposed to Arctic species), which may not react in the same way as species in Alaska. Tests of Corexit® 9500-dispersed oil using Arctic species have shown that they are somewhat less sensitive than non-Arctic species (Figure 6). However, this result was likely affected by a difference in exposure regimes from that particular dataset. Toxicity tests using Arctic species mostly applied spiked exposures, whereas toxicity tests using temperate species used primarily constant concentration exposures (i.e., static, static-renewal, or flow through) (Attachment B-1 to Appendix B of the BA) (Windward and ERM, 2014). Because spiked exposures tend to result in increased LC50 values, regardless of species, the apparent insensitivity of Arctic species shown in Figure 6 is likely an artifact.

Most importantly, the analysis presented above, which uses acute laboratory data, does not incorporate two very important sources of uncertainty. Although sublethal and chronic impacts are discussed in a cursory way in Section 3.2, such impacts are not incorporated into the determination of the HC5s. PAHs are thought to be the most toxic component of oil, and chemical dispersants generally increase the exposure of aquatic species to PAHs by making PAHs more bioavailable (Ramachandran et al., 2004; Yamada et al., 2003; Milinkovitch et al., 2011; Lee, 2013). Sublethal effects may occur at much lower exposure concentrations than the HC5s (Smit et al., 2009), and such effects may have lasting impacts on aquatic species.

Also of great importance is the fact that traditional laboratory testing of aquatic toxicity is conducted in chambers without UV light in order to control the photodegradation of PAHs or other similarly degraded toxicants. But PAHs are known to be up to 1,000 times more toxic when exposed to UV light (Barron and Ka'aihue, 2001). In the shallow ocean, solar irradiance is ubiquitous; furthermore, there can be extreme light conditions in Alaska, depending on the time of year (i.e., polar day phenomenon). For these reasons, it can be assumed that an ecologically relevant exposure to PAHs, made more bioavailable by the application of dispersants (Ramachandran et al., 2004), will occur in conjunction with photo-enhanced toxicity, particularly in species or life stages of fish and invertebrates that are translucent (Barron et al., 2008).

In the case of Corexit® 9527-dispersed oil, the HC5 was calculated as less than the minimum calculated genus geomean LC50 value. Although this is appropriate for small datasets (with < 20 species or genera represented) (Posthuma et al., 2002), it is somewhat uncertain to extrapolate a protective concentration beyond measured levels.

The other HC5 values were not extrapolated in this same manner, as the datasets included toxicity values from more than 20 species or genera (Tables 3 through 5).

5.3 PAH Toxicity

5.3.1 Fish

A major point of uncertainty in the analyses provided in this appendix has to do with the use of surrogate fish species in the estimation of impacts on fish. For example, the fish included in the SSD presented in Section 3.3 include many taxa that are not found in Alaska waters and that are not managed under an FMP. Greater uncertainty in assigning relative sensitivities to managed species arises from the use of somewhat dissimilar species (e.g., within the same order but different families or functionally similar forage fish but taxonomically dissimilar) as surrogates. For several managed species (e.g., sharks and skates), reasonable surrogate data are not available for any chemical mixture of interest.

Similarly, for two species (i.e., warty sculpin and saffron cod), the potential for exposure could not be determined directly from available data for those species. Data regarding the eggs of warty sculpin is unavailable, but, using data from others in the genus *Myoxocephalus* (i.e., plain and great sculpins), it is unlikely (i.e., no/low potential) that warty sculpin eggs will be exposed.[40] Larval life stage data for saffron cod is unavailable, but it is expected to be similar to other cold-water cod species (e.g., Arctic and Pacific cods), which have a high potential to be exposed as planktonic larvae.

Surrogate sensitivity data used for small forage fish (i.e., eulachon, capelin, and Pacific sand lance) were based on a wide range of values. It is unclear how sensitive or insensitive these species will be to crude or chemically dispersed oil based on the available data.

Oil, particularly the toxic component PAHs in oil (Barron, 2012; Milinkovitch et al., 2011; Roy et al., 1999; Brannon et al., 2006; Carls et al., 1999, 2000; Meador, 2003; Payne et al., 2003), can have various sublethal impacts on fish species (Stige et al., 2011; ITOPF, 2011). Metabolites of PAHs are often more toxic than their parent compounds, so adverse impacts on fish are most likely to occur after accumulation and metabolism of parent compounds, but before excretion (Payne et al., 2003). Payne et al. (2003) provided a concise review of the historically reported sublethal impacts of PAHs on fish, including genotoxicity, immunotoxicity, histopathological impacts (e.g., hepatic lesions), behavioral impacts, and reproductive impacts. Such impacts may result in reduced fitness, leading to the death of individuals. A clear example of this impact is

[40] The most sensitive life stage of warty sculpin is the larval life stage, at which point they are planktonic. The likelihood of exposure for warty sculpin was based on their larval life stage rather than their egg life stage in order to be more protective.

provided by Claireaux et al. (2013), who showed that European sea bass (*Dicentrarchus labrax*) exposed to oil and dispersed oil were more susceptible to normal environmental perturbations than were those not exposed to oil or dispersed oil. To test this, both chemically exposed and control fish were placed in a chamber that became hypoxic for a time and, subsequently, very warm for a time; the fish were then transferred to the field for monitoring of growth and survival. Those fish exposed (after exposure to oil or dispersed oil) to low dissolved oxygen and high temperatures had a significantly higher rate of mortality or a significantly lower rate of growth than the control fish, suggesting that their fitness was compromised by chemical exposure (Claireaux et al., 2013).

As noted above, many studies have linked PAH exposures to sublethal impacts on fish; however, it is not entirely clear whether or how sublethal impacts will lead to significant adverse impacts, such as reduced survival, growth, or reproduction. For example, due to the complex nature of PAH toxicity, certain sublethal impacts of PAH exposure (e.g., narcosis) might be reversible over time (NRC, 2005; Incardona et al., 2004), whereas other sublethal impacts might result in delayed responses (Hicken et al., 2011; Claireaux et al., 2013). It is even less clear whether such impacts would have a population-level response in managed fisheries.

Another important consideration for fish, particularly unpigmented, early life stage fish that reside in the upper water column, is the possibility of photo-enhanced toxicity; this is discussed in Section 5.1. As with invertebrates, the potential for acute mortality in prey fish species or larval life stages of managed fisheries under natural lighting conditions may be underestimated by the analyses presented in Section 3.3, which do not address photo-enhanced toxicity.

Although dermal exposures of fish may increase after chemical dispersion, it is not clear how dermal exposures to dispersed oil will impact fish at the individual level (e.g., decreased survival, growth, or reproduction). It is possible that topical lesions may occur (Logan, 2007), but these do not directly relate to reduced growth, reproduction, or survival.

5.3.2 Invertebrates

As with fish (Section 5.3.1), using surrogates to assign likely sensitivities to crude oil, chemical dispersants, and chemically dispersed oil results in somewhat uncertain conclusions. For example, toxicity data was only available for tanner crab exposed to Corexit® 9500. All other sensitivities were based on surrogates, many of which were decapods of various sizes, life histories, and physiologies.

Both decapod and bivalve surrogate toxicity data tended to be quite variable, so results for species that used these ranges of surrogate data are fairly uncertain. When available, only larger species of decapods were used as surrogates; for example, red king crab data was used as the surrogate to assign tanner, other king, and snow crab sensitivities to crude oil, even though other decapod data were available (e.g., from relatively small shrimp species).

There are various potential reasons for uncertainty in drawing conclusions about the likelihood of impacts of dispersed oil on invertebrate species when using acute toxicity data. Based on the uncertainties identified in Section 5.2, it is possible that dispersed oil will have an impact on planktonic invertebrates (e.g., larval life stages of most species), more so than the analysis presented in Section 3.2 (based on acute toxicity) would suggest.

5.4 INDIRECT IMPACTS OF DISPERSED OIL TOXICITY

Planktonic species that are immobile (aside from moving with ocean currents) have the greatest potential to be directly impacted by chemically dispersed oil (Barron and Ka'aihue, 2001), and shallow-dwelling nekton and neustonic species or life stages are expected to be exposed to both concentrated dispersed oil and untreated crude oil (i.e., within the upper 1 m of the water column). However, it is unclear whether the mortality of plankton in the vicinity of a treated oil spill will result in significant, indirect impacts on managed fish species. For example, salmonids are known to feed over large areas (NMFS, 2003) and may not be impacted by a localized mortality of sensitive plankton. Although many sensitive species may be killed during an oil spill or after chemical dispersion (Almeda et al., 2013; Lee, 2013), the biomass contained within a planktonic community may remain much the same over time (Varela et al., 2006) and/or recover quickly from chemical disturbance (Varela et al., 2006; Abbriano et al., 2011); therefore, prey resources may not be reduced. The rate of recruitment into impacted areas may be due to various potential factors, including the rapid reproduction of planktonic species (Varela et al., 2006; Abbriano et al., 2011), the ability of some species (e.g., copepods) to selectively avoid oil droplets in water (Abbriano et al., 2011), and the circulation and mixing of the ocean (Varela et al., 2006); dispersion and degradation of oil in the water column were also cited as potential reasons for the rapid recovery of the planktonic community after DHOS (Abbriano et al., 2011).

