ESSENTIAL FISH HABITAT ASSESSMENT
For
The Northwest Training Range Complex

Prepared for:
Department of the Navy
Commander, U.S. Pacific Fleet

JULY 2009
EXECUTIVE SUMMARY
This assessment of the effects of Navy training in the Northwest Training Range Complex (NWTRC) on Essential Fish Habitat (EFH) covers regulatory issues, proposed actions, impacts, and mitigation measures.

The Magnuson-Stevens Fisheries Conservation and Management Act ("Magnuson Act") of 1976 mandates identification and conservation of EFH. A second habitat type is also identified to focus conservation efforts: Habitat Areas of Particular Concern (HAPC). These subsets of EFH are rare, sensitive, ecologically important, or located in an area that is already stressed. Federal agencies are required to consult with the National Marine Fisheries Service (NMFS) and to prepare an EFH assessment describing potential adverse effects on EFH.

The NWTRC includes offshore air, sea, and undersea space; nearshore air, land, sea, and undersea space, and inland airspace and land ranges. Offshore and nearshore operating areas contain EFH for species covered under Fishery Management Plans (managed species) including: salmonids, coastal pelagic species, Pacific Coast groundfish, and highly migratory species. The NWTRC is located within the California Current System: the offshore and nearshore areas adjacent to Washington, Oregon and northern California coasts; and the marine and estuarine waters of the inshore basins of Puget Sound.

Navy training activities in the NWTRC include: air combat maneuvers; missile, gunnery, bombing, vessel sink, and electronic combat exercises; antisubmarine warfare tracking and extended echo ranging exercises; mine countermeasures training; insertion and extraction activities; naval special warfare training; intelligence, surveillance, and reconnaissance activities; and unmanned aerial vehicle activities.

The following factors were considered in the analysis of potential impacts: the duration, frequency, intensity, and spatial extent of the impact; the sensitivity or vulnerability of the habitat; the habitat functions that might be altered by the impact; and the timing of the impact relative to when managed species or life stages may need the habitat. Adverse effects are defined as any impact that reduces the quality or quantity of EFH. According to 5090.1C temporary or minimal impacts are not considered to "adversely affect" EFH. Temporary effects are limited in duration and allow the environment to recover without measurable impact. Minimal effects do not cause significant changes in ecological function.

Effects on EFH and managed species could be associated with vessel movement, aircraft overflight, military expended materials, hazardous chemicals, detonation of explosive ordnance, weapons training, and sound generating devices. Navy activities could have temporary or minimal direct and indirect impacts on individual species, modify their habitat, or alter water quality.

Vessel movement and aircraft overflights would cause brief, reversible disruptions in fish distribution. Potential impacts from expended materials could result from contact or ingestion, or exposure to chemicals. The small quantity of material expended, the rapid dilution of dissolved constituents, the relatively non-toxic nature of the expended materials, and eventual encrustation and incorporation of expended materials into the sediments would minimize adverse effects on resident marine communities. Expended materials would not adversely disturb the sea floor or compromise habitat components that support feeding, resting, sheltering, reproduction, or migration of managed species.

Underwater detonations and explosions could disrupt habitats, release chemical by-products, kill or injure marine life, affect hearing organs, modify behavior, mask biologically relevant sounds, induce stress, and have indirect effects on prey species and other components of the food web. Initial concentrations of explosion by-products are not hazardous to marine life and would not accumulate because training activities are widely dispersed over time and space. Beyond the range of direct, lethal, or sub-lethal impacts to fish, minor, short-term behavioral reactions would not be ecologically adverse or impact a species’ ability to survive, grow, and reproduce. No adverse effects from underwater detonations or weapons training on habitat suitability or on the food web are expected.
Most fish species would be able to detect mid-frequency sonar at the lower end of its range. Short-term behavioral responses such as startle and avoidance may occur, but are not likely to adversely affect indigenous fish communities. Auditory damage from sonar signals is not expected and there is no indication that non-impulsive acoustic sources result in fish mortality.

The assessment concludes that, based on the limited extent, duration, and magnitude of potential impacts from NWTRC training activities, there would not be adverse effects on managed species or EFH. Range operations and potential enhancements would not significantly contribute to cumulative impacts on present or future uses of the area.
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# ACRONYMS AND ABBREVIATIONS

<table>
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<th>Acronym</th>
<th>Description</th>
<th>Metric</th>
<th>Unit</th>
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<tbody>
<tr>
<td>A-A</td>
<td>Air-to-Air</td>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>AAW</td>
<td>Anti-Air Warfare</td>
<td>MMA</td>
<td>Multimission Maritime Aircraft</td>
</tr>
<tr>
<td>ASUW</td>
<td>Anti-Surface Warfare</td>
<td>MMPA</td>
<td>Marine Mammal Protection Act</td>
</tr>
<tr>
<td>ASW</td>
<td>Anti-Submarine Warfare</td>
<td>MOA</td>
<td>Military Operating Area</td>
</tr>
<tr>
<td>ATCAA</td>
<td>Air Traffic Controlled Assigned Airspace</td>
<td>MSFCMA</td>
<td>Magnus-Stevens Fishery Conservation and Management Act</td>
</tr>
<tr>
<td>°C</td>
<td>Degrees Celsius</td>
<td>°C</td>
<td>Degrees Fahrenheit</td>
</tr>
<tr>
<td>CCS</td>
<td>California Current System</td>
<td>N</td>
<td>North</td>
</tr>
<tr>
<td>CDFG</td>
<td>California Department of Fish and Game</td>
<td>NEW</td>
<td>Net Explosive Weight</td>
</tr>
<tr>
<td>CEQ</td>
<td>Council on Environmental Quality</td>
<td>NAS</td>
<td>Naval Air Station</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
<td>NAVSTA</td>
<td>Naval Station</td>
</tr>
<tr>
<td>CIWS</td>
<td>Close-In Weapon System</td>
<td>NBK</td>
<td>Naval Base Kitsap</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeter</td>
<td>NEPA</td>
<td>National Environmental Policy Act</td>
</tr>
<tr>
<td>DoN</td>
<td>Department of the Navy</td>
<td>nm</td>
<td>Nautical Miles</td>
</tr>
<tr>
<td>EC</td>
<td>Electronic Combat</td>
<td>NMFS</td>
<td>National Marine Fisheries Service</td>
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<tr>
<td>EEZ</td>
<td>Exclusive Economic Zone</td>
<td>NOAA</td>
<td>National Oceanic &amp; Atmospheric Administration</td>
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<tr>
<td>EFH</td>
<td>Essential Fish Habitat</td>
<td>NSW</td>
<td>Naval Special Warfare</td>
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<td>EIS</td>
<td>Environmental Impact Statement</td>
<td>NWTRC</td>
<td>Northwest Training Range Complex</td>
</tr>
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<td>EOD</td>
<td>Explosive Ordnance Disposal</td>
<td>OEIS</td>
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<td>Environmental Protection Agency</td>
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<td>Degrees Fahrenheit</td>
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<td>ESA</td>
<td>Endangered Species Act</td>
<td>OPAREA</td>
<td>Operating Area</td>
</tr>
<tr>
<td>FL</td>
<td>Fork Length</td>
<td>OPNAVINST</td>
<td>Chief of Naval Operations Instruction</td>
</tr>
<tr>
<td>FMP</td>
<td>Fishery Management Plan</td>
<td>RDT&amp;E</td>
<td>Research, Development, Test and Evaluation</td>
</tr>
<tr>
<td>FRTP</td>
<td>Fleet Readiness Training Plan</td>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>ft</td>
<td>Foot/Feet</td>
<td>RHIB</td>
<td>Rigid Hull Inflatable Boat</td>
</tr>
<tr>
<td>Hz</td>
<td>Hertz</td>
<td>S-A</td>
<td>Surface-to-Air</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram</td>
<td>SFA</td>
<td>Sustainable Fisheries Act</td>
</tr>
<tr>
<td>kHz</td>
<td>Kilohertz</td>
<td>SINKEX</td>
<td>Sinking Exercise</td>
</tr>
<tr>
<td>km</td>
<td>Kilometer</td>
<td>S-S</td>
<td>Surface-to-Surface</td>
</tr>
<tr>
<td>km²</td>
<td>Square Kilometers</td>
<td>SSGN</td>
<td>Guided Missile Submarine</td>
</tr>
<tr>
<td>lb</td>
<td>Pound</td>
<td>STW</td>
<td>Strike Warfare</td>
</tr>
<tr>
<td>m</td>
<td>Meter</td>
<td>TNT</td>
<td>Trinitrotoluene</td>
</tr>
<tr>
<td>m²</td>
<td>Square Meter</td>
<td>TORPEX</td>
<td>Torpedo Exercise</td>
</tr>
<tr>
<td>MARPOL</td>
<td>International Convention for the Prevention of Pollution from Ships</td>
<td>U.S.</td>
<td>United States of America</td>
</tr>
<tr>
<td>mi</td>
<td>Mile</td>
<td>UNDET</td>
<td>Underwater Detonation</td>
</tr>
<tr>
<td>MIW</td>
<td>Mine Warfare</td>
<td>USC</td>
<td>United States Code</td>
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1 INTRODUCTION

This assessment evaluates the impact of United States Navy training activities as already identified in the Northwest Training Range Complex (NWTRC) Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) on fish (Section 3.7 in the EIS/OEIS) and essential fish habitat (EFH). It covers the

- Regulatory background;
- Project area;
- Environmental setting;
- Fishery management plans;
- Managed species;
- Designated EFH in the NWTRC;
- Proposed actions;
- Project impacts;
- Mitigation measures; and
- Cumulative impacts

The NWTRC EIS/OEIS details Navy training activities in the NWTRC (See Figure 1-1), describes the existing environment for marine biology and fish, and discusses potential environmental effects associated with ongoing and proposed naval activities. The Marine Resources Assessment (MRA) prepared for the Pacific Northwest Operating Area (Department of the Navy [DoN] 2006) also contains comprehensive descriptions of the ocean environment, including climate; marine geology; physical, chemical, and biological oceanography; marine biology; marine habitats; and protected species in the project area.

This assessment uses the term “fish” to include both cartilaginous species (that is, sharks, skates, and rays) and bony species. Cartilaginous fish have a skeleton of cartilage, which is partially calcified but is not true bone. Bony fish also have cartilage, but their skeletons consist of calcified bone.

This section also addresses important invertebrate species, including market squid and the euphausiid shrimp species that form the bulk of the area’s krill community. These species typically are managed in coordination with fish species so extensively that essential fish habitat (see the discussion in the next section) has been designated for two species of euphausiid shrimp.

1.1 REGULATORY SETTING

1.1.1 The Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (“Magnuson Act”) of 1976 is included in 16 United States Code (USC) § 1801 et seq. The Magnuson Act established jurisdiction over marine fishery resources in the 200-nautical-mile U.S. Exclusive Economic Zone (EEZ). The Magnuson Act was reauthorized and amended by the Sustainable Fisheries Act (SFA) of 1996 (Public Law 104-297), which provided a new habitat conservation tool, the “essential fish habitat” (EFH) mandate.
Figure 1-1: Northwest Training Range Complex
Regional fishery management councils are required to prepare fishery management plans that

- Establish objectives for specific fishery resources;
- Formulate strategies to achieve those objectives;
- Identify EFH for the managed species covered under the plans;
- Describe potential and actual impacts to EFH from fishing and non-fishing activities;
- Designate habitat areas of particular concern; and
- Suggest measures to conserve and enhance EFH.

The National Marine Fisheries Service (NMFS) participates in fishery management efforts by providing fisheries data and analysis and by supervising the management of highly migratory fish species such as sharks, tuna, and billfish, seven of which occur in the Pacific Northwest Operating Area (OPAREA) (NMFS 2004).

Several fishery management plans cover the area included within the NWTRC. These include the:

- Coastal Pelagic Species Fishery Management Plan prepared by the Pacific Fishery Management Council (PFMC 2003a);
- Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species (PFMC 2007);
- Pacific Coast Salmon Plan (PFMC 2003b); and
- Pacific Coast Groundfish Fishery Management Plan (PFMC 2006a).

### 1.1.2 Essential Fish Habitat

EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (16 USC §1802[10]). The term “fish” is defined in the SFA as “finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds.”

Habitat consists of the geographic area and the characteristics of that area where species may be found during any phase of their life history. Habitat characteristics include geomorphological, physical, biological, and chemical parameters. Interactions between environmental parameters make up habitat and determine the biological niche of a species. Habitat parameters affecting fish distribution throughout the NWTRC include physical variables such as water depth, substrate, temperature, salinity, and dissolved oxygen; and biological variables such as the presence of forage, competitor species, and predators.

The NMFS in 2002 further clarified EFH with the following definitions:

- “Waters” include all aquatic areas and their associated biological, chemical, and physical properties that are used by fish and may include aquatic areas historically used by fish, where appropriate.
- “Substrate” includes sediment, hard bottom, structures underlying the waters, and associated biological communities.
- “Necessary” means the habitat required to support a sustainable fishery and the managed species’ contribution to a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity” covers a species’ full life cycle” (NMFS 2002; see 50 Code of Federal Regulations (CFR) §§ 600.05–600.930).
Essential fish habitat must be identified and mapped for each managed species (NMFS 2007a). With respect to EFH, nearshore areas are considered to be shallower than 120 feet (36 meters), with offshore areas beyond that depth. The continental shelf is considered to begin at the 200-meters contour.

The NMFS and regional councils determine the species distributions by life stage and characterize associated habitats. The SFA requires federal agencies to consult with the NMFS on activities that may adversely affect EFH. Adverse effect is any impact which reduces the quality or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to benthic organisms, prey species, and their habitat, and other ecosystem components. Adverse effects may be site specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.910[a]).

For actions that affect a threatened or endangered species, or its critical habitat, and its EFH, federal agencies may integrate Endangered Species Act (ESA) and EFH consultations. A Biological Evaluation (BE) has been prepared to analyze potential impacts to ESA species and critical habitat.

An EFH assessment is a critical review of the proposed project and its potential impacts to EFH. Based on the requirements in 50 CFR 600.920(c)(3), such assessments must include:

- A description of the proposed action;
- An analysis of the effects of the action on EFH and managed species;
- The federal agency’s conclusions regarding the effects of the action on EFH; and
- Proposed mitigation, if applicable.

Once NMFS learns of a federal or state activity that would adversely effect designated EFH, NMFS is required to develop EFH conservation recommendations for the activity. These recommendations may include measures to avoid, minimize, mitigate, or otherwise offset adverse effects on EFH (NMFS 2002a).

In addition to EFH designations, areas called habitat areas of particular concern (HAPC) are designated to provide additional focus for conservation efforts and represent a subset of EFH that may be designated as distinct geographic areas or as specific habitat types. The HAPC designation alone does not confer additional protection or restriction on non-fishing related activities within the habitat; however, NMFS may promulgate fishing related management measures to help conserve HAPCs. Federal regulations identify these areas as habitat types or locations within EFH, based on one or more of the following considerations:

- The importance of the ecological function provided by the habitat;
- The extent to which the habitat is sensitive to human-induced environmental degradation;
- Whether, and to what extent, development activities are or will be stressing the habitat type; or
- The rarity of the habitat type (50 CFR 600.815[a][8]).

Managed species in the NWTRC and their essential habitat are discussed in more detail in Section 1.4.

### 1.2 PROJECT AREA

Military training activities in the NWTRC occur on the ocean surface, under the ocean surface, in the air, and on land. To aid in the description of the ranges covered in the NWTRC EIS/OEIS, the range is comprised by three functional subdivisions. Each of the individual ranges falls into one of these three subdivisions:

- The Offshore Area includes all air, sea, and underwater ranges west of the coastline.
• The Inshore Area includes all air, land, sea, and undersea ranges inland of the coastline and includes Puget Sound, but excludes ranges that are used exclusively by Explosive Ordnance Disposal (EOD) or Naval Special Warfare (NSW) forces.

• The EOD ranges are land, sea, and undersea ranges used by NSW and EOD forces.

Figure 1-2 depicts the bathymetry and relief of the NWTRC. Figure 1-3 illustrates the EOD ranges within the NWTRC.

1.3 ENVIRONMENTAL SETTING

The NWTRC is situated in a region of diverse, highly productive fisheries (Leet et al. 2001). Predominant ecosystems found in the NWTRC include:

• Nearshore coastal systems, including rocky intertidal habitats and estuaries;
• The continental shelf, including upwelling zones and bottom (benthic) habitats; and
• Oceanic (pelagic) systems, including surface, mid-depth, and bottom-dwelling (benthic) communities.

The majority of the fishery resources are found in the mid-depth and benthic areas of the continental shelf ecosystem. Important marine species include:

• Coastal pelagic fish such as mackerel, anchovy, herring, and jack;
• Shelf and slope groundfish such as flatfish, rockfish, and roundfish;
• Salmonids such as Chinook salmon, coho salmon, chum salmon, sockeye salmon, pink salmon, steelhead, and bull trout;
• Highly migratory fish like sharks, tuna, and swordfish;
• Invertebrates like euphausiid shrimp, market squid, and Dungeness crab; and
• Kelp.

The Pacific salmon are among the most important living marine resource within the Pacific Northwest region. Currently, the NWTRC supports habitats of “endangered” and “threatened” populations of Chinook, coho, and chum salmon, and steelhead and bull trout (NMFS 2005h; 2005c).

The NWTRC falls within the California Current System (CCS) which travels the full length of the U.S. Pacific Coast south to Baja California. The CCS is rich in microscopic organisms, such as single-celled diatoms and dinoflagellates, that form the base of the food chain in the NWTRC, especially in areas where consistent ocean upwelling occurs along the coast. Grazers like small coastal pelagic fish and squid depend on the planktonic food supply of diatoms, small plankters, krill, and other zooplanktonic organisms, and in turn are prey for larger, more migratory species like sharks, tuna, and swordfish (NMFS-SWR 2006).

Along the Pacific continental margin off northern California, Oregon, and Washington, the distribution of fish is influenced by the northern half of the CCS (Field et al. 2006; NMFS-NWR 2006). Pelagic fish include a small number of endemic coastal and offshore species, and a larger mixture of subarctic, transitional, and subtropical species, some of which are at the limits of their geographic range (Brodeur et al. 2003). North-south differences in the composition and relative distribution of the dominant species is apparent, especially around the Columbia River; Cape Blanco, Oregon; and Cape Mendocino, California (Brodeur et al. 2004).
Figure 1-2: Bathymetry and Relief of the NWTRC

Source: NWTRC EIS/OEIS
Figure 1-3: EOD Ranges within the NWTRC
The continental shelf and slope support a large biomass of groundfish (Dark and Wilkins 1994), particularly along the Washington and Oregon coasts (Williams and Ralston 2002). Typically, the groundfish community in the northern CCS exhibits the strong depth-gradient affinity in species composition and diversity (Tolimieri and Levin 2006) that is found in many other fish communities common at or near the bottom on the continental shelf and upper slope (Colvocoresses and Musick 1984; Jay 1996; Mahon et al. 1998; Mueter and Norcross 2002). Information is lacking about similar fish communities in deeper regions or how such depth-related patterns may change with latitude (Tolimieri and Levin 2006).

Physical and geographic features within the CCS that influence the distribution and abundance of pelagic fish and groundfish include the northward-flowing California Undercurrent and Davidson Current, ocean upwelling areas, Columbia River plume, submarine canyons, seamounts, large submerged rocky reefs, coastal promontories, and submarine ridges (Doyle 1992; Dower and Perry 2001; Nasby-Lucas et al. 2002; Williams and Ralston 2002a; Bosley et al. 2004; Emmett et al. 2004; Emmett et al. 2006).

1.4 Fishery Management Plans and Essential Fish Habitat in the NWTRC

The PFMC, in conjunction with NMFS, is charged with designating EFH and developing management plans for all managed species occurring within the boundary of the EEZ in the NWTRC from Point Delgada at Cape Mendocino in northern California to the U.S./Canada border. In the NWTRC, managed species include fish and invertebrate species in the following categories: groundfish, salmonids, coastal pelagic species (which include invertebrates), and highly migratory species (Table 1-1).

<table>
<thead>
<tr>
<th>Table 1-1: Fish and Invertebrate Species with EFH Designated in the NWTRC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pacific Salmon and Trout Species</strong></td>
</tr>
<tr>
<td>Chinook salmon (Oncorhynchus tshawytscha)</td>
</tr>
<tr>
<td>Coho salmon (Oncorhynchus kisutch)</td>
</tr>
<tr>
<td><strong>Coastal Pelagic Species</strong></td>
</tr>
<tr>
<td>Northern anchovy (Engraulis mordax)</td>
</tr>
<tr>
<td>Jack mackerel (Trachurus symmetricus)</td>
</tr>
<tr>
<td><strong>Invertebrates</strong></td>
</tr>
<tr>
<td>Market squid (Loligo opalescens)</td>
</tr>
<tr>
<td><strong>Krill</strong></td>
</tr>
<tr>
<td>Euphausia pacifica</td>
</tr>
<tr>
<td><strong>Pacific Coast Groundfish Species</strong></td>
</tr>
<tr>
<td>Arrowtooth flounder (Atheresthes stomias)</td>
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<tr>
<td>Butter sole (Isossetta isopleis)</td>
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<tr>
<td>Curlfin sole (Pleuronichthys decurrens)</td>
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<tr>
<td>Dover sole (Microstomus pacificus)</td>
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<tr>
<td>English sole (Parophrys vetulus)</td>
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<tr>
<td>Flathead sole (Hippoglossoides elassodon)</td>
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<tr>
<td><strong>Rockfish</strong></td>
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<tr>
<td>Aurora rockfish (Sebastes aurora)</td>
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<tr>
<td>Bank rockfish (Sebastes rufus)</td>
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<tr>
<td>Black rockfish (Sebastes melanops)</td>
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<tr>
<td>Black-and-yellow rockfish (Sebastes chrysomelas)</td>
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</tbody>
</table>
Table 1-1: Fish and Invertebrate Species with EFH Designated in the NWTRC (continued)

<table>
<thead>
<tr>
<th>Rockfish (continued)</th>
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<tbody>
<tr>
<td>Blackgill rockfish (Sebastes melanostomus)</td>
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<tr>
<td>Blue rockfish (Sebastes mystinus)</td>
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<tr>
<td>Bocaccio (Sebastes paucispinis)</td>
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<tr>
<td>Bronzespotted rockfish (Sebastes gilli)</td>
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<tr>
<td>Brown rockfish (Sebastes auriculatus)</td>
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<tr>
<td>Canary rockfish (Sebastes pinniger)</td>
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<tr>
<td>Chilipepper (Sebastes goodei)</td>
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<tr>
<td>China rockfish (Sebastes nebulosus)</td>
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<tr>
<td>Copper rockfish (Sebastes caurinus)</td>
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<tr>
<td>Cowcod (Sebastes levis)</td>
</tr>
<tr>
<td>Darkblotched rockfish (Sebastes crameri)</td>
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<tr>
<td>Dusky rockfish (Sebastes variabilis)</td>
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<tr>
<td>Flag rockfish (Sebastes rubrivinctus)</td>
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<tr>
<td>Gopher rockfish (Sebastes carmani)</td>
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<tr>
<td>Grass rockfish (Sebastes rastrelliger)</td>
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<tr>
<td>Greenblotched rockfish (Sebastes rosenblatti)</td>
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<td>Greenspotted rockfish (Sebastes chlorostictus)</td>
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<tr>
<td>Greenstriped rockfish (Sebastes elongatus)</td>
</tr>
<tr>
<td>Harlequin rockfish (Sebastes variegates)</td>
</tr>
</tbody>
</table>

| Thornyhead                                   |
| Longspine thornyhead (Sebastolobus altivelis) | Shortspine thornyhead (Sebastolobus alascanus) |

| Roundfish                                   |
| Cabezon (Scorpaenichthys marmoratus)        | Pacific cod (Gadus macrocephalus)            |
| Kelp greenling (Hexagrammos decagrammatus)  | Pacific hake (Merluccius productus)          |
| Lingcod (Opiodon elongatus)                 | Sablefish (Anoplopoma fimbria)               |

| Skates, Sharks, and Chimeras                |
| Big skate (Raja binoculata)                 | Soupfin shark (Galeorhinus zyopterus)        |
| California skate (Raja inornata)            | Spiny dogfish (Squalus acantbias)            |
| Longnose skate (Raja rhina)                 | Spotted ratfish (Hydrolagus coliei)          |
| Leopard shark (Triakis semifasciata)        |                                               |

| Highly Migratory Species                    |
| Sharks                                      |
| Common thresher shark (Alopias vulpinus)    | Shortfin mako shark (Isurus oxyrinchus)       |
| Bigeye thresher shark (Alopias superciliosus)| Blue shark (Prionace glauca)                  |

| Tunas                                       |
| Albacore tuna (Thunnus alalunga)            | Northern bluefin tuna (Thunnus orientalis)    |

| Swordfish                                   |
| Broadbill swordfish (Xiphias gladius)       |                                               |

*Source: Turgeon et al. (1998); Nelson et al. (2004); McLaughlin (2005); PFMC (2008).*
The marine and estuarine waters of the inshore basins of Puget Sound are designated EFH for salmonids, coastal pelagic species, and groundfish (Table 1-2). EFH for these species includes all waters from nearshore and tidal submerged environments within the state territorial waters of Washington, Oregon, and California to the western boundary of the EEZ, 200 nautical miles offshore. State fish and game agencies are responsible for managing fisheries within 3 nautical miles of shore in a manner consistent with federal law. The distribution, habitat preference, life history, and common prey species for EFH species are summarized below, based primarily on information provided in PFMC 1998a, 1998b, 1999b, 2000, 2003c, and 2006c.

### Table 1-2: Pacific Salmon Species Complex, Coastal Pelagic Species, and Pacific Coast Groundfish Species and Life History Stages With Designated EFH

<table>
<thead>
<tr>
<th>Group/Family/Species</th>
<th>Adult</th>
<th>Spawning/ Mating</th>
<th>Juvenile</th>
<th>Young Juvenile</th>
<th>Larvae</th>
<th>Eggs/ Parturition</th>
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<td><strong>Pacific Salmon Species</strong></td>
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<tr>
<td>Chinook salmon</td>
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<td>Coho salmon</td>
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<td>Puget Sound pink salmon</td>
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<td><strong>Coastal Pelagic Species</strong></td>
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<tr>
<td>Northern anchovy</td>
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<td>Jack mackerel</td>
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<td><strong>Pacific Coast Groundfish Species</strong></td>
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<td>Arrowtooth flounder</td>
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<td>Curlfin sole</td>
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<td>English sole</td>
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<td>Flathead sole</td>
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<td>Aurora rockfish</td>
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</table>
Table 1-2: Pacific Salmon Species Complex, Coastal Pelagic Species, and Pacific Coast Groundfish Species And Life History Stages With Designated EFH (continued)

<table>
<thead>
<tr>
<th>Group/Family/Species</th>
<th>Adult</th>
<th>Spawning/Mating</th>
<th>Juvenile</th>
<th>Young Juvenile</th>
<th>Larvae</th>
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<tr>
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<td>Dusky rockfish</td>
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### Table 1-2: Pacific Salmon Species Complex, Coastal Pelagic Species, And Pacific Coast Groundfish Species And Life History Stages With Designated EFH (continued)

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<th>Group/Family/Species</th>
<th>Adult</th>
<th>Spawning/Mating</th>
<th>Juvenile</th>
<th>Young Juvenile</th>
<th>Larvae</th>
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<td>Big skate</td>
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<td>Shortfin mako shark</td>
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*Source: DoN (2002a); PFMC (2008).*
1.4.1 Pacific Coast Salmonids

Since 1977, the ocean salmon fisheries in federal waters of the U.S. EEZ have been managed under a “framework” plan entitled the Pacific Coast Salmon Fish Management Plan (PFMC 2003d). The salmon fisheries region extends from the Washington/Canada border south to the Mexico border, with nearly all of the salmon fisheries being located north of Point Conception, California (NMFS-NWR 2003b). Three of the four salmon fishery management areas occur within the NWTRC (NMFS-NWR 2003a).

Chinook (king) salmon and coho (silver) salmon are primarily harvested. Small numbers of pink salmon are also harvested, especially in odd-numbered years and primarily off Washington and Oregon (NMFS-NWR 2004a). The PFMC monitors species and prohibits inappropriate catch; for example, if fishers targeting highly migratory species catch Pacific salmon, they must release them immediately.

All waters that support anadromous fish are considered EFH by NMFS, that is, all streams, lakes, ponds, wetlands, and other water bodies currently or historically accessible to salmon in Washington. Salmon EFH extends from the nearshore and tidal submerged environments within state territorial waters out to the full extent of the Exclusive Economic Zone offshore of Washington (PFMC 2000 and 2006c).

Pacific salmon (genus *Oncorhynchus*) range from San Francisco Bay, California, northward along the Pacific Rim and southward along the coasts of Russia, Japan, and Korea (Eggers 2004). There are seven species of Pacific salmon, five of which reproduce in North America waters—sockeye (*O. nerka*), pink (*O. gorbuscha*), chum (*O. keta*), Chinook (*O. tshawytscha*), and coho (*O. kisutch*) (Groot and Margolis 1991). In general, the life history of Pacific salmon includes incubation, hatching and emergence in freshwater, migration to the ocean, and subsequent initiation of maturation and return to freshwater for completion of maturation and spawning (Myers et al. 1998). Salmon are anadromous, meaning that they migrate up rivers and streams from the sea to spawn in freshwater. Pacific salmon spawn in gravel beds in rivers, streams and along lake-shores where females lay their eggs in nests or “redd” (Groot and Margolis 1991; DFO 2002). Depending on the species, they spend between one to seven years at sea, with most making extensive and complicated migrations (Groot and Margolis 1991; Eggers 2004). Generally, Pacific salmon return to their natal rivers to spawn and, with few exceptions, die soon after (Augerot and Foley 2005). The death of these salmon returns much needed nutrients from the ocean to the otherwise nutrient-poor streams (Quinn 2005). Anadromy and the strong fidelity of homing to their natal streams have resulted in the development of many reproductively isolated subpopulations such that little inbreeding occurs between salmon from one river and another (Quinn 2005, Groot and Margolis 1991). These subpopulations are exposed to different physical and biotic factors such as temperature, flow, gravel size, predators, prey, competitors, and pathogens (Quinn 2005). These variations between streams have lead to the evolution of specializations to help the salmon survive in their home rivers (Quinn 2005). These distinct habitat dynamics require these subpopulations to be managed individually rather than as a species (Quinn 2005).