Impacts on larger, long-lived, or more slowly reproducing species that serve as prey (e.g., forage fish) may result in indirect impacts on piscivorous fishes and invertebrates. The potential for chemical dispersant impacts on managed forage fish (e.g., capelin, eulachon, and Pacific sand lance) is provided in Section 4.2 of this appendix, and the potential for impacts on Pacific herring (an ESA-candidate species and ecologically important forage fish) is provided in Appendix B to the BA (Windward and ERM, 2014).

5.5 Toxicity of Dispersant Components and Degradates/Metabolites

The analyses of dispersant toxicity presented in Sections 3.1 through 4.3 do not include a specific discussion of the individual component chemicals within dispersant mixtures. It is unclear, based on the analyses presented in this appendix, what the toxicities of these individual components are. However, components of Corexit® formulations will not be applied singly but as the entire product mixture. Therefore, it is not necessary or relevant to this assessment to provide additional toxicity information regarding the components of chemical dispersants.

There is a general paucity of data regarding the toxicity and fate and transport of the degradates or metabolites (created primarily via biodegradation) of chemical dispersant component chemicals (Table 1). It is not clear whether such products will be more or less toxic than or equally toxic to parent chemicals in chemical dispersants. The assessment of the toxicity of chemical dispersants alone does not directly address this uncertainty.

5.6 Seasonality and the Potential for Exposure

As noted in Section 2.4.2, the potentials for exposure for various species at various life stages are likely influenced by seasonality. First, species will only be present in certain locations during certain seasons. As an example, salmon migrations tend to occur during consistent time periods, and, based on the strength of particular spawning runs, certain fisheries may be closed (in order to maintain a sustainable population) (NMFS, 2012). Species present in the marine environment as eggs and larvae may only be present at a vulnerable life stage for a matter of months. This is particularly important for species that have planktonic larvae that later settle out (e.g., flatfish, sculpin); impacts related to chemically dispersed oil are expected to be much greater for shallow-dwelling, early life stage individuals than for juvenile or adult demersal individuals of the same species.

Second, the seasonality of oil spills is likely to result in a variable potential for exposure in terms of geography. Spills of petroleum to marine waters in Alaska (where chemical dispersants could be used) are more frequent during certain seasons and in certain areas. To summarize the example given in Section 2.4.2, spills to marine waters (almost entirely diesel fuels) are most prevalent during the summer in southeast Alaska and the Aleutian Islands, whereas crude oil tends to be spilled in Cook Inlet during the winter (although infrequently). In other areas such as the North Slope (and Arctic management areas) and Western Alaska (e.g., Bering Sea and northern portions of Aleutian Island management areas), spills are quite infrequent. Historically, the largest spills occurred in PWS, Cook Inlet, Kodiak Island, and GOA (i.e., EVOS) and the Aleutian Islands (i.e., M/V *Selendang Ayu*).

6 Conclusion

The following conclusions are made in Sections 2, 3, or 4:

- Crude oil, when released into the environment, is less likely to come into contact with managed fish and invertebrate species (and their EFH) than chemically dispersed oil due to the dispersion of droplets deeper into the water column.
  - Exposures to crude oil are limited to the upper 1 m of the water column.
  - Exposures to chemical dispersants and chemically dispersed oil are limited to the upper 10 m of the water column, which is relatively shallow compared to the EFH of many species and life stages.
  - Sensitive larval life stages of managed species have the greatest potential to be exposed in the upper 10 m of the water column and to experience adverse impacts.
  - Chemically dispersed oil is more bioavailable than crude oil.
- Chemical dispersants alone are less acutely toxic (i.e., causing mortality) than chemically dispersed oil or crude oil.
- In general, when focusing on acute lethality data (i.e., 48- or 96-hour LC50s), fish and invertebrates tend to be slightly less sensitive to chemically dispersed oil than to crude oil.
  - Exposure of translucent individuals (e.g., eggs, larvae, and planktonic prey) that have previously been exposed to oil and/or dispersed oil to UV light may result in significantly greater toxicity than suggested by laboratory data, particularly for individuals exposed to chemically dispersed oil.
  - Sublethal impacts of exposure to components of oil may be more pronounced after chemical dispersion than under the baseline condition; however, the significance of sublethal impacts is uncertain.
- Planktonic prey species have the potential (and neustonic and shallow-dwelling nektonic plankton have a high potential) to be exposed and may be adversely impacted by the chemical dispersion of crude oil. This represents an indirect effect on managed species (and a direct impact on EFH). Neustonic prey are expected to be exposed to crude oil under the baseline condition.
- Effects on the planktonic community (as a prey resource), although possible, may not be long-term.
- Toxic components of chemically dispersed oil (e.g., PAHs) are more bioavailable than the same components in untreated crude oil.

- **The potential exists for impacts on the EFH of many fish and invertebrate species (Table 9).**
  - Although exposures of less sensitive, juvenile or adult life stage individuals may occur, this evaluation, which focused on the potential for impacts to sensitive, early life stage individuals, is intended to be conservative at the population and community level.

The main text of the EFH assessment provides information regarding the potential for an implementation of the Unified Plan to impact EFH. This assessment provides an in-depth assessment of only one type of impact, "exposure to contaminants." The conclusions stated herein are summarized in the main text of the EFH assessment (Section 3.2 of the main text), and the potential for EFH to be exposed to contaminants such that it may adversely affect managed fisheries is provided in applicable subsections within Section 3.2.2 of the main text.

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ATTACHMENT A1. EFH EXPOSURE AND EFFECTS ANALYSIS

Attachment A1. EFH Exposure and Effects Analysis

Table A1-1. Potential for Exposure Table

Common name	Species	Early Life Stages*		Juveniles	Adults	Citation(s)
		Egg	Larvae			
Alaska plaice	*Pleuronectes quadrituberculatus*	Potential	High potential	High potential	No potential	NMFS (2005c, d, 2013a, b); Johnson et al. (2012)
Alaska skate	*Bathyraja parmifera*	No potential	No potential	No potential	No potential	NMFS (2005c, d, 2013a, b)
Aleutian skate	*Bathyraja aleutica*	No potential	No potential	No potential	No potential	NMFS (2005c, d, 2013a, b)
Arctic cod	*Arctogadus glacialis*	No potential	High potential	Potential	High potential	NPFMC (2009); Campana (1996); ICES/GLOBEC (2005)
Arrowtooth flounder	*Atheresthes stomias*	Potential	High potential	No/low potential	High potential	NMFS (2005c, d, 2013a, b); PFMC (2005)
Atka mackerel	*Pleurogrammus monopterygius*	Potential	High potential	Potential	High potential	NMFS (2005c, d, 2013a, b); Zavolokin et al. (2007)
Bering Sea scallop	*Chlamys behringiana*	No/low potential	Potential	No potential	No potential	NMFS (2005a, 2006, 2014)
Bering skate	*Bathyraja interrupta*	No potential	No potential	No potential	No potential	NMFS (2005c, d, 2013a, b)
Bigmouth sculpin	*Hemitripterus bolini*	No/low potential	High potential	No potential	No potential	NMFS (2005c, d, 2013a, b)
Blackspotted rockfish	*Sebastes melanostictus*	No potential	Potential	Potential	No potential	NMFS (2013a, b)
Blue king crab	*Paralithodes platypus*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011)
Boreal clubhook squid	*Onychoteuthis borealjaponica*	No potential	High potential	High potential	High potential	NMFS (2005c, d, 2013a, b)
Butter sole	*Isopsetta isolepis*	Potential	High potential	High potential	No/low potential	NMFS (2005c, d, 2013a, b); PFMC (2005); Busby et al. (2000); Abookire et al. (2000); Johnson et al. (2012)
Butterfly sculpin	*Hemilepidotus papilio*	No/low potential	High potential	No potential	No potential	NMFS (2005c, d, 2013b)
Canary rockfish	*Sebastes pinniger*	No potential	Potential	No potential	No potential	NMFS (2005d, 2013b); Orr et al. (2000)
Capelin	*Mallotus villosus*	High potential	High potential	High potential	High potential	NMFS (2005c, d, 2013a, b)
China rockfish	*Sebastes nebulosus*	No potential	Potential	High potential	No potential	NMFS (2005d, 2013b); Orr et al. (2000); Johnson et al. (2012)
Chinook salmon	*Oncorhynchus tshawytscha*	No potential	No potential	High potential	High potential	NMFS (2005e, 2012); Johson et al. (2012)
Chum salmon	*Oncorhynchus keta*	No potential	No potential	High potential	High potential	NMFS (2005e, 2012); Johson et al. (2012)
Coho salmon	*Oncorhynchus kisutch*	No potential	No potential	High potential	High potential	NMFS (2005e, 2012); Johson et al. (2012)
Copper rockfish	*Sebastes caurinus*	No potential	Potential	High potential	No potential	NMFS (2005d, 2013b); Orr et al. (2000); Johnson et al. (2012)
Dover sole	*Microstomus pacificus*	Potential	High potential	High potential	No potential	NMFS (2005c, d, 2013a, b); PFMC (2005); Abookire et al. (2000)
Dusky rockfish	*Sebastes variabilis*	No potential	Potential	No potential	No potential	NMFS (2005c, d, 2013a, b); Orr et al. (2000)
Eastern Pacific bobtail squid	*Rossia pacifica*	No potential	High potential	No/low potential	No/low potential	NMFS (2005c, d, 2013a, b)
Eastern Pacific red octopus	*Octopus rubescens*	No potential	No potential	High potential	High potential	NMFS (2013a)
English sole	*Parophrys vetulus*	Potential	High potential	High potential	No/low potential	NMFS (2005d, 2013b); PFMC (2005); Brodeur and Rugen (1993); Busby et al. (2000); Abookire et al. (2000); Johnson et al. (2012)
Eulachon	*Thaleichthys pacificus*	No potential	High potential	High potential	High potential	NMFS (2005c, d, 2013a, b)
Flapjack octopus	*Opisthoteuthis californiana*	No potential	Potential	No potential	No potential	NMFS (2013a, b)
Flathead sole	*Hippoglossoides elassodon*	Potential	High potential	No/low potential	No potential	NMFS (2005c, d, 2013a, b); Busby et al. (2000); Abookire et al. (2000)
Giant or robust clubhook squid	*Moroteuthis robusta*	No potential	High potential	No potential	No potential	NMFS (2005c, d, 2013a, b)
Giant Pacific octopus	*Enteroctopus dofleini*	No potential	Potential	Potential	Potential	NMFS (2005c, d, 2013a, b); Woodford and Donohue (2007)
Golden king crab	*Lithodes aequispina*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011)
Great sculpin	*Myoxocephalus polyacanthocephalus*	No potential	High potential	High potential	No potential	NMFS (2005c, d, 2013a, b); Johnson et al. (2012)
Greenland turbot	*Reinhardtius hippoglossoides*	No/low potential	High potential	No potential	No potential	NMFS (2005c, d, 2013a, b); Alton et al. (1988)
Grooved Tanner crab	*Chionoecetes tanneri*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011)
Kamchatka flounder	*Atheresthes evermanni*	No/low potential	No/low potential	No potential	No potential	NMFS (2013b)
Longhead dab	*Pleuronectes proboscidea*	Potential	High potential	High potential	No potential	NMFS (2005a, 2013a)
Longspine thornyhead rockfish	*Sebastolobus altivelis*	Potential	Potential	No/low potential	No potential	NMFS (2005c, d, 2013a, b)
none	*Graneledone boreopacifica*	No potential	No potential	No potential	No potential	NMFS (2013a)
none	*Japetella diaphana*	No potential	No potential	No potential	No potential	NMFS (2013a, b); Young (2013)
none	*Octopus* sp. Jorgensen	No potential	No potential	No potential	No potential	NMFS (2013a, b)
none	*Benthoctopus oregonensis*	No potential	No potential	No potential	No potential	NFMS (2013a)
North Pacific bigeye octopus	*Octopus californicus*	No potential	No potential	No potential	No potential	NMFS (2013b)
Northern rock sole	*Lepidopsetta polyxystra*	No potential	High potential	High potential	No potential	Rugen (1993); Busby et al. (2000); Abookire et al. (2000); Johnson et al. (2012)
Northern rockfish	*Sebastes polyspinus*	No potential	Potential	No potential	No potential	NMFS (2005c, d, 2013a, b); Orr et al. (2000); Orr and Matarese
Pacific cod	*Gadus macrocephalus*	No potential	High potential	High potential	No potential	NMFS (2005c, d, 2013a, b); Johnson et al. (2012)
Pacific ocean perch	*Sebastes alutus*	No potential	No/low potential	No/low potential	No potential	NMFS (2005c, d, 2013a, b)
Pacific sand lance	*Ammodytes hexapterus*	High potential	High potential	Potential	Potential	NMFS (2005c, d, 2013a, b); Gotthardt et al. (2005)
Pacific sleeper shark	*Somniosus pacificus*	No/low potential	N/A**	No/low potential	No/low potential	NMFS (2005c, d, 2013a, b)
Pink salmon	*Oncorhynchus gorbuscha*	No potential	No potential	High potential	High potential	NMFS (2005e, 2012); Busby et al. (2000); Johson et al. (2012)
Pink scallop	*Chlamys rubida*	No/low potential	Potential	No potential	No potential	NMFS (2005a, 2006, 2014)
Plain sculpin	*Myoxocephalus jaok*	No/low potential	High potential	High potential	Potential	NMFS (2005c, d, 2013a, b); Johnson et al. (2012)
Quillback rockfish	*Sebastes maliger*	No potential	Potential	High potential	Improbable	NMFS (2005d, 2013b); Orr et al. (2000); Johnson et al. (2012)

Table A1-1. Potential for Exposure Table

Common name	Species	Early Life Stages*		Juveniles	Adults	Citation(s)
		Egg	Larvae			
Red Irish lord	*Hemilepidotus hemilepidotus*	High potential	High potential	High potential	No potential	NMFS (2005c, d, 2013b); Johnson et al. (2012)
Red king crab	*Paralithodes camtschaticus*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011)
Red or magistrate armhook squid	*Berryteuthis magister*	No potential	No potential	High potential	High potential	NMFS (2005c, d, 2013a, b); EOL (2014a)
Rex sole	*Glyptocephalus zachirus*	Potential	High potential	No/low potential	No potential	NMFS (2005c, d, 2013a, b); PFMC (2005); Abookire et al. (2000)
Rock scallop	*Crassadoma gigantean*	No/low potential	Potential	No potential	No potential	NMFS (2005a, 2006, 2014)
Rosethorn rockfish	*Sebastes helvomaculatus*	No potential	Potential	No potential	No potential	NMFS (2005d, 2013b); Orr et al. (2000)
Rougheye rockfish	*Sebastes aleutianus*	No potential	Potential	No potential	No potential	NMFS (2005c, d, 2013a, b); Orr et al. (2000)
Sablefish	*Anoplopoma fimbria*	No potential	High potential	High potential	No potential	NMFS (2005c, d, 2013a, b); Johnson et al. (2012)
Saffron cod	*Eleginus gracilis*	No/low potential	High potential	High potential	High potential	NPFMC (2009); Dunn and Materese (1987); Johnson et al. (2012)
Salmon shark	*Lamna ditropis*	Potential	N/A**	Potential	Potential	NMFS (2005c, d, 2013a, b)
Sand sole	*Psettichthys melanostictus*	Potential	High potential	High potential	No/low potential	NMFS (2005d, 2013b); PFMC (2005); Brodeur and Rugen (1993); Busby et al. (2000); Johnson et al. (2012)
Scarlet king crab	*Lithodes couesi*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011)
Shortraker rockfish	*Sebastes borealis*	No potential	Potential	No potential	No potential	NMFS (2005c, d, 2013a, b); Orr et al. (2000)
Shortspine thornyhead rockfish	*Sebastolobus alascanus*	Potential	Potential	No/low potential	No potential	NMFS (2005c, d, 2013a, b); Orr et al. (2000)
Smoothskin octopus	*Benthoctopus leioderma*	No potential	No potential	No potential	No potential	NMFS (2013a, b)
Snow crab	*Chionoecetes opilio*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011); NPFMC (2009)
Sockeye salmon	*Oncorhynchus nerka*	No potential	No potential	High potential	High potential	NMFS (2005e, 2012); Johson et al. (2012)
Southern rock sole	*Lepidopsetta bilineata*	No potential	High potential	High potential	No potential	(1993); Busby et al. (2000); Abookire et al. (2000); Johnson et al. (2012)
Spiny dogfish	*Squalus acanthias*	Potential	N/A**	Potential	No/low potential	NMFS (2005c, d, 2013a, b); PFMC (2005)
Spiny scallop	*Chlamys hastata*	No/low potential	Potential	No potential	No potential	NMFS (2005a, 2006, 2014)
Starry flounder	*Platichthys stellatus*	High potential	High potential	High potential	No/low potential	NMFS (2005c, d, 2013a, b); PFMC (2005); Busby et al. (2000); Johnson et al. (2012)
Tanner crab	*Chionoecetes bairdi*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011)
Tiger rockfish	*Sebastes nigrocinctus*	No potential	Potential	No potential	No potential	NMFS (2005d, 2013b); Orr et al. (2000)
Triangle Tanner crab	*Chionoecetes angulatus*	No potential	High potential	No potential	No potential	NMFS (2005b, 2011)
Vampire squid	*Vampyroteuthis infernalis*	No potential	No potential	No potential	No potential	NFMS (2005c, d, 2013b); EOL (2014b)
Walleye pollock	*Theragra chalcogramma*	Potential	Potential	High potential	No potential	NMFS (2005c, d, 2013a, b); Johnson et al. (2012)
Warty sculpin	*Myoxocephalus verrucosus*	Unclear	High potential	No potential	No potential	NMFS (2013a)
Weathervane scallop	*Patinopecten caurinus*	No/low potential	Potential	No potential	No potential	NMFS (2005a, 2006, 2014)
White scallop	*Chlamys albida*	No/low potential	Potential	No potential	No potential	NMFS (2005a, 2006, 2014)
Yellow Irish lord	*Hemilepidotus jordani*	Potential	High potential	No potential	No potential	NMFS (2005c, d, 2013a, b)
Yelloweye rockfish	*Sebastes ruberrimus*	No potential	Potential	No potential	No potential	NMFS (2005d, 2013b); Orr et al. (2000)
Yellowfin sole	*Limanda aspera*	Potential	High potential	High potential	No/low potential	(2012)

* The potential for exposure for early life stages of each species was carried forward into the synthesis (Table A1-3); the use of early life stages as the basis of the synthesis is assumed to be the most protective approach.