Anadromous salmon depend on the ecological integrity and connectivity of a suite of habitats extending from the natal freshwater spawning or rearing streams to estuaries and then to coastal, shelf, and offshore waters for their growth (Duffy et al. 2005). The relative importance of estuarine and coastal marine environments differs within and among the various salmon species due to differences in residence times and utilization of these environments (Duffy et al. 2005). Juvenile salmon reside mainly in nearshore intertidal waters that provide five key functions: migration corridors, food, physiological refuge, refuge from predators, and refuge from high-energy environments, such as those with strong currents and wave action (Thorpe 1994; Anchor Environmental L.L.C. and People for Puget Sound 2002). After achieving a size threshold or after a specific residence time, salmon reportedly move from shallow nearshore to offshore surface waters in estuarine and marine waters (Duffy et al. 2005).

**Status.** Pacific salmon are federally protected by the designation of evolutionarily significant units, defined by NMFS as a population that is “substantially reproductively isolated from conspecific populations and represents an important component in the evolutionary legacy of the species” (WCSBRT
In addition to these units, the ESA requires the National Oceanic & Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (USFWS) to designate “critical habitat” for species listed under the ESA. “Critical habitat” is defined as: 1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and 2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation (NOAA [no date]). Currently, the species of Pacific salmonids that have evolutionarily significant units with critical habitat designated within the NWTRC include: Chinook chum, coho, and Puget Sound pink salmon, and steelhead and bull trout. (NMFS 2005h, NMFS 2005c, USFWS 2005b).

Navy has prepared a biological evaluation to analyze potential impacts to listed salmonid species and critical habitat.

1.4.1.1 Salmonid EFH

The geographic extent of marine EFH for Pacific salmon is shown in Figure 1-4. The PFMC (2000) defines freshwater EFH as all streams, lakes, ponds, wetlands, tributaries, and other water bodies currently viable and most of the habitat historically accessible to salmon within Washington, Oregon, Idaho, and California.

1.4.1.2 Chinook Salmon (Oncorhynchus tshawytscha)

**Distribution**—The Chinook salmon’s historical range extended from the Ventura River in California to Point Hope, Alaska in North America (Myers et al. 1998). The natural freshwater range for Chinook salmon extends throughout the Pacific rim of North America. This species has been identified from the San Joaquin River in California to the Mackenzie River in northern Canada (Healey 1991). The oceanic range encompasses Washington, Oregon, California, throughout the northern Pacific Ocean, and as far south as the U.S./Mexico border (PFMC 2000).

**Habitat Preference**

**Depth:** Chinook salmon are found in freshwater to euhaline waters from the surface to depths of 250 meters depending on lifestage. They spawn in rivers at depths ranging from 0 meters to 10.0 meters with a preferred depth of greater than 0.24 meters for spring and fall salmon and greater than 0.30 meters for summer salmon (Beauchamp et al. 1983). The depth of the redd is inversely related to water velocity (PFMC 2000). Juvenile Chinook range from 0.0 to 1.2 meters while inhabiting streams, lakes, sloughs, and rivers and continue to stay near the surface during their initial marine stages (Beauchamp et al. 1983; PFMC 2000). After juveniles have advanced past the initial marine phase, they prefer depths ranging from 30 to 70 meters and are often associated with bottom topography (PFMC 2000). Late juveniles and adults may be pelagic, neustonic, or semi-demersal/semi-pelagic (PFMC 2000). EFH for Chinook salmon is shown in Figure 1-5.

**Temperature:** Chinook salmon may be found in water temperatures ranging from 0° to 26°C but this may vary depending on lifestage and activity (MBC 1987). Adult Chinook salmon prefer water temperatures less than 14°C but can survive in deep pools in the summer with surface temperatures of 23°C (Beauchamp et al. 1983; PFMC 2000). Chinook cannot spawn at temperatures above 22°C (Beauchamp et al. 1983). Ideal spawning temperatures range from 5.6° to 13.9°C but spawning can occur from 4.4° to 18.0°C (Beauchamp et al. 1983). Eggs and alevin can tolerate temperatures as high as 18.1°C with alevin being more tolerant of lower temperatures (0.0°C – alevin, 1.6°C – eggs) (MBC 1987). Temperatures from 5.8° to 14.2°C promote the best egg development and 11.0°C is the optimum temperature for both eggs and fry (Beauchamp et al. 1983). Optimum temperature for fingerlings is 17.0°C with freshwater juveniles found in waters from 7.4° to 25.0°C. Ocean-type juveniles are found in waters from 1° to 15°C but few Chinook are found at temperatures below 5°C (MBC 1987; PFMC 2000).
Figure 1-4: EFH for All Marine Lifestages of Pacific Salmon

Source: Map adapted from: PFMC (2000).
Figure 1-5: EFH for Chinook Salmon
Dissolved Oxygen: Chinook salmon can survive, when resting, with dissolved oxygen levels as low as 2.0 parts per million (ppm); migrating adults may pass through waters with dissolved oxygen levels as low as 3.5/4.0 ppm (Beauchamp et al. 1983; Emmett et al. 1991).

Substrate: Adult Chinook salmon spawn in gravel ranging from 6 to 14 centimeters (centimeters) in diameter. Gravel substrates range from 1.3 to 10.2 centimeters in diameter (Beauchamp et al. 1983). Chinook salmon require enough current on spawning beds to ventilate the eggs during incubation (Beauchamp et al. 1983). No substrate preference has been documented for adults in the marine environment (Beauchamp et al. 1983).

Movements and migrations: As Chinook salmon grow they move from shallow littoral habitats into deeper river channels inhabiting pools, riffles, off-channel habitat, and undercut banks. Large woody debris or boulder structures provide cover and shelter from predation and storm events. Riparian vegetation provides the following to Chinook salmon rearing: shade for temperature regulation, vegetation inputs for food resources, and stream bank stabilization from roots and large woody debris recruitment. Fry and smolt inhabit freshwater from 1 to 18 months (Beauchamp et al. 1983). Timing of migration to seawater for juveniles is highly variable (PFMC 2000). Ocean-type juveniles may migrate to the ocean immediately after hatching but most remain in fresh water for 30 to 90 days (PFMC 2000). Some Chinook migrate seaward as fingerlings in the late summer of their first year while others, particularly in less-productive or cold-water systems, migrate as young-of-the-year fish (PFMC 2000).

Significant variations of fingerling and yearling migrants within a population may occur from year to year (PFMC 2000). Ocean-type juveniles typically inhabit estuaries for several months before migrating to higher salinity waters (PFMC 2000). Fry enter the upper reaches of estuaries in late winter for the more southern populations or early spring for the more northern populations (PFMC 2000). Regardless of time of entry, ocean-type Chinook spend from one to three months in estuaries (PFMC 2000). Smaller fry prefer more protected, lower salinity habitats. As fish get larger, they gradually leave the well protected habitats for higher salinity waters (PFMC 2000).

Reproduction: Chinook salmon are gonochoristic, oviparous, and semelparous (Emmett et al. 1991). Spawning may range from May/June to December/January depending on location but periods are specific for each run or stock (Emmett et al. 1991; Healey 1991; PFMC 2000). Spawning may occur from the tidewater to 3,200 kilometers upstream in the Yukon River (Healey 1991). Chinook spawning populations are relatively small but increase in numbers with increased stream size (Healey 1991). Rivers associated with the northern and southern limits of the species range, such as the Sacramento-San Joaquin River system, tend to support populations as large as or larger than those in major rivers near the middle of the range, such as the Columbia and Fraser Rivers (Healey 1991). Stream-type and ocean-type spawning populations are separated considerably (Healey 1991). Alaskan spawning populations are predominately stream-type, and all Asian spawning stocks are apparently stream-type (Healey 1991). In North America there seems to be a sudden shift from stream-type to ocean-type stocks near the Alaska-British Columbia border (Healey 1991). South of approximately 56°N, stream-type Chinook are only found in larger rivers with ocean-type salmon dominating the majority of the runs (Healey 1991).

Chinook salmon may return to their natal streams during any month but there are one to three peaks associated with salmon migratory activity (Healey 1991). These peaks vary between river systems. Northern River systems generally see a single peak in migratory activity around June with the run possible extending through April to August (Healey 1991). The Columbia River experiences a late August run and significantly smaller spring and summer runs (Healey 1991). The Klamath River also sees a late August run with a smaller run occurring in the spring (Healey 1991). Generally, stream-type fish spawn one to two months (spring and early summer) before ocean-type fish (summer and fall) in the central and southern portions of the species range (Healey 1991; PFMC 2000). Larger variations in spawning time may occur in species associated with larger river systems such as the Columbia River (Healey 1991). Chinook salmon may spawn at depths ranging from a few centimeters to
several meters in streams from two to three meters wide to large rivers (PFMC 2000). Chinook redd range in size from 2 to 40 m². Redd depth is inversely related to water velocity ranging from 10 to 700 centimeters deep in water velocities from 10 to 150 centimeters per second (centimeters/sec) (Healey 1991). Typically, Chinook redd are 5 to 15 m² in areas with water velocities from 40 to 60 centimeters/sec (PFMC 2000). The large size of Chinook eggs allows them to withstand higher water velocities than other species of salmon but a small surface-to-volume ratio may make them more sensitive to dissolved oxygen levels (PFMC 2000).

**Life History**—Chinook salmon exhibit one of the more diverse and complex life history strategies of all Pacific salmon and are separated into two generalized life-history types: stream-type and ocean-type fish (Myers et al. 1998; PFMC 2000). The majority of stream-type Chinook stocks are found in Alaska, north of 56°N (Healey 1991). For a year or more, they reside as fry or parr in freshwater where they exhibit downstream dispersal and utilize a variety of freshwater rearing environments before migrating to sea (Healey 1991). They perform extensive offshore oceanic migrations and return to their natal river during the spring and early summer, several months prior to spawning (Healey 1991). Ocean residency varies but may last from one to six years (Healey 1991). Stream-type adults often enter freshwater in the spring and summer as immature “bright” fish and spawn in upper watersheds in late summer or early fall (PFMC 2000). Stream-type life history strategies, with long rearing periods that require more stable or less degraded habitats, may be adapted to watersheds or parts of watersheds that are more productive and less susceptible to dramatic changes in water flow, as (Healey 1991). ESUs with stream-type life history strategies include: upper Columbia River spring ESU; and Snake River spring/summer ESU (Myers et al. 1998).

Ocean-type Chinook are found near the center of their species range and migrate to the ocean within the first year (typically within a few months) after emergence where they spend an average of four to five years (Myers et al. 1998; PFMC 2000; Augerot and Foley 2005). Estuaries may be more important than freshwater environments in the life history of ocean-type Chinook due to longer time spent there (PFMC 2000). Juvenile Chinook utilize estuaries for rearing, physiological transition, and refugia, and tend to congregate in areas where estuary morphology favors detritus retention, such as weed beds, salt marshes, and braided or meandering channels (Healey 1991). Ocean-type Chinook salmon spend most of their ocean life in coastal waters, and return to their natal river during the spring, summer, fall, late fall and winter (Healey 1991). Ocean-type Chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of rivers, and spawn within a few days or weeks of freshwater entry (Healey, 1991). ESUs with ocean-type life history strategies include Puget Sound ESU, Lower Columbia River ESU, and Snake River fall ESU (Myers et al. 1998).

There is further life history variation within each type, which allows full utilization of freshwater, estuarine and ocean environments. In order to complete these life history strategies successfully, Chinook salmon need access to freshwater, estuarine, coastal and open ocean environments. In these environments they require adequate water quantity and quality, temperature, velocity, shelter, food resources, riparian vegetation, space, and safe passage conditions (Healey 1991).

**Common Prey Species**—The primary food source for Chinook salmon in freshwater habitats is postulated to be adult and larval insects (Healey 1991). Diets vary considerably from estuary to estuary but Chinook utilize a wide range of prey including: gammarid amphipods, insects, mysids, isopods, copepods, and fish larvae (Beauchamp et al. 1983; Healey 1991). As Chinook grow and move into marine environments, their diets shift to consist of crab zoea, rockfish, Pacific sand lance, eulachon, herring, anchovy, copepods, euphausiids, cephalopods, isopods, and amphipods (Beauchamp et al. 1983).

1.4.1.3 **Coho Salmon (Oncorhynchus kisutch)**

**Distribution**—Coho salmon are found in freshwater drainages from Monterey Bay, California north along the west coast of North America to Alaska, around the Bering Sea south through Russia to Hokkaido, Japan (California Department of Fish and Game [CDFG] 2002a). Oceanic lifestages can be found from
Camalu Bay, Baja California north to Point Hope, Alaska and from there, south to Korea (MBC 1987; Sandercock 1991). In the northeastern Pacific, coho can be found south of 40°N, but only in the coastal waters of the California Current (MBC 1987).

**Habitat Preference**

**Depth:** Coho salmon are found in fresh water to euhaline water at depths ranging from the surface to 250 m. In marine environments, both juveniles and adults stay within 10 meters of the surface unless water conditions are considerably warm (Emmett et al. 1991). Eggs and alevins are found buried in gravel bottoms from 8 to 15 centimeters deep (MBC 1987). Adult coho need a minimum water depth of 18 centimeters to spawn (Laufle et al. 1986). Fry and smolt prefer variable depths with fry ranging from 0.3 to 1.2 meters, generally associated with submerged riffle areas. Avoidance of strong currents and predators seems to be the most important factor in determining habitat for young fish (Laufle et al. 1986; PFMC 2000).

**Temperature:** Eggs and alevins are found at temperature from 4.4° to 21°C but optimal incubation occurs between 4.4° and 13.3°C (Emmett et al. 1991). Juvenile coho can tolerate stream temperatures ranging from 0° to 26°C with no abrupt changes (PFMC 2000). They prefer streams ranging from 10° to 15°C and growth ceases at 20.3°C due to increased metabolic rate (Laufle et al. 1986; Emmett et al. 1991; PFMC 2000). Oceanic coho are found at temperatures ranging from 4.0° to 15.2°C but prefer temperatures from 8° to 12°C (Emmett et al. 1991).

**Salinity:** Eggs, alevins, fry, and parr inhabit freshwater while juveniles and adults are anadromous (Laufle et al. 1986).

**Dissolved Oxygen:** Embryos and juvenile coho salmon require the highest dissolved oxygen concentrations. Embryo survival is sharply reduced at dissolved oxygen levels less than 8.0 ppm, whereas juvenile food consumption is reduced at levels less than 4.0 ppm (Laufle et al. 1986; Emmett et al. 1991). Levels below 2.0 ppm for extended periods of time are lethal (PFMC 2000).

**Substrate:** Smolts, subadults, and adults migrate over a variety of substrates (Emmett et al. 1991). Cover availability is more important than substrate selection for juvenile coho (Emmett et al. 1991). Spawning occurs on beds composed of gravel ranging from 1.3 to 10.2 centimeters in diameter and, unlike other salmon, coho redd can contain approximately 10 percent mud (Emmett et al. 1991).

**Movements and migrations:** Adult coho salmon migrate to their natal streams from June to February; the higher the latitude, the earlier the return (Emmett et al. 1991; Sandercock 1991). There is also a tendency for fish that enter streams early to move further upstream than those that migrate later (Sandercock 1991). Throughout their range, coho exhibit a variety of return timing patterns (Sandercock 1991). Migration into streams is very dependent on flow conditions (Sandercock 1991). Impassable conditions (such as stream mouths that normally are blocked by sand) may become passable during elevated flow conditions, while certain obstacles that act as water velocity barriers may be more easily traversed during low flow conditions (Sandercock 1991).

Migration upstream generally occurs when temperatures range from 7.2° to 15.6°C, depths are greater than 18 centimeters, and water velocity is less than 2.44 m/sec (Sandercock 1991). Juveniles reside in freshwater for about a year (longer in northern streams) before migrating to the ocean (Emmett et al. 1991; PFMC 2000). Most juvenile migration occurs from April to August with a peak in May (Emmett et al. 1991). Generally, higher latitudes result in an increase in estuarine residency time for juveniles (PFMC 2000). Upon entering the ocean, coho may spend several weeks or their entire first summer in coastal waters before migrating north (PFMC 2000). The later dispersal pattern is the most common within the NWTRC (PFMC 2000). Tag, release, and recovery studies suggests that coho salmon of California origin can be found as far north as southeast Alaska and coho salmon from Oregon and Washington as far north as the northern Gulf of Alaska (PFMC 2000).
The extent of coho salmon migrations appears to extend westward along the Aleutian Island chain ending somewhere around Emperor Seamount (believed to be an area of high prey abundance) (PFMC 2000). While the southern extent of the population expands and contracts annually, Point Conception, California is generally considered the faunal break for the coho and other temperate marine species (PFMC 2000).

Adult coho may enter freshwater as early as July in the Alaska and as late as December or January in California (Sandercock 1991; PFMC 2000). Summer-run coho may enter rivers exceptionally early (spring or early summer) (PFMC 2000). Larger rivers have a wider range of entry times than smaller systems (PFMC 2000).

Reproduction: Coho salmon are gonochoristic, oviparous, and semelparous (Emmett et al. 1991). In North America, coho generally spawn from October to March with populations found at the northern extent of the species range tend to spawn earlier than those at the southern extent (Sandercock 1991; PFMC 2000). Both spawning and migration times can be highly variable (Sandercock 1991).

Preferred spawning grounds for coho salmon include clean, coarse gravel (PFMC 2000). Coho salmon typically spawn in small streams with water velocities ranging from 0.08 to 0.70 m/sec, with preferred velocities between 0.3 and 0.5 m/sec (Emmett et al. 1991; PFMC 2000). Stream depths range from 0.05 to 0.66 meters in areas of gradient increases and moderate currents, such as pool tailouts and riffles (Emmett et al. 1991; PFMC 2000). Redd size is typically 1.5 m² and is constructed of relatively silt-free gravel ranging from 0.2 to 10.0 centimeters in diameter (PFMC 2000). Redd must be well-oxygenated and located near cover (PFMC 2000).

Life History—Adult coho salmon migrate into streams where they deposit their eggs in gravel (Sandercock 1991). Coho are semelparous, which means adult salmon die soon after spawning (Sandercock 1991). Eggs incubate throughout the winter and emerge in the spring as free-swimming fry (Sandercock 1991). The fry reside in the stream for a year or more when they begin migrating toward the ocean as smolt (Sandercock 1991). Juveniles spend a minimum of 18 months at sea before returning to their natal streams to repeat the process (Sandercock 1991).

Common Prey Species—Coho salmon are opportunistic feeders with a diet that reflects the availability of the prey in their area (Emmett et al. 1991). Emerging fry feed on a variety of invertebrates including spiders, mites, and snails (Emmett et al. 1991). Parr feed on invertebrates and possibly other salmon in stream environments, but in reservoirs their diets consists of zooplankton, insects, and amphipods (Emmett et al. 1991). Juveniles feed on amphipods, insects, mysids, decapod larvae, and larval and juvenile fishes in estuarine environments (Emmett et al. 1991). Ocean-dwelling coho initially feed on decapod larvae, gammarid and hyperiid amphipods, euphausiids, terrestrial insects, copepods, cephalopods, Cnideria, gastropods, planktonic annelids, and larval and juvenile fishes (Emmett et al. 1991). As juveniles get larger they become more piscivorous, feeding on northern anchovy, Pacific herring, Pacific sardine, juvenile scorpaenids, capelin (Mallotus villosus), and other fish species (Emmett et al. 1991).

1.4.1.4 Puget Sound Pink Salmon (Oncorhynchus gorbuscha)

Habitat Preference

**Depth:** Pink salmon are found in fresh water to euhaline water at depths ranging from the surface to 250 m. Current velocity and substrate play a more important role in habitat selection during spawning than depth (Bonar et al. 1989). Spawning depths range from 30 to 100 centimeters but preferred depths range from 20 to 25 centimeters (Heard 1991).

**Temperature:** Lethal temperature limits for pink salmon are 0.0°C and 25.6°C with preferred temperatures ranging from 5.6°C to 14.4°C (Emmett et al. 1991). Optimal temperature for pink salmon is 10.1°C (Bonar et al. 1989). Pink salmon generally spawn at temperatures ranging from 7.2°C to 12.8°C (Bonar et al. 1989). Preferred incubation temperatures range from 4.4°C to 13.3°C (Bonar et al. 1989).

**Salinity:** Pink salmon eggs and alevins are primarily in fresh water but can withstand salinities of 18 psu for extended periods of time and salinities as high as 33 psu for brief periods (Emmett et al. 1991). Fry adapt quickly to high salinity levels and juveniles can tolerate a wide range of salinities (Bonar et al. 1989).

**Dissolved Oxygen:** Embryos and alevins need well oxygenated water (> 6.0 ppm) with preferred levels at or near saturation (Bonar et al. 1989; Emmett et al. 1991). In juveniles, growth, food consumption, and food utilization can all be affected by low dissolved oxygen levels (Bonar et al. 1989). Low dissolved oxygen levels can also hamper swimming performance in migrating adults (Bonar et al. 1989).

**Substrate:** Spawning adults, as well as eggs and alevins, prefer gravel ranging from 1.3 to 10.2 centimeters in diameter (Emmett et al. 1991). Fry, juveniles, and adults do not show any preference for particular substrates (Emmett et al. 1991).

**Movements and migrations:** Generally, pink salmon move quickly from their natal stream after emergence from gravel (Emmett et al. 1991; PFMC 2000). Pink salmon, on average, spend less time in fresh water after emergence than any of the Pacific salmon species (Heard 1991). Some stocks of pink salmon stocks can grow and reproduce successfully without leaving freshwater (Heard 1991). There are wide variations in downstream migration between regions, years, and streams (Heard 1991). Seaward migration peaks in late March and mid-May for pink salmon in British Columbia, Washington, and Oregon. Downstream migration occurs around late-February in the Fraser River (Heard 1991). These seaward movements seem to be influenced by a variety of factors including general size and location of the spawning stream, characteristics of adjacent shoreline, marine basin topography, tidal fluctuations, current patterns, physiological and behavioral changes, and possible different genetic characteristics between stocks (Heard 1991).

The majority of juvenile pink salmon pass directly through the estuaries, using the nearshore habitat, some stocks however, do spend one to two months residing in estuaries (PFMC 2000). Heard (1991) noted that pink salmon may enter coastal environments through any of the following routes: long open straits with large inland waters often interspersed with islands such as Tatar Strait, Cook Inlet, Strait of Georgia, and Puget Sound; complex interconnecting fiords and channels common to much of central British Columbia, southeastern Alaska, parts of Prince William Sound, and Kodiak Island; and, relatively open areas, generally with more or less direct access to major seas, bays, or open ocean, such as the Alaska Peninsula, Bristol Bay, and much of the Far East. Juvenile salmon found in Puget Sound from October to November are probably a resident stock that never migrates to the open ocean (Heard 1991). Pink salmon exhibit schooling behavior immediately after entering marine waters (PFMC 2000).

During early marine life, they spend the majority of their time along shorelines in waters only a few centimeters deep (Heard 1991). As pink salmon grow they begin to migrate to the open ocean with larger juveniles making the first migrations (Heard 1991). Tagging studies suggest that pink salmon from Puget Sound and the Fraser River leave these waters very quickly and migrate northward along the coast of British Columbia and southeastern Alaska from July through October (Heard 1991). Catch summaries indicate a second southwest migration of pink salmon along the south-central Alaska and Alaska...
Peninsula coastline from August to October (Heard 1991). After northward migrations to approximately Yakutat, Alaska, Washington, pink salmon move out into the Gulf of Alaska where they follow the main current in the gyre. From the gyre, they migrate southward during their first fall and winter at sea and then shift northward during the following spring and summer (PFMC 2000). Afterward, they move south, entering coastal waters as they head for their natal streams (PFMC 2000). Homeward migrations for pink salmon may be relatively direct or may include significant divergence (Heard 1991). Pink salmon migrate to the open ocean and return to coastal waters with remarkable consistency from year to year forming the basis for coastal fisheries (Heard 1991). Factors influencing a timely return include abundance of a particular brood, unusual oceanographic features, or characteristics of odd-year and even-year abundance patterns in the region (Heard 1991). Adult pink salmon enter freshwater from June to September, with northern populations entering earlier than southern populations (PFMC 2000). From mid-July (Dungeness River) to September, odd-year pink salmon from Puget Sound typically enter freshwater. Both even and odd-year pink salmon use the Snohomish River with the even-year populations entering three to four weeks earlier (Heard 1991).

**Reproduction:** Pink salmon have the most consistent life history of any of the Pacific salmon (Bonar et al. 1989). The pink salmon’s spawning cycle is so consistent that fish running in even-numbered years are absolutely isolated from fish running in odd-numbered calendar years resulting in no gene flow between the stocks (Bonar et al. 1989). Generally spawning occurs in freshwater close to the sea or in the intertidal zone, however, they may spawn several miles upstream (Bonar et al. 1989). Pink salmon are considered the most specialized of the Pacific salmon due to their lack of dependence on freshwater (Bonar et al. 1989). Spawning times generally range from late August through early October for the majority of their distribution (Bonar et al. 1989).

Preferred spawning grounds for pink salmon include clean course gravel in shallow pools and riffles exposed to moderately fast currents (Heard 1991). Water velocities associated with pink salmon spawning grounds range from 30 to 140 centimeters/sec with average velocities from 60 to 80 centimeters/sec (Heard 1991). Preferred spawning depths range from 20 to 25 centimeters but they may spawn as deep as 150 centimeters (Heard 1991). In dry years, nests may be found as shallow as 10 to 15 centimeters (Heard 1991). Pink salmon select sites with gradient increases and fast currents (PFMC 2000). They prefer beds consisting of coarse gravel and a few large cobblestones, a mixture of sand, and a small amount of silt (Heard 1991). Eggs are deposited from August to October in Washington and British Columbia. In Puget Sound and the upper Dungeness River they are deposited slightly earlier than elsewhere in northern Washington (PFMC 2000).

**Life History**—Pink salmon are the most abundant of the Pacific salmon species and have the simplest and most specialized life history (Heard 1991). Fry migrate quickly to sea after emergence where they make extensive feeding migrations (Heard 1991). Pink salmon spend approximately 18 months in the ocean where they grow rapidly before returning to their natal streams to spawn and die (Heard 1991).

**Common Prey Species**—Juvenile pink salmon feed on pelagic copepods and other epibenthic and planktonic organisms (Bonar et al. 1989). Juveniles found in southeastern Alaska and Puget Sound feed on harpacticoid copepods, copepod nauplii, invertebrate eggs, tunicates, and barnacle larvae (Bonar et al. 1989). Pink salmon found in marine waters feed on amphipods, fish, euphausiids, copepods, squid, and crustacean larvae. Amphipods and crustaceans were the most important prey items for nearshore fish, whereas, offshore fish preferred copepods and euphausiids (Bonar et al. 1989).

### 1.4.2 Coastal Pelagic Species

Coastal pelagic species in the NWTRC include: northern anchovy, jack mackerel, Pacific mackerel, Pacific sardine, market squid, and krill. All of these species are managed under a single Fisheries Management Plan (FMP); designated EFH extends along the length of the Pacific Coast from the shoreline to the 1,829 meter subsurface contour line (isobath) and to a depth of 400 meters.
The northern anchovy and Pacific sardine are considered part of the forage fish resources in Puget Sound which contribute to a major portion of the diet of other fishes, seabirds, and marine mammals (Bargmann 1998). The northern anchovy abundance in nearshore areas varies from year to year due to changes in behavior (Bargmann 1998). Eggs have been observed in the plankton during the spring in the southern Strait of Georgia, mid-Dabob Bay, mid-Saratoga Passage, and Skagit Bay with young-of-the-year being observed during the summer in San Juan Islands (Miller and Borton 1980; Washington Sea Grant Program 2000). Due to the restrictions placed on the sardine fisheries after its collapse, this species is becoming more abundant during the warmer months (Bargmann 1998; PFMC 1998b).

Several coastal pelagic species support fisheries along the West Coast from southern California to Alaska, including the Pacific sardine, northern anchovy, jack mackerel, chub (Pacific) mackerel, and market squid (PFMC 1998b). The coastal pelagic species management plan distinguishes between “actively managed” and “monitored” species. Actively managed species (Pacific sardine and Pacific mackerel) are assessed annually by harvest guidelines and fishing seasons (NMFS 2006e). The remaining coastal pelagic species (northern anchovy, jack mackerel, and market squid) are monitored to ensure their stocks are stable, but annual stock assessments and federal fishery controls are not used.

**Status**—Recent stock assessments indicate that both of the actively managed species (Pacific sardine and Pacific mackerel) are increasing in relative abundance while none of the monitored stocks (northern anchovy, jack mackerel, and market squid) managed under the plan are considered overfished (PFMC 2002, 2003a, NMFS 2004f, 2004b, 2005k, 2005e).

**EFH Designations**—EFH is identified for the coastal pelagic species complex (finfish and invertebrate) as one management unit and is based upon a thermal range bordered within the geographic area where a species occurs at any life stage; where the species have occurred historically, or where conditions do not preclude colonization (PFMC 1998b). EFH is shown on Figure 1-6.

For the NWTRC, the east-west, EFH geographic boundary for the Pacific sardine, Pacific mackerel, jack mackerel, and northern anchovy, and market squid is defined as all marine and estuarine waters from the shoreline to the limits of the EEZ (200 nm), above the thermocline, where SSTs range between 10° to 26°C. The southern geographic boundary occurs south of the U.S./Mexico border, where SSTs exceed 26°C (extent of species thermal tolerance). The northern boundary is more dynamic due to the seasonal cooling of the SST and corresponds to the position of the 10°C isotherm, which varies both seasonally and annually (PFMC 1998b).

The designation of EFH for krill is based on information about the two principal species, *Euphausia pacifica* and *Thysanoessa spinifera*, and discussed in more detail in Section 1.4.3.4.2.