**Sharks do not have a larval life stage.

Note: the complete list of references cited in this table are provided at the end of the attachment.

Attachment A1. EFH Exposure and Effects Analysis

Table A1-2. Sensitivities of Managed Species with Surrogate Information

Species	Common Name	Crude oil				Corexit 9500				Corexit 9527			
		Species or surrogate(s)	SSD percentile*	Sensitivity bin (based on SSD)	Geomean LC50* (ppm TPH)	Species or surrogate(s)	SSD percentile*	Sensitivity bin (based on SSD)	Geomean LC50* (ppm)	Species or surrogate(s)	SSD percentile*	Sensitivity bin (based on SSD)	Geomean LC50* (ppm)
Bathyraja parmifera	Alaska skate	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Bathyraja aleutica	Aleutian skate	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Bathyraja interrupta	Bering skate	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Onychoteuthis borealjaponica	Boreal clubhook squid	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Rossia pacifica	Eastern Pacific bobtail squid	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Moroteuthis robusta	Giant or robust clubhook squid	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Somniosus pacificus	Pacific sleeper shark	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Berryteuthis magister	Red or magistrate armhook squid	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Lamna ditropis	Salmon shark	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Squalus acanthias	Spiny dogfish	None	No data	No data	No data	None	No data	No data	No data	None	No data	No data	No data
Octopus rubescens	Eastern Pacific red octopus	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Opisthoteuthis californiana	Flapjack octopus	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Enteroctopus dofleini	Giant Pacific octopus	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Graneledone boreopacifica	none	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Japetella diaphana	none	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Octopus sp. Jorgensen	none	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Benthoctopus oregonensis	none	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Octopus californicus	North Pacific bigeye octopus	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Benthoctopus leioderma	Smoothskin octopus	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Vampyroteuthis infernalis	Vampire squid	*Octopus pallidus*	2%	Sensitive	0.39	None	No data	No data	No data	None	No data	No data	No data
Oncorhynchus nerka	Sockeye salmon	*Oncorhynchus nerka*	16%	Sensitive	1.1	*Oncorhynchus mykiss*	92%	Insensitive	354	*Oncorhynchus mykiss*	82%	Insensitive	158
Arctogadus glacialis	Arctic cod	*Boreogadus saida*	19%	Sensitive	1.2	None	No data	No data	No data	None	No data	No data	No data
Gadus macrocephalus	Pacific cod	*Boreogadus saida*	19%	Sensitive	1.2	None	No data	No data	No data	None	No data	No data	No data
Oncorhynchus gorbuscha	Pink salmon	*Oncorhynchus gorbuscha*	30%	Moderately sensitive	1.3	*Oncorhynchus mykiss*	92%	Insensitive	354	*Oncorhynchus mykiss*	82%	Insensitive	158
Oncorhynchus kisutch	Coho salmon	*Oncorhynchus kisutch*	35%	Moderately sensitive	1.5	*Oncorhynchus mykiss*	92%	Insensitive	354	*Oncorhynchus mykiss*	82%	Insensitive	158
Oncorhynchus keta	Chum salmon	*Oncorhynchus* spp.	37%	Moderately sensitive	1.7	*Oncorhynchus mykiss*	92%	Insensitive	354	*Oncorhynchus mykiss*	82%	Insensitive	158
Theragra chalcogramma	Walleye pollock	*Theragra chalcogramma*	44%	Moderately sensitive	1.7	None	No data	No data	No data	None	No data	No data	No data
Platichthys stellatus	Starry flounder	*Platichthys stellatus*	46%	Moderately sensitive	1.8	*Scophthalmus maximus*	56%	Moderately insensitive	75	*Platichthys flesus*	76%	Insensitive	100
Myoxocephalus jaok	Plain sculpin	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp.	44%	Moderately sensitive	1.9	None	No data	No data	No data	None	No data	No data	No data
Myoxocephalus verrucosus	Warty sculpin	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp.	44%	Moderately sensitive	1.9	None	No data	No data	No data	None	No data	No data	No data
Chlamys behringiana	Bering Sea scallop	*Chlamys* spp.	49%	Moderately sensitive	1.9	*Crassostrea virginica*	84%	Insensitive	167	*Crassostrea gigas, Protothaca staminea*	9-79% (44%)	Moderately sensitive	6.6-100 (26)
Chlamys rubida	Pink scallop	*Chlamys* spp.	49%	Moderately sensitive	1.9	*Crassostrea virginica*	84%	Insensitive	167	*Crassostrea gigas, Protothaca staminea*	9-79% (44%)	Moderately sensitive	6.6-100 (26)
Crassadoma gigantean	Rock scallop	*Chlamys* spp.	49%	Moderately sensitive	1.9	*Crassostrea virginica*	84%	Insensitive	167	*Crassostrea gigas, Protothaca staminea*	9-79% (44%)	Moderately sensitive	6.6-100 (26)
Chlamys hastata	Spiny scallop	*Chlamys* spp.	49%	Moderately sensitive	1.9	*Crassostrea virginica*	84%	Insensitive	167	*Crassostrea gigas, Protothaca staminea*	9-79% (44%)	Moderately sensitive	6.6-100 (26)
Patinopecten caurinus	Weathervane scallop	*Chlamys* spp.	49%	Moderately sensitive	1.9	*Crassostrea virginica*	84%	Insensitive	167	*Crassostrea gigas, Protothaca staminea*	9-79% (44%)	Moderately sensitive	6.6-100 (26)
Chlamys albida	White scallop	*Chlamys* spp.	49%	Moderately sensitive	1.9	*Crassostrea virginica*	84%	Insensitive	167	*Crassostrea gigas, Protothaca staminea*	9-79% (44%)	Moderately sensitive	6.6-100 (26)
Paralithodes platypus	Blue king crab	*Paralithodes camtschaticus*	56%	Moderately insensitive	2.2	*Chionoecetes bairdi*	36%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Lithodes aequispiba	Golden king crab	*Paralithodes camtschaticus*	56%	Moderately insensitive	2.2	*Chionoecetes bairdi*	36%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Chionoecetes tanneri	Grooved Tanner crab	*Paralithodes camtschaticus*	56%	Moderately insensitive	2.2	*Chionoecetes bairdi*	36%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Paralithodes camtschaticus	Red king crab	*Paralithodes camtschaticus*	58%	Moderately insensitive	2.2	*Chionoecetes bairdi*	36%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Lithodes couesi	Scarlet king crab	*Paralithodes camtschaticus*	56%	Moderately insensitive	2.2	*Chionoecetes bairdi*	36%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Chionoecetes opilio	Snow crab	*Paralithodes camtschaticus*	56%	Moderately insensitive	2.2	*Chionoecetes bairdi*	36%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Chionoecetes bairdi	Tanner crab	*Paralithodes camtschaticus*	56%	Moderately insensitive	2.2	Chionoecetes bairdi	37%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Chionoecetes angulatus	Triangle Tanner crab	*Paralithodes camtschaticus*	56%	Moderately insensitive	2.2	*Chionoecetes bairdi*	36%	Moderately sensitive	45	*Callinectes sapidus, Palaemon serenus, Palaemonetes pugio, Penaeus* spp., *Litopenaeus vannemai*	15-97% (50%)	Moderately insensitive	20-840 (69)
Myoxocephalus polyacanthocephalus	Great sculpin	*Myoxocephalus polyacanthocephalus*	60%	Moderately insensitive	2.2	None	No data	No data	No data	None	No data	No data	No data
Eleginus gracilis	Saffron cod	*Eleginus gracilis*	61%	Moderately insensitive	2.3	None	No data	No data	No data	None	No data	No data	No data
Pleurogrammus monopterygius	Atka mackerel	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp., *Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Hemitripterus bolini	Bigmouth sculpin	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp., *Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes melanostictus	Blackspotted rockfish	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp., *Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Hemilepidotus papilio	Butterfly sculpin	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp., *Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes pinniger	Canary rockfish	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp., *Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes nebulosus	China rockfish	*Myoxocephalus polyacanthocephalus*, *Myoxocephalus* spp., *Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data

Table A1-2. Sensitivities of Managed Species with Surrogate Information

Species	Common Name	Crude oil				Corexit 9500				Corexit 9527			
		Species or surrogate(s)	SSD percentile*	Sensitivity bin (based on SSD)	Geomean LC50* (ppm TPH)	Species or surrogate(s)	SSD percentile*	Sensitivity bin (based on SSD)	Geomean LC50* (ppm)	Species or surrogate(s)	SSD percentile*	Sensitivity bin (based on SSD)	Geomean LC50* (ppm)
Sebastes caurinus	Copper rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes variabilis	Dusky rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastolobus altivelis	Longspine thornyhead rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes polyspinus	Northern rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes alutus	Pacific ocean perch	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes maliger	Quillback rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Hemilepidotus hemilepidotus	Red Irish lord	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes helvomaculatus	Rosethorn rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes aleutianus	Rougheye rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Anoplopoma fimbria	Sablefish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes borealis	Shortraker rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastolobus alascanus	Shortspine thornyhead rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes nigrocinctus	Tiger rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Hemilepidotus jordani	Yellow Irish lord	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Sebastes ruberrimus	Yelloweye rockfish	*Myoxocephalus polyacanthocephalus, Myoxocephalus spp., Cottus cognatus*	44-65% (55%)	Moderately insensitive	1.9 - 3 (2.4)	None	No data	No data	No data	None	No data	No data	No data
Mallotus villosus	Capelin	*Clupea pallasii, Atherinops affinis, Aulorhynchus flavidus, Fundulus similis, Cyprinidon variegatus, Menidia beryllina, Melanotaenia fluviatilis* (small forage fish)	21-91% (59%)	Moderately insensitive	1.2-9.4 (3.3)	*Menidia beryllina, Atherinosoma microstoma, Fundulus grandis, Cyprinodon variegatus* (small forage fish)	44-88% (64%)	Moderately insensitive	50-263 (101)	Atherinops affinis, Menidia beryllina, Brevoortia tyrannus, Cyprinodon variegatus, Fundulus heteroclitus, Pimephales promelas (similar functionally)	33-91% (55%)	Moderately insensitive	35-201 (65)
Thaleichthys pacificus	Eulachon	*Clupea pallasii, Atherinops affinis, Aulorhynchus flavidus, Fundulus similis, Cyprinidon variegatus, Menidia beryllina, Melanotaenia fluviatilis* (small forage fish)	21-91% (59%)	Moderately insensitive	1.2-9.4 (3.3)	*Menidia beryllina, Atherinosoma microstoma, Fundulus grandis, Cyprinodon variegatus* (small forage fish)	44-88% (64%)	Moderately insensitive	50-263 (101)	Atherinops affinis, Menidia beryllina, Brevoortia tyrannus, Cyprinodon variegatus, Fundulus heteroclitus, Pimephales promelas (similar functionally)	33-91% (55%)	Moderately insensitive	35-201 (65)
Ammodytes hexapterus	Pacific sand lance	*Clupea pallasii, Atherinops affinis, Aulorhynchus flavidus, Fundulus similis, Cyprinidon variegatus, Menidia beryllina, Melanotaenia fluviatilis* (small forage fish)	21-91% (59%)	Moderately insensitive	1.2-9.4 (3.3)	*Menidia beryllina, Atherinosoma microstoma, Fundulus grandis, Cyprinodon variegatus* (small forage fish)	44-88% (64%)	Moderately insensitive	50-263 (101)	Atherinops affinis, Menidia beryllina, Brevoortia tyrannus, Cyprinodon variegatus, Fundulus heteroclitus, Pimephales promelas (similar functionally)	33-91% (55%)	Moderately insensitive	35-201 (65)
Oncorhynchus tshawytscha	Chinook salmon	*Oncorhynchus tshawytscha*	74%	Moderately insensitive	4.1	*Oncorhynchus mykiss*	92%	Insensitive	354	Oncorhynchus mykiss	82%	Insensitive	158
Pleuronectes quadrituberculatus	Alaska plaice	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Atheresthes stomias	Arrowtooth flounder	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Isopsetta isolepis	Butter sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Microstomus pacificus	Dover sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Parophrys vetulus	English sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Hippoglossoides elassodon	Flathead sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Reinhardtius hippoglossoides	Greenland turbot	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Atheresthes evermanni	Kamchatka flounder	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Pleuronectes proboscidea	Longhead dab	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Lepidopsetta polyxystra	Northern rock sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Glyptocephalus zachirus	Rex sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Psettichthys melanostictus	Sand sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Lepidopsetta bilineata	Southern rock sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100
Limanda aspera	Yellowfin sole	*Platichthys stellatus, P. flesus*	95%	Insensitive	12	*Scophthalmus maximus*	56%	Moderately insensitive	75	Platichthys flesus	76%	Insensitive	100

* Range of values based on several potential surrogate percentiles or genus geomean LC50 values; reported as range with the arithmetic mean percentile or geometric mean LC50 value in parentheses

Note: the sensitivities presented in this table are based on the analyses provided in Appendix A to the EFH assessment, Appendix B to the Biological Assessment, and the toxicity data presented in Attachment B1 to Appendix B to the Biological Assessment
Red text used for species geomean data (rather than genus geomean, when species of interest data available); percentiles based on the SSD of species geomeans

Color key:

- Species of interest
- Surrogate--similar family or genus
- Surrogate--similar order
- Surrogate -- dissimilar taxonomically, but similar functionally (e.g., forage fish, filter-feeding bivalve)

Table A1-2. Sensitivities of Managed Species with Surrogate Information

		Corexit 9500-dispersed oil				Corexit 9527-dispersed oil			
Species	**Common Name**	**Species or surrogate(s)**	**SSD percentile***	**Sensitivity bin (based on SSD)**	**Geomean LC50* (ppm TPH)**	**Species (species or surrogate)**	**SSD percentile***	**Sensitivity bin (based on SSD)**	**Geomean LC50* (ppm TPH)**
Bathyraja parmifera	Alaska skate	None	No data	No data	No data	None	No data	No data	No data
Bathyraja aleutica	Aleutian skate	None	No data	No data	No data	None	No data	No data	No data
Bathyraja interrupta	Bering skate	None	No data	No data	No data	None	No data	No data	No data
Onychoteuthis borealjaponica	Boreal clubhook squid	None	No data	No data	No data	None	No data	No data	No data
Rossia pacifica	Eastern Pacific bobtail squid	None	No data	No data	No data	None	No data	No data	No data
Moroteuthis robusta	Giant or robust clubhook squid	None	No data	No data	No data	None	No data	No data	No data
Somniosus pacificus	Pacific sleeper shark	None	No data	No data	No data	None	No data	No data	No data
Berryteuthis magister	Red or magistrate armhook squid	None	No data	No data	No data	None	No data	No data	No data
Lamna ditropis	Salmon shark	None	No data	No data	No data	None	No data	No data	No data
Squalus acanthias	Spiny dogfish	None	No data	No data	No data	None	No data	No data	No data
Octopus rubescens	Eastern Pacific red octopus	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Opisthoteuthis californiana	Flapjack octopus	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Enteroctopus dofleini	Giant Pacific octopus	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Graneledone boreopacifica	none	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Japetella diaphana	none	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Octopus sp. Jorgensen	none	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Benthoctopus oregonensis	none	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Octopus californicus	North Pacific bigeye octopus	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Benthoctopus leioderma	Smoothskin octopus	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Vampyroteuthis infernalis	Vampire squid	None	No data	No data	No data	*Octopus pallidus*	21%	Sensitive	1.8
Oncorhynchus nerka	Sockeye salmon	*Oncorhynchus tshawytscha*	95%	Insensitive	76	None	No data	No data	No data
Arctogadus glacialis	Arctic cod	*Boreogadus saida*	89%	Insensitive	45	None	No data	No data	No data
Gadus macrocephalus	Pacific cod	*Boreogadus saida*	89%	Insensitive	45	None	No data	No data	No data
Oncorhynchus gorbuscha	Pink salmon	*Oncorhynchus tshawytscha*	95%	Insensitive	76	None	No data	No data	No data
Oncorhynchus kisutch	Coho salmon	*Oncorhynchus tshawytscha*	95%	Insensitive	76	None	No data	No data	No data
Oncorhynchus keta	Chum salmon	*Oncorhynchus tshawytscha*	95%	Insensitive	76	None	No data	No data	No data
Theragra chalcogramma	Walleye pollock	*Boreogadus saida*	89%	Insensitive	45	None	No data	No data	No data
Platichthys stellatus	Starry flounder	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Myoxocephalus jaok	Plain sculpin	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Myoxocephalus verrucosus	Warty sculpin	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Chlamys behringiana	Bering Sea scallop	*Crassostrea gigas*	11%	Sensitive	1.8	*Crassostrea gigas*	14%	Sensitive	1.0
Chlamys rubida	Pink scallop	*Crassostrea gigas*	11%	Sensitive	1.8	*Crassostrea gigas*	14%	Sensitive	1.0
Crassadoma gigantean	Rock scallop	*Crassostrea gigas*	11%	Sensitive	1.8	*Crassostrea gigas*	14%	Sensitive	1.0
Chlamys hastata	Spiny scallop	*Crassostrea gigas*	11%	Sensitive	1.8	*Crassostrea gigas*	14%	Sensitive	1.0
Patinopecten caurinus	Weathervane scallop	*Crassostrea gigas*	11%	Sensitive	1.8	*Crassostrea gigas*	14%	Sensitive	1.0
Chlamys albida	White scallop	*Crassostrea gigas*	11%	Sensitive	1.8	*Crassostrea gigas*	14%	Sensitive	1.0
Paralithodes platypus	Blue king crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Lithodes aequispiba	Golden king crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Chionoecetes tanneri	Grooved Tanner crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Paralithodes camtschaticus	Red king crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Lithodes couesi	Scarlet king crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Chionoecetes opilio	Snow crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Chionoecetes bairdi	Tanner crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Chionoecetes angulatus	Triangle Tanner crab	*Palaemon serenus, Litopenaeus setiferus*	16-47% (32%)	Moderately sensitive	3.6-7.5 (5.2)	*Palaemon serenus*	50%	Moderately insensitive	8.1
Myoxocephalus polyacanthocephalus	Great sculpin	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Eleginus gracilis	Saffron cod	*Boreogadus saida*	89%	Insensitive	45	None	No data	No data	No data
Pleurogrammus monopterygius	Atka mackerel	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Hemitripterus bolini	Bigmouth sculpin	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes melanostictus	Blackspotted rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Hemilepidotus papilio	Butterfly sculpin	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes pinniger	Canary rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes nebulosus	China rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data