### 1.4.2.1 Northern Anchovy (*Engraulis mordax*)

**Distribution**—Northern anchovy range from the Queen Charlotte Islands, British Columbia, to Cabo San Lucas, southern Baja California; but has recently colonized the Gulf of California (Jacobson 1992; Bergen and Jacobson 2001; Love et al. 2005). The population is divided into northern, central, and southern subpopulations, or stocks (Kucas 1988). Only the northern subpopulation whose geographic range extends from Vancouver Island, Canada to north of San Francisco, California, occurs within the NWTRC (Vrooman and Smith 1970). The central subpopulation, the bulk of which is located in the Southern California Bight, supports significant commercial fisheries in the U.S. and Mexico (PFMC 1998b).
Figure 1-6: Estimated EFH for All Lifestages of Coastal Pelagic Species Based on Warmest and Coldest Year Averages from 1982 through 2001

Habitat Preference—All life stages of the northern anchovy are found in the near surface waters over various substrates in the EEZ (Hart 1973; Squire and Smith 1977). Adults are oceanic-neritic occurring from the surface to 300 meters in waters located 157 kilometers offshore, whereas juveniles are surface and often highly abundant in shallow nearshore areas and estuaries (<90 meters) (Methot 1989). Adults can also be abundant in nearshore areas and estuaries (Emmett et al. 1991). Larvae and eggs are neritic and surface out to 480 kilometers offshore with larvae being distributed from the surface to 75 meters, but usually in the upper 50 meters, and eggs from the surface to 50 meters, but normally in the upper 20 meters (Hart 1973; Emmett et al. 1991). Northern anchovy typically occur in water temperatures ranging from 10° to 25°C: adults/juveniles - 5° to 25°C, larvae - 14° to 17.4°C, and eggs - 10° to 23.3°C (Emmett et al. 1991). From Oregon to Vancouver Island, the northern anchovy overwinters in the upper mixed layer temperatures ranging from 8° to 9°C (Brewer 1976). Adults, juveniles, and larvae can be found in estuarine and marine waters, while eggs are found in euhaline waters (32 to 35 psu) (Simenstad 1983).

Life History—Northern anchovy do not take extensive migrations, but undergo inshore-offshore movements and alongshore movements (MBC 1987). They form large schools from the surface down to 55 meters during the fall and winter and small, scattered schools, often 14 meters below the surface in the spring and summer (Love 1996). During the fall, very large schools may also be found at depths of 110 to 220 meters along submarine canyons and over deep banks and basins (Love 1996; Starr et al. 1998). Northern anchovy undertake diel vertical migrations during the summer, descending to depths of 110 to 183 meters during the day and ascending to the surface at night (MBC 1987). Adults, juveniles, and larvae form small low-density schools during the day and disperse into a thin surface layer at night (Emmett et al. 1991). Within the NWTRC, adults and juveniles move into estuaries during spring and summer, then return to the ocean in the fall (Emmett et al. 1991).

Northern anchovy are gonochoristic, oviparous, and iteroparous with external fertilization. This species is a batch spawner that reproduces at night in the upper, mixed layer of the water column (< 10 meters) from nearshore out to 482 kilometers, but normally within 100 kilometers of the shoreline (Baxter 1966; Hart 1973; Hunter and Macewicz 1980). Spawning occurs from Barkley Sound and the Strait of Georgia, British Columbia to Magdalena Bay, Baja California and in the Gulf of California but primarily between Point Conception and Point San Juanico, Baja California (MBC 1987). Within the NWTRC, the spawning season is more restricted taking place off Oregon (between 43° and 47°N latitude) 65 to 157 kilometers offshore of the Columbia River from June to August and off the Fraser River, British Columbia in July and August (Baxter 1966; Hart 1973; Love 1996). Females spawn eggs at intervals as short as six to eight days. Preferred spawning temperature is between 12° to 15°C (Methot 1989).

Common Prey Species—Northern anchovy prey upon phytoplankton and zooplankton, primarily planktonic crustaceans (euphausiids and large copepods), arrowworms, and fish larvae (MBC 1987; PFMC 1998b).

1.4.2.2 Jack Mackerel (Trachurus symmetricus)

Distribution—Jack mackerel range throughout the northeastern Pacific, from the Pacific coast of the U.S. to an offshore limit approximated by a line running from Cabo San Lucas, southern Baja California, to the eastern Aleutian Islands, Alaska. Much of its geographical range lies outside the EEZ (MacCall and Stauffer 1983).

Habitat Preference—All lifestages of the jack mackerel are pelagic (Eschmeyer et al. 1983). Adults occur offshore from the surface to 403 meters, but are most abundant at depths ranging from 9 to 73 m; whereas juveniles are found at depths of 9 to 55 meters around floating debris, kelp beds, piers, oil drilling platforms, shallow rock banks, and islands (Hart 1973; MacCall and Stauffer 1983). Larvae and eggs are distributed from the surface to 140 meters up to 2,400 kilometers offshore, but are found normally within the upper 50 meters of the water column (MBC 1987). Jack mackerel typically occur in water temperatures ranging from 10° to 27°C: adults - 11° to 27°C, juveniles - 13° to 27°C, and...
larvae/eggs - 10° to 19.5°C (Hart 1973; MacCall and Stauffer 1983; PFMC 1998b). All life stages are found in euhaline waters (32.0 to 34.5 psu) (MacCall and Stauffer 1983).

**Life History**—Jack mackerel demonstrate migratory patterns onshore-offshore and along the coast. They are more common on offshore banks during late spring, summer, and early fall than during the remainder of the year (PFMC 1998b). Fish longer than 45 centimeters generally occur further offshore of northern California, Oregon, and Washington as solitary or loose aggregations, whereas fish less than 45 centimeters are more abundant in southern California waters in dense schools (Hart 1973; Love 1996). Jack mackerel are oviparous and multiple spawners reproducing in the surface (MBC 1987; Mason 1992). Spawning occurs between 25° and 47°N latitude from 64 to 1,800 kilometers offshore at temperatures of 14° to 16°C (Love 1996). Spawning grounds are located off southern California and northern Baja California from 64 to 577 kilometers offshore February to October with peak activity from March to July (MacCall and Prager 1988). Spawning also occurs within the NWTRC offshore of Oregon from 160 to 1,600 kilometers and off Washington from 320 to 1,800 kilometers August to October (MacCall and Stauffer 1983; Mason and Bishop 2001).

**Common Prey Species**—Jack mackerel prey upon zooplankton (copepods, pteropods, and euphausiids), juvenile squid, and northern anchovy (Hart 1973; Feder et al. 1974; PFMC 1998b).

### 1.4.2.3 Pacific Mackerel (*Scomber japonicus*)

**Distribution**—Pacific or chub mackerel circumnavigate temperate and tropical seas (Collette and Nauen 1983; Love 1996). In the northeastern Pacific, this species ranges from Banderas Bay (Puerto Vallarta), Mexico, to southeastern Alaska (Hart 1973) and is common from Monterey Bay, California, to Cabo San Lucas, Baja California. Pacific mackerel are most abundant south of Point Conception, California (MBC 1987; PFMC 1998b).

**Habitat Preference**—All lifestages of the Pacific mackerel are primarily pelagic, and to a lesser extent surface or subsurface over the continental slope (Collette and Nauen 1983). Adults are commonly found from the surface to depths of 300 meters within 30 kilometers of shore near shallow banks, but may be distributed as far as 400 kilometers offshore (Konno 1992; Konno et al. 2001). Juveniles occur off sandy beaches and in open bay kelp beds from the surface to 50 meters (PFMC 1998b). Larvae occur from the surface to 66 m; whereas most eggs are found in the upper 20 meters, but occur at depths down to 176 meters (MBC 1987). Pacific mackerel typically occur in water temperatures ranging from 10° to 26°C: adults - 10° to 22.2°C, juveniles - 10° to 26°C, and larvae/eggs - 14°C (MBC 1987; Love 1996; PFMC 1998b). This species is found at salinities of 33.5 to 35.0 psu (Collette and Nauen 1983).

**Life History**—Pacific mackerel migrate north in summer and south in winter (MBC 1987). In the northeastern Pacific, they move coastwise between Tillamook, Oregon and Magdalena Bay, Baja California. Northerly movement is increased during summer months during El Niño events (MacCall et al. 1985). There is also an inshore-offshore migration off California, with increased inshore abundance taking place from July to November and peak offshore abundance from March to May (PFMC 1998b). Larval Pacific mackerel undertake diel vertical migrations, ascending to the surface at night (MBC 1987). Pacific mackerel often school with other pelagic species, particularly jack mackerel, Pacific sardine, and Pacific bonito (*Sarda chiliensis*) (Collette and Nauen 1983).

Pacific mackerel are oviparous (Love 1996) and batch spawners with actively spawning fish capable of spawning every day or every other day (PFMC 1998b; Starr et al. 1998). Three spawning stocks of Pacific mackerel occur along the Pacific Coast of the U.S. and Mexico: Gulf of California; Cabo San Lucas; and along the Pacific Coast north of Punta Abreojos, Baja California (Collette and Nauen 1983; MBC 1987; PFMC 1998b). Within the Pacific Northwest OPAREA, the northeastern Pacific stock spawn from Eureka, California, south to Cabo San Lucas in Baja California (MBC 1987). Spawning occurs in schools at night, generally within the upper 72 meters of the water column between 3 and 320 kilometers offshore peaking from late April to July (MacCall and Prager 1988). Like most small pelagic species,
Pacific mackerel have indeterminate fecundity and seem to spawn whenever sufficient food is available and appropriate environmental conditions prevail (Dickerson et al. 1992).

**Common Prey Species**—Pacific mackerel prey upon pelagic crustaceans such as copepods, pteropods, and krill, juvenile squid, fish larvae, and small fish like anchovy (Hart 1973; Collette and Nauen 1983).

1.4.2.4 Pacific Sardine (*Sardinops sagax*)

**Distribution**—Sardine (genus *Sardinops*) inhabit coastal subtropical and temperate waters within the eastern boundary currents of the Atlantic and Pacific oceans, and the western boundary currents of the Indo-Pacific oceans (PFMC 1998b). Off the Pacific Coast of North America, Pacific sardine comprise three separate subpopulations or stocks: a northern stock (northern Baja California to Alaska), a southern stock (off Baja California), and a Gulf of California stock (Wolf and Smith 1992; Wolf et al. 2001).

**Habitat Preference**—Pacific sardine are pelagic throughout their life cycle and are typically the most abundant fish species in the California Current (Barnes et al. 1992). Dramatic changes in their distribution and abundance, which are probably related to environmental conditions, exist in sardine populations around the world (Lluch-Belda et al. 1991). Within the NWTRC, during times of high abundance, Pacific sardine are found from the tip of Baja California (23°N latitude) to southeastern Alaska (57°N latitude). However, during periods of low abundance, sardine are not found in commercial quantities north of Point Conception, California and are restricted to waters off southern and central Baja California (PFMC 1998b). Currently, very little is known about the mechanisms responsible for Pacific sardine distribution (McFarlane and Beamish 1988). This species is found in estuaries but is most common in nearshore and offshore domains along the coast (PFMC 1998b). Pacific sardine typically occur in water temperatures ranging from 10° to 26°C: adults/juveniles - 10° to 26°C, larvae - 13° to 16°C, and eggs - 13° to 15°C (Lluch-Belda et al. 1991).

**Life History**—Pacific sardine are highly mobile, moving seasonally along the coast with no significant overlap occurring between the northern and southern stocks (Radovich 1982). Older adults may move from spawning grounds in southern California and northern Baja California to feeding grounds off the Pacific Northwest and Canada. Younger adults (ages two to four) appear to migrate to feeding grounds primarily in central and northern California. Juveniles occur in nearshore waters off northern Baja California and southern California (PFMC 1998b). Larvae and eggs occur nearly everywhere adults are found (Lo et al. 1996).

Pacific sardine are oviparous and multiple-batch spawners with an annual fecundity that is highly age-dependent or size-dependent. Spawning occurs year-round in loosely aggregated schools in the upper 50 meters of the water column. Eggs and larvae are concentrated 50 to 150 kilometers offshore when abundance is high and concentrated closer to shore when abundance is low (Butler et al. 1993; Starr et al. 1998). These patterns are dependent on both SST and sardine density (PFMC 1998b).

The spatial and temporal (seasonal) distribution of spawning in the Pacific sardine is influenced by water temperature. During periods of warm water incursions, the center of sardine spawning shifts northward and spawning extends over a longer period of time (PFMC 1998b). Recent spawning has been concentrated in the region offshore and just north of Point Conception, California (Lo et al. 1996). In the southern stock, spawning peaks April to August between Point Conception and Magdalena Bay, Baja California and January to April in the Gulf of California (PFMC 1998b). Within the NWTRC, spawning has also observed in the Columbia River Plume off Tillamook Head, Oregon in 1994 (Bentley et al. 1996) and off British Columbia in 1992 (PFMC 1998b).

**Common Prey Species**—Pacific sardine prey upon phytoplankton, fish larvae, and zooplankton (copepods) (Wolf et al. 2001).
1.4.2.5 Invertebrates

Eight euphausiid shrimp species that form the bulk of the krill community in the California Current System have been added to the coastal pelagic species management plan (PFMC 2006) and have designated EFH (NMFS-SWR 2006). The coastal pelagic species complex – finfish and invertebrates – is managed as single unit based on a thermal range bordered within the geographic area where the species occurs at any life stage, where it has occurred historically, or where environmental conditions do not preclude colonization (PFMC 1998b).

For the NWTRC, invertebrates include the market squid and krill.

1.4.2.5.1 Market Squid (Loligo opalescens)

**Distribution**—Market or opalescent squid range throughout the California and Alaska current systems, from the southern tip of Bahia Asuncion, Baja California, Mexico (23°N) to southeastern Alaska (55°N) (Dickerson and Leos 1992). They are common between Monterey Bay, California and Punta Eugenio, Baja California, and are found north of Puget Sound only during, or shortly after, El Nino years (Cailliet et al. 1979; Yaremko 2001).

**Habitat Preference**—Market squid are typically found in pelagic waters over the continental shelf from the surface to depths of at least 800 meters. Adults are primarily neritic from the surface to 460 meters and occasionally are located in tidepools (MBC 1987). Juveniles are also neritic with smaller individuals inhabiting the surface to 15 meters and larger individuals from the surface to 200 meters (Recksiek and Kashiwada 1979). Paralarvae (or hatchlings) have been located in nearshore waters (7 kilometers) above the 80 meters depth (Zeidberg and Hamner 2002); whereas eggs occur on mud-sand bottoms at depths of 15 to 50 meters in semi-protected bays (Roper et al. 1984). Market squid typically occur in water temperatures ranging from 10° to 26°C: adults/eggs - 7° to 17°C and juveniles - 13° to 20°C. This species lives in euhaline waters (MBC 1987).

**Life History**—Market squid migrate from pelagic waters to nearshore areas over sandy habitats for spawning (Dickerson and Leos 1992; Yaremko 2001). Vertical distribution by squid during daylight hours ranges from 100 to 600 m. At night, adults are located closer to the water’s surface, within the upper 100 meters of the water column (Zeidberg and Hamner 2002). The migration patterns of juveniles and prespawning adults are unknown (CDFG 2005).

Market squid are oviparous and semelparous (Roper et al. 1984). Spawning squid concentrate in dense schools with most activity involving groups of six to eight individuals (MBC 1987). Factors that determine ideal spawning grounds have not been precisely identified (PFMC 1998b). Known major spawning areas include shallow, semi-protected nearshore areas with sandy or mud bottoms adjacent to submarine canyons (PFMC 1998b). In these locations, egg deposition is between depths of 5 to 55 meters in the water column and most common between 20 to 35 m. Market squid spawn from Barkley Sound, British Columbia to South Coronado Island, Baja California (MBC 1987). Spawning occurs year-round: off southern California during the fall-spring, off central California during spring-fall, off Oregon from May to July, and off Washington and British Columbia from May to September (Roper et al. 1984; NMFS-NWR 2004c). Year-round spawning suggests that stock abundance is not dependent on spawning success during a single short season, or a single spawning area (Yaremko 2001). Spawning is continuous and eggs of varying developmental stages may be present at one site. Paralarvae are dispersed from egg beds by ocean currents and occur most commonly inshore, concentrated in areas where water masses converge (Zeidberg and Hamner 2002).