Table A1-2. Sensitivities of Managed Species with Surrogate Information

		Corexit 9500-dispersed oil				Corexit 9527-dispersed oil			
Species	**Common Name**	**Species or surrogate(s)**	**SSD percentile***	**Sensitivity bin (based on SSD)**	**Geomean LC50* (ppm TPH)**	**Species (species or surrogate)**	**SSD percentile***	**Sensitivity bin (based on SSD)**	**Geomean LC50* (ppm TPH)**
Sebastes caurinus	Copper rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes variabilis	Dusky rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastolobus altivelis	Longspine thornyhead rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes polyspinus	Northern rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes alutus	Pacific ocean perch	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes maliger	Quillback rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Hemilepidotus hemilepidotus	Red Irish lord	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes helvomaculatus	Rosethorn rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes aleutianus	Rougheye rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Anoplopoma fimbria	Sablefish	*Boreogadus saida*	89%	Insensitive	45	None	No data	No data	No data
Sebastes borealis	Shortraker rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastolobus alascanus	Shortspine thornyhead rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes nigrocinctus	Tiger rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Hemilepidotus jordani	Yellow Irish lord	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Sebastes ruberrimus	Yelloweye rockfish	*Myoxocephalus* spp.	74%	Moderately insensitive	17	None	No data	No data	No data
Mallotus villosus	Capelin	*Atherinops affinis, Menidia beryllina, Cypridon variegatus, Melanotaenia fluviatilis* (similar functionally)	32-79% (56%)	Moderately insensitive	1.4-19 (6.5)	*Atherinops affinis, Menidia beryllina, Melanotaenia fluviatilis* (similar functionally)	36-86% (61%)	Moderately insensitive	0.74-29 (3.8)
Thaleichthys pacificus	Eulachon	*Atherinops affinis, Menidia beryllina, Cypridon variegatus, Melanotaenia fluviatilis* (similar functionally)	32-79% (56%)	Moderately insensitive	1.4-19 (6.5)	*Atherinops affinis, Menidia beryllina, Melanotaenia fluviatilis* (similar functionally)	36-86% (61%)	Moderately insensitive	0.74-29 (3.8)
Ammodytes hexapterus	Pacific sand lance	*Atherinops affinis, Menidia beryllina, Cypridon variegatus, Melanotaenia fluviatilis* (similar functionally)	32-79% (56%)	Moderately insensitive	1.4-19 (6.5)	*Atherinops affinis, Menidia beryllina, Melanotaenia fluviatilis* (similar functionally)	36-86% (61%)	Moderately insensitive	0.74-29 (3.8)
Oncorhynchus tshawytscha	Chinook salmon	*Oncorhynchus tshawytscha*	**95%**	Insensitive	76	None	No data	No data	No data
Pleuronectes quadrituberculatus	Alaska plaice	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Atheresthes stomias	Arrowtooth flounder	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Isopsetta isolepis	Butter sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Microstomus pacificus	Dover sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Parophrys vetulus	English sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Hippoglossoides elassodon	Flathead sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Reinhardtius hippoglossoides	Greenland turbot	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Atheresthes evermanni	Kamchatka flounder	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Pleuronectes proboscidea	Longhead dab	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Lepidopsetta polyxystra	Northern rock sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Glyptocephalus zachirus	Rex sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Psettichthys melanostictus	Sand sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Lepidopsetta bilineata	Southern rock sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75
Limanda aspera	Yellowfin sole	None	No data	No data	No data	*Platichthys flesus*	93%	Insensitive	75

* Range of values based on several potential surrogate percentiles or genus geomean LC50 values; reported as range with the arithmetic mean percentile or geometric mean LC50 value in parentheses

Note: the sensitivities presented in this table are based on the analyses provided in Appendix A to the EFH assessment, Appendix B to the Biological Assessment, and the toxicity data presented in Attachment B1 to Appendix B to the Biological Assessment
Red text used for species geomean data (rather than genus geomean, when species of interest data available); percentiles based on the SSD of species geomeans

Color key:

Species of interest
Surrogate--similar family or genus
Surrogate--similar order
Surrogate -- dissimilar taxonomically, but similar functionally (e.g., forage fish, filter-feeding bivalve)

Attachment A1. EFH Exposure and Effects Analysis

Table A1-3a. Approach to Potential for Exposure and Sensitivity Synthesis

Potential for Exposure	Sensitivity				
	Insensitive	Moderately Insensitive	Moderately sensitive	Sensitive	No data
No potential	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
No/low potential	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Potential	May affect	May affect	May affect	May affect	May affect/ sensitivity unknown
High potential	May affect	May affect	Most likely to affect	Most likely to affect	May affect/ sensitivity unknown

Table A1-3b. Result of Synthesis of Potential for Exposure and Sensitivity Data

		Potential for Exposure, Early Life Stages			Sensitivity					Synthesis Result				
Common name	**Species**	**Egg**	**Larvae**	**Maximum Potential***	**Crude oil****	**Corexit 9500**	**Corexit 9527**	**Corexit 9500-dispersed oil**	**Corexit 9527-dispersed oil**	**Crude oil****	**Corexit 9500**	**Corexit 9527**	**Corexit 9500-dispersed oil**	**Corexit 9527-dispersed oil**
Alaska plaice	*Pleuronectes quadrituberculatus*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Alaska skate	*Bathyraja parmifera*	No potential	No potential	No potential	No data	No data	No data	No data	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Aleutian skate	*Bathyraja aleutica*	No potential	No potential	No potential	No data	No data	No data	No data	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Arctic cod	*Arctogadus glacialis*	No potential	High potential	High potential	Sensitive	No data	No data	Insensitive	No data	Most likely to affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Arrowtooth flounder	*Atheresthes stomias*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Atka mackerel	*Pleurogrammus monopterygius*	Potential	High potential	High potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Bering Sea scallop	*Chlamys behringiana*	No/low potential	Potential	Potential	Moderately sensitive	Insensitive	Moderately sensitive	Sensitive	Sensitive	Effect unlikely	May affect	May affect	May affect	May affect
Bering skate	*Bathyraja interrupta*	No potential	No potential	No potential	No data	No data	No data	No data	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Bigmouth sculpin	*Hemitripterus bolini*	No/low potential	High potential	High potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Blackspotted rockfish	*Sebastes melanostictus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Blue king crab	*Paralithodes platypus*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect
Boreal clubhook squid	*Onychoteuthis borealjaponica*	No potential	High potential	High potential	No data	No data	No data	No data	No data	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown
Butter sole	*Isopsetta isolepis*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Butterfly sculpin	*Hemilepidotus papilio*	No/low potential	High potential	High potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Canary rockfish	*Sebastes pinniger*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Capelin	*Mallotus villosus*	High potential	High potential	High potential	Moderately insensitive	Moderately insensitive	Moderately insensitive	Moderately insensitive	Moderately insensitive	May affect	May affect	May affect	May affect	May affect
China rockfish	*Sebastes nebulosus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Chinook salmon***	*Oncorhynchus tshawytscha*	No potential	No potential	No potential	Moderately insensitive	Insensitive	Insensitive	Insensitive	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Chum salmon***	*Oncorhynchus keta*	No potential	No potential	No potential	Moderately sensitive	Insensitive	Insensitive	Insensitive	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Coho salmon***	*Oncorhynchus kisutch*	No potential	No potential	No potential	Moderately sensitive	Insensitive	Insensitive	Insensitive	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Copper rockfish	*Sebastes caurinus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Dover sole	*Microstomus pacificus*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Dusky rockfish	*Sebastes variabilis*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown

Table A1-3b. Result of Synthesis of Potential for Exposure and Sensitivity Data

Common name	Species	Potential for Exposure, Early Life Stages			Sensitivity					Synthesis Result				
		Egg	Larvae	Maximum Potential*	Crude oil**	Corexit 9500	Corexit 9527	Corexit 9500-dispersed oil	Corexit 9527-dispersed oil	Crude oil**	Corexit 9500	Corexit 9527	Corexit 9500-dispersed oil	Corexit 9527-dispersed oil
Eastern Pacific bobtail squid	*Rossia pacifica*	No potential	High potential	High potential	No data	No data	No data	No data	No data	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown
Eastern Pacific red octopus***	*Octopus rubescens*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
English sole	*Parophrys vetulus*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Eulachon	*Thaleichthys pacificus*	No potential	High potential	High potential	Moderately insensitive	Moderately insensitive	Moderately insensitive	Moderately insensitive	Moderately insensitive	May affect	May affect	May affect	May affect	May affect
Flapjack octopus	*Opisthoteuthis californiana*	No potential	Potential	Potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect
Flathead sole	*Hippoglossoides elassodon*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Giant or robust clubhook squid	*Moroteuthis robusta*	No potential	High potential	High potential	No data	No data	No data	No data	No data	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown
Giant Pacific octopus	*Enteroctopus dofleini*	No potential	Potential	Potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect
Golden king crab	*Lithodes aequispiba*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect
Great sculpin	*Myoxocephalus polyacanthocephalus*	No potential	High potential	High potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Greenland turbot	*Reinhardtius hippoglossoides*	No/low potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Grooved Tanner crab	*Chionoecetes tanneri*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect
Kamchatka flounder	*Atheresthes evermanni*	No/low potential	No/low potential	No/low potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Longhead dab	*Pleuronectes proboscidea*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Longspine thornyhead rockfish	*Sebastolobus altivelis*	Potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
none	*Graneledone boreopacifica*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
none	*Japetella diaphana*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
none	*Octopus sp. Jorgensen*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
none	*Benthoctopus oregonensis*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
North Pacific bigeye octopus	*Octopus californicus*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Northern rock sole	*Lepidopsetta polyxystra*	No potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Northern rockfish	*Sebastes polyspinus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Pacific cod	*Gadus macrocephalus*	No potential	High potential	High potential	Sensitive	No data	No data	Insensitive	No data	Most likely to affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Pacific ocean perch	*Sebastes alutus*	No potential	No/low potential	No/low potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Pacific sand lance	*Ammodytes hexapterus*	High potential	High potential	High potential	Moderately insensitive	Moderately insensitive	Moderately insensitive	Moderately insensitive	Moderately insensitive	May affect	May affect	May affect	May affect	May affect
Pacific sleeper shark	*Somniosus pacificus*	No/low potential	N/A**	No/low potential	No data	No data	No data	No data	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Pink salmon***	*Oncorhynchus gorbuscha*	No potential	No potential	No potential	Moderately sensitive	Insensitive	Insensitive	Insensitive	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely

Table A1-3b. Result of Synthesis of Potential for Exposure and Sensitivity Data

		Potential for Exposure, Early Life Stages			Sensitivity					Synthesis Result				
Common name	Species	Egg	Larvae	Maximum Potential*	Crude oil**	Corexit 9500	Corexit 9527	Corexit 9500-dispersed oil	Corexit 9527-dispersed oil	Crude oil**	Corexit 9500	Corexit 9527	Corexit 9500-dispersed oil	Corexit 9527-dispersed oil
Pink scallop	*Chlamys rubida*	No/low potential	Potential	Potential	Moderately sensitive	Insensitive	Moderately sensitive	Sensitive	Sensitive	Effect unlikely	May affect	May affect	May affect	May affect
Plain sculpin	*Myoxocephalus jaok*	No/low potential	High potential	High potential	Moderately sensitive	No data	No data	Moderately insensitive	No data	Most likely to affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Quillback rockfish	*Sebastes maliger*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Red Irish lord	*Hemilepidotus hemilepidotus*	High potential	High potential	High potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Red king crab	*Paralithodes camtschaticus*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect
Red or magistrate armhook squid***	*Berryteuthis magister*	No potential	No potential	No potential	No data	No data	No data	No data	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Rex sole	*Glyptocephalus zachirus*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Rock scallop	*Crassadoma gigantean*	No/low potential	Potential	Potential	Moderately sensitive	Insensitive	Moderately sensitive	Sensitive	Sensitive	Effect unlikely	May affect	May affect	May affect	May affect
Rosethorn rockfish	*Sebastes helvomaculatus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Rougheye rockfish	*Sebastes aleutianus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Sablefish	*Anoplopoma fimbria*	No potential	High potential	High potential	Moderately insensitive	No data	No data	Insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Saffron cod	*Eleginus gracilis*	No/low potential	High potential	High potential	Moderately insensitive	No data	No data	Insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Salmon shark	*Lamna ditropis*	Potential	N/A**	Potential	No data	No data	No data	No data	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown
Sand sole	*Psettichthys melanostictus*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Scarlet king crab	*Lithodes couesi*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect
Shortraker rockfish	*Sebastes borealis*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Shortspine thornyhead rockfish	*Sebastolobus alascanus*	Potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Smoothskin octopus	*Benthoctopus leioderma*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Snow crab	*Chionoecetes opilio*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect
Sockeye salmon***	*Oncorhynchus nerka*	No potential	No potential	No potential	Sensitive	Insensitive	Insensitive	Insensitive	No data	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Southern rock sole	*Lepidopsetta bilineata*	No potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Spiny dogfish	*Squalus acanthias*	Potential	N/A**	Potential	No data	No data	No data	No data	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect/ sensitivity unknown
Spiny scallop	*Chlamys hastata*	No/low potential	Potential	Potential	Moderately sensitive	Insensitive	Moderately sensitive	Sensitive	Sensitive	Effect unlikely	May affect	May affect	May affect	May affect
Starry flounder	*Platichthys stellatus*	High potential	High potential	High potential	Moderately sensitive	Moderately insensitive	Insensitive	No data	Insensitive	Most likely to affect	May affect	May affect	May affect/ sensitivity unknown	May affect
Tanner crab	*Chionoecetes bairdi*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect

Table A1-3b. Result of Synthesis of Potential for Exposure and Sensitivity Data

		Potential for Exposure, Early Life Stages			Sensitivity					Synthesis Result				
Common name	**Species**	**Egg**	**Larvae**	**Maximum Potential***	**Crude oil****	**Corexit 9500**	**Corexit 9527**	**Corexit 9500-dispersed oil**	**Corexit 9527-dispersed oil**	**Crude oil****	**Corexit 9500**	**Corexit 9527**	**Corexit 9500-dispersed oil**	**Corexit 9527-dispersed oil**
Tiger rockfish	*Sebastes nigrocinctus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Triangle Tanner crab	*Chionoecetes angulatus*	No potential	High potential	High potential	Moderately insensitive	Moderately sensitive	Moderately insensitive	Moderately sensitive	Moderately insensitive	May affect	Most likely to affect	May affect	Most likely to affect	May affect
Vampire squid	*Vampyroteuthis infernalis*	No potential	No potential	No potential	Sensitive	No data	No data	No data	Sensitive	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely	Effect unlikely
Walleye pollock	*Theragra chalcogramma*	Potential	Potential	Potential	Moderately sensitive	No data	No data	Insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Warty sculpin	*Myoxocephalus verrucosus*	Unclear	High potential	High potential	Moderately sensitive	No data	No data	Moderately insensitive	No data	Most likely to affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Weathervane scallop	*Patinopecten caurinus*	No/low potential	Potential	Potential	Moderately sensitive	Insensitive	Moderately sensitive	Sensitive	Sensitive	Effect unlikely	May affect	May affect	May affect	May affect
White scallop	*Chlamys albida*	No/low potential	Potential	Potential	Moderately sensitive	Insensitive	Moderately sensitive	Sensitive	Sensitive	Effect unlikely	May affect	May affect	May affect	May affect
Yellow Irish lord	*Hemilepidotus jordani*	Potential	High potential	High potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	May affect	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Yelloweye rockfish	*Sebastes ruberrimus*	No potential	Potential	Potential	Moderately insensitive	No data	No data	Moderately insensitive	No data	Effect unlikely	May affect/ sensitivity unknown	May affect/ sensitivity unknown	May affect	May affect/ sensitivity unknown
Yellowfin sole	*Limanda aspera*	Potential	High potential	High potential	Insensitive	Moderately insensitive	Insensitive	No data	Insensitive	May affect	May affect	May affect	May affect/ sensitivity unknown	May affect

red text = used surrogate information from within this table
N/A -- not applicable
*Maximum potential based on the highest likelihood of exposure between egg and larval life stages
**Likelihood of oil impacts not determined unless "likely" to be exposed (i.e., found in very shallow water where an individual could come into contact with crude oil)
***Potential for exposure as juveniles is greater than during either larval or egg life stages, and therefore species may be affected (although impacts may be lower due to advanced life stage, increased pigmentation, etc.)
Note: the colors presented in Table A1-3b are the same as those presented in Table A1-3a and equate to the same meaning