**Common Prey Species**—Market squid prey upon copepods, euphausiids, small crustaceans (sergestid shrimp), small fish (northern anchovy), and other squid (PFMC 1998b).
EFH Designations— (NMFS-SWR 2006)

The east-west EFH geographic boundary for the Market squid is the same as the previously discussed coastal pelagic species: all marine and estuarine waters from the shoreline to the limits of the EEZ, above the thermocline, where SSTs range between 10° to 26°C. The southern geographic boundary occurs south of the U.S./Mexico border, where SSTs exceed 26°C (extent of species thermal tolerance). The northern boundary is more dynamic due to the seasonal cooling of the SST and corresponds to the position of the 10°C isotherm, which varies both seasonally and annually (PFMC 1998b).

1.4.2.5.2 Krill

Krill provide a critical link in oceanic food webs between phytoplankton food and upper level predators. As major inhabitants and herbivores encompassing the transition zone of the California Current System, krill act as conduits of nutrients and primary production from the various upwelling areas off the coast to the higher trophic levels of the broader marine ecosystem. Animals that feed on krill include squid, ecologically important protected marine mammals and seabirds, and commercially important fish like groundfish, salmon and tuna (Phillips 1964; Alverson and Larkins 1969; Pinkas et al. 1971; Karpov and Cailliet 1979; Benson et al. 2002; Ainley et al. 2005).

The U.S. West Coast EEZ is dominated by eight species of krill. The two most common species, Euphausia pacifica and Thysanoessa spinifera, form large, dense surface or near-surface aggregations that support commercial harvesting (NMFS-SWR 2006). The six less common species prefer the deep layers of the thermocline, or are only abundant during strong El Niño years (Niptiphanes simplex, Nematocelis difficilis, Thysanoessa gregaria, Euphausia recurva, E. gibboides, and E. eximia; Brinton and Townsend 2003). Commercial krill fishing is prohibited in the state waters of Washington, Oregon, and California, and they are included in the “prohibited harvest” category which prohibits the harvest and retention of krill in the U.S. EEZ (Amendment 12; NMFS-SWR 2006). EFH is shown in Figure 1-7.

Status—Large-scale commercial fishing of krill does not occur in California, Oregon, or Washington waters, but does occur in the Strait of Georgia, British Columbia (Nicol and Endo 1997). Commercial krill fishing is prohibited in the state waters of Washington, Oregon, and California, and they are included in the “prohibited harvest” category which prohibits the harvest and retention of krill in the U.S. EEZ (Amendment 12; NMFS-SWR 2006).

1.4.2.5.2.1 North Pacific Krill (Euphausia pacifica)

Distribution—Euphausia pacifica is broadly distributed across the North Pacific occurring from the California Current west across the Pacific to Japanese waters. It ranges throughout the subarctic Pacific, including the Gulf of Alaska and as far south as 25°N (Brinton 1981).

Habitat Preference—E. pacifica is oceanic generally occurring within the U.S. West Coast EEZ from the surface to bottom depths of 400 m. This species is found seaward to the outer boundary of the EEZ and beyond with its highest densities occurring within the inner third of the EEZ (NMFS-SWR 2006). Within the Pacific northwest region (<3 to 110 nm from the coast), adults and juveniles can be found throughout both inshore and offshore areas, whereas larvae are often most abundant in upwelling areas. Larvae are generally inshore of the 1,823 meters in mid-summer and offshore over the deeper waters of the continental shelf during the rest of the year (Gómez-Gutiérrez et al. 2005). Off Oregon, the greatest concentration of adults appears to be located within 10 to 20 nm either side of the shelf break (~200 meters isobath) (Gómez-Gutiérrez et al. 2005).

Life History—This species performs extensive vertical migrations. Adults live at a daytime depth of 200 to 400 meters (occasionally down to 1,000 meters) rising during the night towards the surface often concentrating in the upper 20 to 50 meters (NMFS-SWR 2006). Their upward movement is inhibited by temperatures (> 20°C) Iguchi and Ikeda 2005). The North Pacific krill has been reported to form surface swarms during the day for feeding and reproductive purposes.
Figure 1-7: Essential Habitat for *Euphausia pacifica* and *Thysanoessa spinifera*
E. pacifica is a batch spawner broadcasting eggs freely into the water column where they sink upon entry. Under optimal feeding conditions, females could spawn every two months (NMFS-SWR 2006). Recruitment occurs year-round off Oregon (Heceta Bank and Cape Blanco areas), northern California (Bodega Canyon, Cordell Bank, etc.), and southern California (Channel Islands with distinct peaks being associated with upwelling periods) (Chess et al. 1988; Croll et al. 1998; Fiedler et al. 1998; Ainley et al. 2005; Ressler et al. 2005; Tynan 2005; NMFS-SWR 2006). Recruitment typically is prolonged occurring in open ocean and more exposed coastal areas moving along the coastline from mid-Baja California (February to April) to southern California (May to July), Monterey Bay (spring and summer) and Oregon (August to December) (NMFS-SWR 2006). Off Washington, there is one large recruitment pulse in the spring and a lesser one in late summer (NMFS-SWR 2006). Due to their shorter life span and relatively few cohort pulses, maximum stock size is reached immediately after successful recruitment of a single cohort (Siegel 2000). In general, there is no spawning stock-recruitment relationship, highest recruitment occurs from spring/summer cohorts with lesser recruitments in autumn and winter (NMFS-SWR 2006). Reproductive swarms are common along the shelf-break area (NMFS-SWR 2006). Within the various inland basins, such as Puget Sound and the Strait of Georgia, spawning takes place over a relatively short period in the spring (Feinberg and Peterson 2003).

**Common Prey Species**—E. pacifica preys primarily upon phytoplankton, particularly diatoms, small zooplankton, as well as fish eggs and larvae (J.C. Field et al. 2001).

1.4.2.5.2.2 Thysanoessa spinifera

**Distribution**—Thysanoessa spinifera occurs in the northeast Pacific ranging from southeastern Bering Sea south to northern Baja California (NMFS-SWR 2006).

**Habitat Preference**—T. spinifera is a coastal species occurring mainly shoreward of the shelf break with its highest concentrations over the continental shelf and slope (NMFS-SWR 2006). This species is found primarily over the shelf and shelf-break waters from 1 to 40 nm off the coast especially between 3 and 15 nm from shore in water less than 100 meters deep. Adults occur in the outer shelf, shelf-break, and slope waters beyond (9.7 nm) from the coast, whereas juveniles and larvae are restricted to relatively shallow inner shelf waters less than 9.7 nm from shore (NMFS-SWR 2006). Brinton and Townsend (2003) reported T. spinifera disperses extensively offshore toward the main flow of the California Current.

**Life History**—This species undertakes diel vertical migrations within its relatively shallow depth range (<100 meters) (Chess et al. 1988). It is the most predictable and extensive daytime surface swarmer along the California coast from Tomales Bay south to the Channel Islands (Fiedler et al. 1998). Mass strandings have been reported along Oregon beaches to as far south as La Jolla, California (NMFS-SWR 2006).

T. spinifera is a batch spawner with adhesive eggs which help maintain recruits in the neritic zone thus preventing offshore dispersal to less productive waters (NMFS-SWR 2006). Spawning season is prolonged, lasting from spring through summer (May to July) coincident with the peak of the upwelling season (Brinton 1981). Adults are thought to swarm, breeding over a protracted spawning season along the coast from British Columbia (March through July with a late May peak), Oregon (May through October or November), northern California (April through June/July, and central and southern California (August through October (NMFS-SWR 2006). Subadults are also known to swarm near the surface in late summer and fall (Schoenherr 1991; Fiedler et al. 1998). Within the inland basins such as Puget Sound and the Strait of Georgia region of British Columbia, spawning occurs over a relatively short period in the spring (Feinberg and Peterson 2003).

**Common Prey Species**—T. spinifera preys primarily upon unicellular phytoplankton, primarily diatoms along with small zooplankton and fish eggs/larvae (J.C. Field et al. 2001).
**EFH Designations** — (NMFS-SWR 2006)

The designation of EFH for krill is based on information about the two principal species. Isobaths are used as outer boundaries of EFH, because they roughly approximate the outer bounds of densest concentrations of the populations, and the major upwelling areas in which consistently high concentrations of phytoplankton occur. EFH for *Euphausia pacifica*, *E. recurva*, *E. gibboids*, *E. eximia*, *Nictiphanes simplex*, *Nematocelis difficilis*, and *Thysanoessa gregaria* (larvae, juveniles and adults) is identified from the inner boundary of the U.S. West Coast EEZ (beyond 3 nm) seaward to the 1,829 meters isobath, from the U.S.-Mexico border north to the U.S.-Canada border, from the surface to 400 meters deep. EFH for *Thysanoessa spinifera* (larvae, juveniles, and adults) is from the inner boundary of the U.S. West Coast EEZ (beyond 3 nm) seaward to the 914 meters isobath, from the U.S.-Mexico border north to the U.S.-Canada border, from the surface to 100 meters deep.

1.4.3 Pacific Coast Groundfish

Groundfish species are bottom-dwelling finfish managed under the Pacific Coast Groundfish Fishery Management Plan (PFMC 2006c). Managed groundfish species known to occur in the NWTRC include rockfish, flatfish, roundfish, skates, sharks, and chimeras (PFMC 1998a). These groundfish species occupy a variety of ecosystems, encompassing different physical and biological attributes at various stages in their life histories and utilizing habitats ranging from estuaries to the limits of the EEZ. Research on the life histories and habitats of these species varies in completeness. This lack of complete life history information for some species limits the characterizations of this diverse group of species. After an EFH discussion, brief species characterizations are presented, including distribution, habitat preferences, life history, and common prey species (PFMC 1998a). For help in the identification of groundfish species refer to the following literature: Eschmeyer (1983), Lamb and Edgell (1986), Kramer and O’Connell (2003), Kramer et al. (1995), Love et al. (2002), Ebert (2003), and Froese and Pauly (2004).

Many of these fish support important commercial and recreational activities, as well as Tribal “usual and accustomed” fisheries. Washington coastal treaty Indian tribes (Makah, Quileute, Hoh and the Quinault Indian Nation) hold formal allocations in their fishing areas for sablefish (*Anoplopoma fimbria*), Pacific hake (*Merluccius productus*), and black rockfish (*Sebastis* spp.).

**Status.** A preliminary 2002 assessment of groundfish stocks has shown that over half of key groundfish stocks in the south Puget Sound are at or below average abundance (PSWQAT 2002). Some of the species that once dominated the catches of recreational and commercial fishers are now at depressed or critically low numbers, resulting in historic low catches and reduced fisheries (Palsson et al. 1998).

Five groundfish within the NWTRC are designated as overfished – bocaccio, canary rockfish, darkblotched rockfish, widow rockfish, and yelloweye rockfish, Pacific ocean perch (PFMC 2003b, NMFS 2004f, and NMFS 2006a). Additional species are identified as “emphasis species” – sablefish, Dover sole, English sole, Petrale sole, arrowtooth flounder, chilipepper, yellowtail rockfish, shortspine thornyhead, longspine thornyhead, black rockfish, and cabezon. Emphasis species are described as groundfish stocks that are particularly susceptible to bycatch (PFMC 2004a). Two of these emphasis species, the black rockfish and shortspine thornyhead, have been determined to be subject to overfishing (NMFS 2005k).

**Groundfish Essential Fish Habitat.** Within the NWTRC, groundfish are currently managed based on distinction between nearshore, continental shelf, and continental slope ecosystems. The following condition determines the size and distribution of groundfish habitat – ocean bottom topography and depth, the California Current System, and short- and long-term climatic conditions (PFMC 2003b; 2004a). All lifestages of the Pacific Coast groundfish occur within the NWTRC. Estuaries, sea grass beds, canopy kelp, rocky reefs, and other “areas of interest” (e.g., seamounts, offshore banks, canyons) are designated Groundfish HAPCs.
Reproductive adults are separated into spawning (external fertilization, release eggs/sperm) represented by flatfish, roundfish, scorpionfish, and thornyheads and mating (internal fertilization, release live young) represented by rockfish (*Sebastes*) and sharks (including soupfin, leopard, and spiny dogfish). Skates and chimeras have internal fertilization (mating adults) but produce egg cases into the water to develop (Love et al. 2002; McCain et al. 2005).

EFH designation is based upon the aquatic habitat necessary for a long-term sustainable fisheries and a healthy ecosystem (PFMC 1998a). Depending on their lifestage, they may live in kelp or eelgrass beds, rocky reef hardbottoms, hexactinellid sponge reefs, or areas with sandy or muddy sea floors (Simenstad et al. 1979; Palsson 1998; USACE 2001; Jamieson and Chew 2002). Many of these groundfish species utilize the shallow intertidal areas of Puget Sound and the Strait of Juan de Fuca as nursery habitat. These areas provide refuge from predation and sources of food when these fish shift from pelagic to bottom-dwelling habitats (West 1997).

The Pacific Coast groundfish EFH encompasses all known suitable habitat for groundfish, plus an additional buffer to account for gaps in information concerning the distribution of species and their lifestages. This includes all inland waters from the mean high water level or the upriver extent of saltwater intrusion (less than 0.5 potential salt units) to depths up to 3,500 meters. EFH has also been designated for seamounts in waters deeper than 3,500 meters (NMFS-NWR 2006; NMFS 2006b) Figure 1-8 illustrates all areas where habitat suitability probability is greater than zero for at least one lifestage of one groundfish species (NMFS-NWR 2006). NMFS-NWR 2005; PFMC 2005g; 2005a; 2005f; 2005b; 2005c). EFH designation was developed using a precautionary approach based on known maximum depth distribution of all lifestages and to account for uncertainties related to the value of different habitats to individual groundfish or lifestages.

1.4.3.1 Flatfish

Important flatfish species in the NWTR C include the arrowtooth flounder, butter sole, curlfin sole, Dover sole, English sole, flathead sole, petrale sole, rex sole, rock sole, sand sole, starry flounder, pacific, and sanddab. These species, arranged alphabetically by common name, are described below.

1.4.3.1.1 Arrowtooth Flounder (*Atheresthes stomias*)

**Distribution**—Arrowtooth flounder range from Commander Islands and east coast of Kamchatka to Cape Navarin, Bering Sea to Aleutian Islands and Gulf of Alaska to Santa Barbara, southern California with the highest concentration north of Cape Blanco, Oregon (Allen and Smith 1988; Dark and Wilkins 1994; Kramer et al. 1995; Mecklenburg et al. 2002).