Attachment A1. EFH Exposure and Effects Analysis

Table A1-4. Summary of Synthesis Results for Crude Oil and Corexit 9500-dispersed Oil

Common name	Species	Maximum Potential for Exposure*	Crude oil**	Corexit 9500-dispersed oil
Alaska plaice	*Pleuronectes quadrituberculatus*	High potential	May affect	May affect/ sensitivity
Arctic cod	*Arctogadus glacialis*	High potential	Most likely to affect	May affect
Arrowtooth flounder	*Atheresthes stomias*	High potential	May affect	May affect/ sensitivity
Atka mackerel	*Pleurogrammus monopterygius*	High potential	May affect	May affect
Bering Sea scallop	*Chlamys behringiana*	Potential	Effect unlikely	May affect
Bigmouth sculpin	*Hemitripterus bolini*	High potential	May affect	May affect
Blackspotted rockfish	*Sebastes melanostictus*	Potential	Effect unlikely	May affect
Blue king crab	*Paralithodes platypus*	High potential	May affect	Most likely to affect
Boreal clubhook squid	*Onychoteuthis borealjaponica*	High potential	May affect/ sensitivity	May affect/ sensitivity
Butter sole	*Isopsetta isolepis*	High potential	May affect	May affect/ sensitivity
Butterfly sculpin	*Hemilepidotus papilio*	High potential	May affect	May affect
Canary rockfish	*Sebastes pinniger*	Potential	Effect unlikely	May affect
Capelin	*Mallotus villosus*	High potential	May affect	May affect
China rockfish	*Sebastes nebulosus*	Potential	Effect unlikely	May affect
Chinook salmon***	*Oncorhynchus tshawytscha*	No potential	Effect unlikely	Effect unlikely
Chum salmon***	*Oncorhynchus keta*	No potential	Effect unlikely	Effect unlikely
Coho salmon***	*Oncorhynchus kisutch*	No potential	Effect unlikely	Effect unlikely
Copper rockfish	*Sebastes caurinus*	Potential	Effect unlikely	May affect
Dover sole	*Microstomus pacificus*	High potential	May affect	May affect/ sensitivity
Dusky rockfish	*Sebastes variabilis*	Potential	Effect unlikely	May affect
Eastern Pacific bobtail squid	*Rossia pacifica*	High potential	May affect/ sensitivity	May affect/ sensitivity
Eastern Pacific red octopus***	*Octopus rubescens*	No potential	Effect unlikely	Effect unlikely
English sole	*Parophrys vetulus*	High potential	May affect	May affect/ sensitivity
Eulachon	*Thaleichthys pacificus*	High potential	May affect	May affect
Flapjack octopus	*Opisthoteuthis californiana*	Potential	Effect unlikely	May affect/ sensitivity
Flathead sole	*Hippoglossoides elassodon*	High potential	May affect	May affect/ sensitivity
Giant or robust clubhook squid	*Moroteuthis robusta*	High potential	May affect/ sensitivity	May affect/ sensitivity
Giant Pacific octopus	*Enteroctopus dofleini*	Potential	Effect unlikely	May affect/ sensitivity
Golden king crab	*Lithodes aequispiba*	High potential	May affect	Most likely to affect
Great sculpin	*Myoxocephalus polyacanthocephalus*	High potential	May affect	May affect
Greenland turbot	*Reinhardtius hippoglossoides*	High potential	May affect	May affect/ sensitivity
Grooved Tanner crab	*Chionoecetes tanneri*	High potential	May affect	Most likely to affect
Longhead dab	*Pleuronectes proboscidea*	High potential	May affect	May affect/ sensitivity
Longspine thornyhead rockfish	*Sebastolobus altivelis*	Potential	Effect unlikely	May affect
Northern rock sole	*Lepidopsetta polyxystra*	High potential	May affect	May affect/ sensitivity
Northern rockfish	*Sebastes polyspinus*	Potential	Effect unlikely	May affect
Pacific cod	*Gadus macrocephalus*	High potential	Most likely to affect	May affect
Pacific sand lance	*Ammodytes hexapterus*	High potential	May affect	May affect
Pink salmon***	*Oncorhynchus gorbuscha*	No potential	Effect unlikely	Effect unlikely

Table A1-4. Summary of Synthesis Results for Crude Oil and Corexit 9500-dispersed Oil

Common name	Species	Maximum Potential for Exposure*	Crude oil**	Corexit 9500-dispersed oil
Pink scallop	*Chlamys rubida*	Potential	Effect unlikely	May affect
Plain sculpin	*Myoxocephalus jaok*	High potential	Most likely to affect	May affect
Quillback rockfish	*Sebastes maliger*	Potential	Effect unlikely	May affect
Red Irish lord	*Hemilepidotus hemilepidotus*	High potential	May affect	May affect
Red king crab	*Paralithodes camtschaticus*	High potential	May affect	Most likely to affect
Red or magistrate armhook squid***	*Berryteuthis magister*	No potential	Effect unlikely	Effect unlikely
Rex sole	*Glyptocephalus zachirus*	High potential	May affect	May affect/ sensitivity
Rock scallop	*Crassadoma gigantean*	Potential	Effect unlikely	May affect
Rosethorn rockfish	*Sebastes helvomaculatus*	Potential	Effect unlikely	May affect
Rougheye rockfish	*Sebastes aleutianus*	Potential	Effect unlikely	May affect
Sablefish	*Anoplopoma fimbria*	High potential	May affect	May affect
Saffron cod	*Eleginus gracilis*	**High potential**	May affect	May affect
Salmon shark	*Lamna ditropis*	Potential	Effect unlikely	May affect/ sensitivity
Sand sole	*Psettichthys melanostictus*	High potential	May affect	May affect/ sensitivity
Scarlet king crab	*Lithodes couesi*	High potential	May affect	Most likely to affect
Shortraker rockfish	*Sebastes borealis*	Potential	Effect unlikely	May affect
Shortspine thornyhead rockfish	*Sebastolobus alascanus*	Potential	Effect unlikely	May affect
Snow crab	*Chionoecetes opilio*	High potential	May affect	Most likely to affect
Sockeye salmon***	*Oncorhynchus nerka*	No potential	Effect unlikely	Effect unlikely
Southern rock sole	*Lepidopsetta bilineata*	High potential	May affect	May affect/ sensitivity
Spiny dogfish	*Squalus acanthias*	Potential	Effect unlikely	May affect/ sensitivity
Spiny scallop	*Chlamys hastata*	Potential	Effect unlikely	May affect
Starry flounder	*Platichthys stellatus*	High potential	Most likely to affect	May affect/ sensitivity
Tanner crab	*Chionoecetes bairdi*	High potential	May affect	Most likely to affect
Tiger rockfish	*Sebastes nigrocinctus*	Potential	Effect unlikely	May affect
Triangle Tanner crab	*Chionoecetes angulatus*	High potential	May affect	Most likely to affect
Walleye pollock	*Theragra chalcogramma*	Potential	Effect unlikely	May affect
Warty sculpin	*Myoxocephalus verrucosus*	High potential	Most likely to affect	May affect
Weathervane scallop	*Patinopecten caurinus*	Potential	Effect unlikely	May affect
White scallop	*Chlamys albida*	Potential	Effect unlikely	May affect
Yellow Irish lord	*Hemilepidotus jordani*	High potential	May affect	May affect
Yelloweye rockfish	*Sebastes ruberrimus*	Potential	Effect unlikely	May affect
Yellowfin sole	*Limanda aspera*	High potential	May affect	unknown

red text = used surrogate information from within this table
na - not applicable
*Maximum potential based on the highest potential for exposure between egg and larval life stages
**Likelihood of oil impacts not determined unless "likely" to be exposed (i.e., found in very shallow water where an individual could come into contact with crude oil)
***Although the maximum potential for egg or larval life stages is negligible for this species, individuals may be exposed at early or late juvenile life stages. Individuals, if exposed as juveniles, could be adversely impacted, although the magnitude of such impacts would likely decrease in individuals of increasingly advanced age and body size. This species has been included in this table, because adverse impacts in these species are not discountable.

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