**Habitat Preference**—Arrowtooth flounder is the dominant flounder species on the continental shelf from the western Gulf of Alaska to Oregon (McCain et al. 2005). Adult and juveniles are found at or near the bottom and sublittoral-bathyal occurring from depths of 9 to 1,145 meters with young juveniles found in shallow waters (< 200 meters) and older juveniles and adults at water depths ranging from 50 to 500 meters (Dark and Wilkins 1994; Love et al. 2005). These lifestages commonly inhabit sand or sandy gravel substrata, but occasionally are found over low-relief rock-sponge bottoms (McCain et al. 2005). Larvae are neritic in water less than 200 meters, but occasionally may be found at depths up to 3,100 meters (Hart 1973; McCain et al. 2005). Eggs are pelagic occurring in midwater from 75 meters to over 300 meters (Casillas et al. 1998). Arrowtooth flounders typically reside in water temperatures ranging from sub-zero to 9°C: adults – 0° to 9°C, juveniles – sub-zero° to 5°C, larvae – 6.6° to 8.0°C, and eggs – 3.7° to 6.8°C. All lifestages occur exclusively in euhaline waters (McCain et al. 2005).
Figure 1-8: Habitat Suitability Probability is Greater than Zero for at Least One Lifestage of One Groundfish Species

Life History—Arrowtooth flounder exhibit a strong migration from shallow water (50 meters) summer feeding grounds on the continental shelf to winter/spring deep-water (500 meters) spawning grounds over the continental slope (McCain et al. 2005). This species also tends to move into deeper water as its matures (Dark and Wilkins 1994). Arrowtooth flounders are oviparous with external fertilization and batch spawners, reproducing off the coast of Washington between fall and winter (McCain et al. 2005) and in Puget Sound during the winter months (Garrison and Miller 1982).

Common Prey Species—Arrowtooth flounder prey upon crustaceans such as ocean pink shrimp (Pandalus jordani) and krill, and fish such as gadids, herring, and walleye pollock (Hart 1973; McCain et al. 2005).

1.4.3.1.2 Butter Sole (Isopsetta isopleis)

Distribution—Butter sole range from the southeastern Bering Sea and Aleutian Islands (west to Amchitka Island) to Ventura, southern California (Miller and Lea 1972; Kramer et al. 1995; Love et al. 2005).

Habitat Preference—Butter sole inhabit shallow water areas on muddy or silty bottoms (Kramer et al. 1995) and occasionally are found in waters at depths of 2 meters or less to 425 meters (Eschmeyer et al. 1983; Allen and Smith 1988). This species is usually found in coastal waters within 18 kilometers of shore and have been reported from Puget Sound (McCain et al. 2005). Adults are at or near the bottom, whereas the larvae and eggs are pelagic (Casillas et al. 1998).

Life History—Information is unavailable on the migrations and movements of the butter sole (McCain et al. 2005). Spawning in the butter sole takes place primarily in coastal areas from February to April at depths of 27 to 64 meters (Casillas et al. 1998; Matarese et al. 2003). Larvae are abundant in nearshore coastal water off Oregon and Washington in the winter and spring (McCain et al. 2005).

Common Prey Species—Butter sole prey upon polychaetes, mollusks, amphipods, and sea stars (McCain et al. 2005).

1.4.3.1.3 Curlfin Sole (Pleuronichthys decurrens)

Distribution—Curlfin sole range from the Aleutian Islands off northwest coast of Unimak Island and Gulf of Alaska to just south of Punta San Juanico, southern Baja California (Miller and Lea 1972; Kramer et al. 1995; Mecklenburg et al. 2002; Love et al. 2005).

Habitat Preference—Curlfin sole occur on softbottom habitats from the surfzone to a depth of 349 meters (Miller and Lea 1972), but most commonly in water shallower than 90 meters (Eschmeyer et al. 1983; Kramer et al. 1995). Adults are at or near the bottom while eggs are pelagic (Casillas et al. 1998).

Life History—Information is unavailable on the migrations and movements of the curlfin sole (McCain et al. 2005). Spawning in the curlfin sole occurs from late April to August (Eschmeyer et al. 1983).

Common Prey Species—Curlfin sole prey upon benthic organisms such as polychaete worms, nudibranchs, echiuroid proboscises, crustacean (possibly crab) eggs, and brittle star fragments (McCain et al. 2005).

1.4.3.1.4 Dover Sole (Microstomus pacificus)

Distribution—Dover sole range from northwestern and southeastern Bering Sea and Aleutian Islands from Stalemate Bank to just south of Punta San Juanico, southern Baja California (Hagerman 1952; Hart 1973; Love et al. 2005).

Habitat Preference—Dover sole is the dominant flatfish on the continental shelf and slope from Washington to southern California (Allen and Smith 1988). This inner shelf-mesobenthal species (Allen and Smith 1988) inhabits softbottom habitats, including fine sand, silt or mud, in marine and estuarine environments (Casillas et al. 1998). Both adults and juveniles are at or near the bottom (Garrison and Miller 1982). Adults are found from 2 meters or less to 1,372 meters depth in habitats consisting of mud.
and sea urchins (*Allocentrotus*) (Kramer et al. 1995; McCain et al. 2005). Their greatest abundance is below 200 to 300 meters (Allen and Smith 1988). Juveniles are sublittoral-bathyal at depths of 100 to 700 meters and are usually found deeper than 200 meters (Hart 1973). Larvae are found in surface waters and at depths down to 600 meters (McCain 2003). Eggs are surface and are found up to 840 kilometers offshore in surface and midwaters from to 50 meters to beyond the 200 meters isobath where current flows are 10 to 15 centimeters/sec (Starr et al. 1998). Dover sole are found at water temperatures ranging from 4.0° to 15.5°C: eggs - 8° to 10°C (Casillas et al. 1998) and occur in euhaline waters (MBC 1987).

**Life History**—Dover sole are migratory with adults and juveniles moving into shallow-water (50 to 225 meters) feeding grounds in summer and fall, then migrating offshore into deep waters (300 to 1,000 meters) to spawn in late fall (Hunter et al. 1990). This species migrates from onshore to offshore with little coastal north-south movements. Juvenile fish move into deeper water of the oxygen minimum zone with age, and begin seasonal spawning-feeding migrations upon reaching maturity (Henry and Lo 1992; Henry et al. 2001). Larvae are transported offshore and to nursery areas by ocean currents and winds (Hunter et al. 1990). Dover sole are batch spawners and oviparous with external fertilization (Casillas et al. 1998). Spawning occurs from November to April (peaking between December and February) off Washington, Oregon, and California in waters 80 to 550 meters deep at or near mud bottoms (Hart 1973; Garrison and Miller 1982; Horton 1989). Spawning occurs at temperatures of 4.2° to 6.8°C as well as sub-zero temperatures (MBC 1987; McCain 2003).

**Common Prey Species**—Dover sole prey on benthic organisms such as polychaetes, pelecypod and scapopod bivalves, small benthic crustaceans such as pink shrimp, and brittle stars (Hart 1973; Henry and Lo 1992; Henry et al. 2001).

**1.4.3.1.5 English Sole (*Parophrys vetulus*)**

**Distribution**—English sole range from Nunivak Island in the Bering Sea and Agattu Island in the Aleutian Islands, to Bahia San Cristobal Bay, central Baja California Sur (Allen and Smith 1988; Love et al. 2005).

**Habitat Preference**—English sole are very important flatfish in shallow-water, softbottom (including fine sands and mud), marine (including the Strait of Georgia), and estuarine (including Puget Sound, Hood Canal, Skagit Bay, Grays Harbor) environments (Emmett et al. 1991). This inner-shelf, mesobenthal species occurs to 55 meters (Allen and Smith 1988) and is a member of the shallow sublittoral community in Puget Sound and the intermediate depth Nestucca assemblage off Oregon (McCain et al. 2005). Adults and juveniles are benthic, preferring soft substrates and eelgrass habitats (Garrison and Miller 1982). Adults occur from intertidal zone to 550 meters, but are most abundant at depths less than 165 meters (MBC 1987). Juveniles occur in the intertidal zone at depths up to 150 meters and in shallow-water coastal bays and estuarine areas, such as Puget Sound, and protected coastlines (Garrison and Miller 1982; Simenstad 1983). Larvae and eggs are pelagic occurring primarily in waters greater than 200 meters deep (McCain 2003). All life stages of the English sole are found at water temperatures ranging from 4° to 18°C: adults/juveniles – less than 18°C, larvae – 8° to 9°C, and eggs – 4° to 12°C (MBC 1987). Adults occur in euhaline waters; whereas juveniles, larvae, and eggs are found in polyhaline salinities of 25 to 28 psu (Garrison and Miller 1982; MBC 1987).

**Life History**—English sole make limited migrations. Off Washington and British Columbia, English sole exhibit a northward post-spawning migration in the spring on their way to summer feeding grounds, and a southerly movement in the fall (Garrison and Miller 1982). Tidal currents appear to be the mechanism by which English sole larvae are transported to nearshore nursery areas, consisting of shallow coastal waters and estuaries, along the Pacific Coast (Yoklavich 1982). Larvae metamorphose into juveniles in spring and early summer and mature until fall/winter, at which time most emigrate to deeper waters (Gunderson et al. 1990). Early- and late-stage larvae undergo diel vertical migrations (Emmett et al. 1991). English sole are gonochoristic, oviparous, and iteroparous with external fertilization (Garrison and Miller 1982). Spawning occurs over softbottom mud substrates in sheltered waters in channels or bights at depths of 50
to 70 meters from winter to early spring. Timing depends on the stock and extends from October to May for English sole from Eureka, California to Oregon, and January to April, with a peak in February or March, for English sole from Oregon to Puget Sound (Matarese et al. 2003; McCain et al. 2005).

Common Prey Species—English sole preys upon polychaetes, amphipods, mollusks, cumaceans, ophiuroids, and crustaceans (Pearson and Owen 1992; Pearson et al. 2001).

1.4.3.1.6 Flathead Sole (Hippoglossoides elassodon)

Distribution—Flathead sole range from Okhotsk Sea off southwestern Kamchatka and northern Kuril Islands to Gulf of Anadyr, Bearing Sea and Commander-Aleutian chain to Monterey, central California (Miller and Lea 1972; Eschmeyer et al. 1983; Allen and Smith 1988).

Habitat Preference—Flathead sole are mesobenthic inhabiting soft (Eschmeyer et al. 1983), silty or muddy bottoms (Kramer et al. 1995) or mud mixed with gravel or sand (Holladay and Norcross) on the continental shelf in waters from the intertidal zone to as deep as 1,050 meters, but usually at depths less than 366 meters (Allen and Smith 1988). Adult and juveniles are at or near the bottom, whereas eggs and larvae are pelagic (Casillas et al. 1998). Flathead sole are found at water temperatures ranging from 0° to 12°C: adults – 2° to 4°C; juveniles – 5.5° to 10.6°C; and larvae – 6° to 7°C (Paul et al. 1995; Love 1996). This species occurs at the following salinities: adults – 27 to 34 psu, juveniles – 25.0 to 39.6 psu, larvae – 17 to 18 psu, and eggs – 25 to 27 psu (McCain et al. 2005).

Life History—Flathead sole migrate from their wintering grounds on the upper continental slope onto the shelf during the spring and summer where they utilize shallow (< 100 meters) estuaries, bays, and nearshore areas as nurseries (Holladay and Norcross; McCain 2003). Larvae exhibit diel vertical movements including nocturnal ascent, descent, and diffusion (McCain 2003). Flathead sole are oviparous and iteroparous, spawning from February to July peaking around April to May, at temperatures ranging from 6° to 8°C and at depths of 73 to 128 meters (Love 1996; Matarese et al. 2003; McCain et al. 2005).

Common Prey Species—Flathead sole prey upon mysids, fish (primarily Pacific herring), shrimp, polychaetes, and clams (McCain et al. 2005).

1.4.3.1.7 Petrale Sole (Eopsetta jordani)

Distribution—Petrale sole range from Aleutian Islands west as far as Unalaska Island and Gulf of Alaska to Islas Coronados, northern Baja California (Mecklenburg et al. 2002). This species is considered rare north and west of southeast Alaska and in the inside waters of British Columbia (Hart 1973; Garrison and Miller 1982; Love et al. 2005).

Habitat Preference—Petrale sole is common on the outer shelf (100 to 150 meters) over sand, sandy mud, and occasionally muddy substrates (Starr et al. 1998; McCain 2003) and is an important predator on the continental shelf from British Columbia to central California (McCain et al. 2005). Adults are at or near the bottom occurring from the surf line to 550 meters depth, with the highest abundance in waters less than 300 meters deep (Garrison and Miller 1982; McCain 2003). Juveniles are also at or near the bottom (Garrison and Miller 1982) with young juveniles distributed between 18 and 82 meters and larger juveniles 25 to 145 meters (McCain et al. 2005). Larvae are neritic and surface; whereas eggs are pelagic, both often occurring in the upper 50 meters of the water column far offshore (Hart 1973). Larvae have been reported up to 150 kilometers offshore, but off Oregon most are found from 83 to 120 kilometers (Allen and Smith 1988). Petrale sole are found at water temperatures ranging from 4° to 15°C: eggs – 4° to 4° to 10°C (Garrison and Miller 1982) and live in polyhaline to euhaline waters: eggs – 25 to 30 psu (McCain et al. 2005).

Life History—Petrale sole migrate seasonally between deep, winter spawning areas to shallow, summer feeding grounds in water 48 to 128 meters deep (Garrison and Miller 1982). Few north-south movements along the coast have been observed with a maximum distance of 628 kilometers (Hart 1973). Petrale sole
also move into deeper water as they age and increase in size (McCain 2003). Adults may utilize summer feeding grounds in estuaries, while non-migrating subadults overwinter in estuaries (Casillas et al. 1998). Juveniles of offshore stocks often mature within estuaries. Larvae and eggs are transported from offshore spawning locations to nearshore nursery areas by oceanic currents and wind (McCain et al. 2005). Petrale sole are oviparous with external fertilization and a broadcast spawner (Casillas et al. 1998). Spawning occurs from December to April, peaking in February through March along the continental shelf/slope to depths of 550 meters (Garrison and Miller 1982). Nine separate breeding stocks have been identified with all stocks intermingling on summer feeding grounds (Hart 1973). Six of these breeding stocks spawn along the Pacific Northwest coast: two off California – Point Delgada and Cape Mendocino; two off Oregon, and two off Washington (Garrison and Miller 1982).

**Common Prey Species**—Petrale sole prey upon shrimp and other decapod crustaceans, as well as euphausiids, pelagic fishes (herring, anchovies, hake, rockfish, and sand lance), ophiuroids, and juvenile petrale sole (Hart 1973; Thomas 1992, 2001).

1.4.3.1.8 Rex Sole (*Glyptocephalus zacharis*)

**Distribution**—Rex sole range from northern Kuril Islands to Commander Islands in the western Bering Sea to Naravin Canyon in the Aleutian Islands, eastern Bering Sea, and Gulf of Alaska to Cedros Island, central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996; Love et al. 2005). This species is the most widely distributed sole on the continental shelf and upper slope off Oregon (McCain 2003). It also occurs in Puget Sound (McCain et al. 2005).

**Habitat Preference**—Rex sole is a cold-temperate, middle shelf-mesobenthal species that prefers sandy, muddy, and gravelly bottoms and complexes of mud and boulders at depths of 0 to 1,145 meters (Kramer et al. 1995). Greatest abundance is at depths from 50 to 450 meters (Eschmeyer et al. 1983; Allen and Smith 1988; Love 1996; NMFS et al. 1998). Adults and juveniles are benthic (Stull and Tang 1996) with adults most abundant at 55 to 150 meters and juveniles at 150 to 200 meters (McCain et al. 2005). Juveniles settle to bottom habitats mainly on the outer continental shelf during the winter and may utilize the outer continental shelf-upper slope region for nursery areas (McCain 2003). Larvae and eggs are pelagic (Stull and Tang 1996). Larvae are widely distributed offshore being most abundant from 46 to 211 kilometers (McCain et al. 2005). Eggs occur in nearshore and offshore waters (Casillas et al. 1998).

**Life History**—Rex sole move inshore in the summer and make offshore spawning movements in the winter (Love 1996). They also undergo ontogenetic migrations from the shelf to the upper slope habitat (McCain 2003). Spawning time of the rex sole is variable, often occurring throughout the year (Starr et al. 1998). Rex sole spawn at depths between 100 to 300 meters on softbottoms off northern Oregon from January through June peaking from March through April (Matarese et al. 2003; McCain et al. 2005). Spawning coincides with the months of peak average surface and subsurface sea temperatures (Castillo 1995). This species also spawns during the summer off Eureka, California (Quirollo 1992; Quirollo and Dewees 2001).

**Common Prey Species**—Rex sole prey upon benthic invertebrates (amphipods and polychaetes) as well as euphausiids, cumaceans, and salps (*Oikopleura*; Quirollo 1992; Quirollo and Dewees 2001). In Puget Sound, they prey primarily upon *Capitella* spp. (polychaete; McCain et al. 2005).

1.4.3.1.9 Rock Sole (*Lepidopsetta polyxystra* and *L. bilineata*)

**Distribution**—Two of the currently recognized species of rock sole occurs along the Pacific Coast: northern species (*Lepidopsetta polyxystra*) ranges from the northern coast of Hokkaido, Kuril Islands, and Okhotsk Sea to Gulf of Anadyr and vicinity of St. Lawrence Island, Bearing Sea, and Commander-Aleutian chain to Puget Sound, Washington and southern species (*L. bilineata*) from Atka Island, Aleutian Islands and southeastern Bering Sea (Slime Bank north of Unimak Island) to Cortes Bank, southern California (Orr and Matarese 2000; Love et al. 2005).
**Habitat Preference**—Both species prefer sandy or gravel substrata on the coast of the contiguous U.S and steep rock slopes in Puget Sound (Hart 1973; Garrison and Miller 1982; Horton 1989). Northern rock sole occurs at depths from three to five meters to 480 to 517 m; whereas the southern rock sole ranges from 13 to 339 meters (Orr and Matarese 2000). Adults and juveniles are at or near the bottom primarily in shallow water bays (for example in Puget Sound above 55 meters) and over the continental shelf from the intertidal zone to as deep as 732 meters, but generally not below 300 meters (Hart 1973; Garrison and Miller 1982; Horton 1989). Larvae are pelagic and are found in the upper 30 meters of the water column, but sometimes at depths down to 1,000 meters (Hart 1973; Horton 1989; Orr and Matarese 2000). Eggs are at or near the bottom and adhesive (Horton 1989). Rock sole are found at water temperatures from sub-zero to 18°C: adults – 7° to 10°C, larvae – 6°C, and eggs – minus 0° to 15°C (Garrison and Miller 1982; Horton 1989; Love 1996). Adults inhabit almost exclusively in euhaline waters; whereas juveniles, larvae, and eggs live in polyhaline to euhaline waters (Garrison and Miller 1982; Horton 1989).

**Life History**—Rock sole is sedentary (Horton 1989) and undergoes seasonal migrations to overwinter and spawn (deep waters: 125 to 275 meters, edge of continental slope) and post-spawning, move the summer to feed (shallow shelf waters: 18 to 80 meters) (Hart 1973; Horton 1989). Immature rock soles reside in shallow waters in the winter and move to shallower coastal areas in the spring and summer (Orr and Matarese 2000). As rock sole increase in size, they move into deeper waters (Horton 1989). Rock sole larvae exhibit vertical migrations of 5 to 10 meters during the day and up to 30 meters at night in response to peak copepod nauplii abundances. Horizontal movement of larvae is facilitated by wind and tidal currents (McCain 2003). Rock sole are oviparous with external fertilization spawning over a variety of substrates from rocky banks to sand and mud at depths less than 300 meters (Horton 1989). Spawning occurs from winter through early spring depending on stock location, including December to April with a peak in March in Puget Sound, and from February to April in California (Hart 1973; Garrison and Miller 1982; Horton 1989; Orr and Matarese 2000; Matarese et al. 2003).

**Common Prey Species**—Rock sole prey upon sedentary foods such as polychaetes, echiuroids, mollusks, echinoderms, benthic fishes, and urochordates (McCain et al. 2005).

### 1.4.3.1.10 Sand Sole (*Psettichthys melanostictus*)

**Distribution**—Sand sole range from southeastern Bering Sea and Aleutian Islands from Unalaska Island to Port Heiden and Gulf of Alaska to Balboa Pier, Newport Beach, southern California (Garrison and Miller 1982; Mecklenburg et al. 2002; Love et al. 2005).

**Habitat Preference**—Sand sole are considered an inner shelf-outer shelf species occurring from intertidal zone to 325 meters, but are in greatest abundance at depths less than 150 meters (Hart 1973; Allen and Smith 1988; McCain et al. 2005). Adult and older juveniles are at or near the bottom (Casillas et al. 1998) occurring at depths of 183 meters (Kramer et al. 1995). Small juveniles, larvae, and eggs are pelagic (McCain 2003). Small juveniles occur in 5 to 20 meters of water in Puget Sound (Garrison and Miller 1982); whereas larvae are generally found in the upper 10 meters of the water column and in waters less than 200 meters in depth (Garrison and Miller 1982). Eggs generally occur mainly over the shelf (Casillas et al. 1998). In shallow waters along the Pacific Coast, sand sole prefer sandy/muddy substrates (Hart 1973). Adults, juveniles, and larvae are found year-round in some estuaries, while spawning adults, larvae and eggs occur in winter-spring in Puget Sound, Bellingham Bay, and East Sound (Hart 1973). Sand sole are found at water temperatures from sub-zero to 16°C: adults – minus 0° to 16°C and larvae/eggs – 4° to 12°C (Garrison and Miller 1982; Horton 1989). All life stages are found in euhaline waters (McCain et al. 2005).

**Life History**—Sand sole make limited migrations into shallow nearshore waters in early winter to spawn and then move south and offshore in the summer to feed (Casillas et al. 1998). Adults and demersal juveniles tend to move to deeper waters as they age and increase in size (Garrison and Miller 1982), whereas small juveniles and larvae are transported to estuaries and shallow nearshore bays by tidal currents (McCain 2003). Sand sole are oviparous with external fertilization. Spawning occurs in winter...
and spring (Hart 1973) over sandy and muddy substrates in water 20 to 30 meters deep (Garrison and Miller 1982). In Puget Sound and Bellingham Bay, the spawning season is January through April, peaking in February and March respectively (Hart 1973; Matarese et al. 2003).

**Common Prey Species**—Sand sole prey mainly on speckled sanddabs (*Citharichthys stigmatu*s), herring, anchovies, crustaceans, mollusks, and worms (Hart 1973; Barry et al. 1996).

### 1.4.3.1.11 Starry Flounder (*Platichthys stellatus*)

**Distribution**—Starry flounder have a very broad geographic distribution around the rim of the north Pacific ocean (Orcutt 1950) ranging from Sea of Japan off Korean Peninsula and Japan to Sea of Okhotsk to Arctic Ocean in East Siberian Sea, Chukchi Sea, Beaufort Sea, and Canada to Bathurst Inlet, Northwest Territories (Mecklenburg et al. 2002). In the northeastern Pacific, they occur from the western Bering Sea and Commander-Aleutian chain to Los Angeles Harbor, southern California. This species is common in the Puget Sound region (Hart 1973; Garrison and Miller 1982; Kramer et al. 1995; McCain et al. 2005).

**Habitat Preference**—Starry flounder is an important member of the inner continental shelf and shallow sublittoral communities (McCain et al. 2005) ranging from the intertidal zone to depths of about 600 meters (Kramer et al. 1995). Adults and juveniles are at or near the bottom (Garrison and Miller 1982). Adults prefer sandy to coarse substrate including gravel, whereas juveniles are found on sandy to muddy substrate (Cailliet et al. 2000). Adults along with older juveniles are found from 120 kilometers in the upper reaches of streams to the outer continental shelf at 375 m. Most adults occur in ocean waters less than 150 meters (McCain et al. 2005). Adults also occur in estuaries or their freshwater sources year-round in Puget Sound (Garrison and Miller 1982). Juveniles are found in estuaries and the lower reaches of major coastal rivers (Columbia River) (Orcutt 1950; Hart 1973). Larvae and eggs are surface (Garrison and Miller 1982). Larvae are found primarily inshore (within 37 kilometers) and in estuaries (McCain 2003). Eggs occur at or near the surface over water 20 to 70 meters deep (Hart 1973; Garrison and Miller 1982). All lifestages typically occur in water temperatures ranging from 0.0° to 21.5°C (Emmett et al. 1991). Adults and larvae are found in euhaline to freshwater, juveniles in mesohaline to freshwater, and eggs polyhaline to euhaline waters (Hart 1973; Garrison and Miller 1982; Simenstad 1983).

**Life History**—Starry flounder do not migrate extensively (Emmett et al. 1991). They move inshore in late winter-early spring to spawn and offshore to deeper waters in the summer and fall, but these coastal movements are generally less than five kilometers (McCain 2003). Adults and juveniles have been reported to move great distances up major coastal rivers without following any migratory trend. Larvae may be transported long distances by oceanic currents (McCain et al. 2005). Starry flounder are gonochoristic, oviparous, and iteroparous with external fertilization (Orcutt 1950). Spawning occurs annually in a short time during winter and spring, with the exact timing depending on location. In California, spawning occurs from November to February and peaks in December. In Puget Sound it extends from February to April and peaks in March (Orcutt 1950; Hart 1973; Garrison and Miller 1982). Most spawning occurs in estuaries or sheltered inshore bays in water less than 45 meters at water temperatures of 11°C (Orcutt 1950; Emmett et al. 1991).

**Common Prey Species**—Starry flounder prey upon amphipods, isopods, decapods, polychaetes, bivalves, echinoderms, and occasionally fish (northern anchovy) (Orcutt 1950; Haugen 1992; Barry et al. 1996; Haugen and Thomas 2001).

### 1.4.3.1.12 Pacific Sanddab (*Citharichthys sordidus*)

**Distribution**—Pacific sanddab range from Cabo San Lucas, southern Baja California to Holiday Beach, Kodiak Island, western Gulf of Alaska (Garrison and Miller 1982; Mecklenburg et al. 2002; Love et al. 2005). This species is most abundant along north-central California from Eureka to San Francisco (Rackowski and Pikitch 1989).
Habitat Preference—Pacific sanddab inhabit the inner continental shelf along the western U.S. coast and the shallow sublittoral zone of Puget Sound (Hart 1973; McCain 2003). Adults and juveniles are at or near the bottom (Garrison and Miller 1982). Adults inhabit estuaries and coastal waters from the intertidal zone to about 549 meters with highest abundance occurring in waters less than 150 meters over sand and coarser sediments, low-relief rock bottoms, and occasionally mud (Miller and Lea 1972; Hart 1973; Love 1996). In Puget Sound, adults may be found down to 150 meters, but are common in less than 20 meters of water (Garrison and Miller 1982). Off Oregon and Washington, sanddab are most abundant between 37 and 90 meters (McCain 2003). Juveniles are primarily found in shallow coastal waters, bays, and estuaries over substrates of silty sand (Hart 1973; McCain 2003). Larvae and eggs are pelagic (Garrison and Miller 1982). Larvae may occur as far offshore as 724 kilometers in the upper 200 meters of the water column (McCain et al. 2005). Eggs are distributed mainly over the continental shelf (Casillas et al. 1998). Older fish occur in shallower water and nearer to shore than younger fish at higher latitudes (Rackowski and Pikitch 1989). Adults are found in high salinity areas correlated with upwellings (Sakuma and Ralston 1995), whereas larvae occur offshore in areas of low salinity (McCain et al. 2005). Eggs are distributed in polyhaline waters at temperatures between 4° to 12°C (Garrison and Miller 1982).

Life History—Pacific sanddab undergo limited migrations and coastal movements are minimal (McCain et al. 2005). Adults are influenced by prey availability, seasonal temperature fluctuations, and substrate type (Rackowski and Pikitch 1989). Larvae are transported by wind and ocean currents (Casillas et al. 1998). Recent reported evidence has suggested that postflexion sanddab larvae make diurnal vertical migrations through the pycnocline with highest catches occurring at night (McCain 2003). Sanddab are oviparous and iteroparous with eggs fertilized externally (Hart 1973). Spawning occurs from late winter through summer depending on stock and location. In California spawning occurs from July through September and peaks in August. In Puget Sound, it extends from February through spring, peaking in March and April (Hart 1973; Garrison and Miller 1982). Adults spawn near the bottom in bays and the open ocean at low temperatures (Rackowski and Pikitch 1989). Female sanddab may spawn twice per season (Hart 1973; Starr et al. 1998).


1.4.3.2 Rockfish

Rockfish on the Pacific Coast typically inhabit the continental shelf and upper slope regions. As adults, rockfish inhabit rocky reef habitats, slopes, pinnacles, pilings, or submerged debris and typically remain within 30-50 meters of their preferred habitat (Matthews 1990). Rockfish are long-lived and sexual maturity is attained between 5 and 20 years of age. Spawning for most species generally takes place in the early spring or late fall. Once hatched in late winter through mid-summer, the juvenile larvae form part of the pelagic community for up to three years and use nearshore habitats. Due to their long lives and late maturity, rockfish are susceptible to over harvest.

Rockfish known to occur in the NWTRC are described below. The arrangement is alphabetical by common name for the 46 species of rockfish (Sebastes), followed alphabetically by common name for the two species of thornyheads (Sebastolobus).

1.4.3.2.1 Aurora Rockfish (Sebastes aurora)

Distribution—Aurora rockfish range from west of Langara Island, British Columbia to Isla Cedros, central Baja California (Love et al. 2002) and are common from northern Oregon to at least San Diego, southern California (Love et al. 2002).

Habitat Preference—Aurora rockfish is a deepwater slope species that occupies upper slope habitat (Eschmeyer et al. 1983) ranging in depth from 81 to 893 meters (Lauth 2000), with the majority occurring from 300 to 500 meters (Allen and Smith 1988; Orr et al. 2000). Adults and juveniles are found in soft
and hardbottom habitats on the continental slope/basin (NMFS et al.1998; Love et al. 2002). Larvae are pelagic and range in distance 110 to 170 kilometers from shore (NMFS et al. 1998).

**Life History**—Information is lacking on the migrations and movements of the aurora rockfish (McCain et al. 2005). Aurora rockfish reproduce from March to May peaking in April off northern and central California and in May off Oregon (Love et al. 2002; McCain 2003). Young are released during late winter through late spring (Casillas et al. 1998).

**Common Prey Species**—Information is unavailable on the prey of the aurora rockfish (McCain et al. 2005).

### 1.4.3.2.2 Bank Rockfish (Sebastes rufus)

**Distribution**—Bank rockfish range from Queen Charlotte, British Columbia, to central Baja California and Isla Guadalupe, but are most common from Fort Bragg, California southward to at least southern California (Love 1992; Starr et al. 1998; Love et al. 2002; Love et al. 2005).

**Habitat Preference**—Bank rockfish occur offshore (Eschmeyer et al. 1983) at depths from 31 to 454 meters (Love et al. 2002; Love et al. 2005), with adults preferring depths in excess of 210 meters over muddy or sandy bottoms (Miller and Lea 1972; Love et al. 1990). Adults are also found on rocky reefs, among boulder fields, cobble, mixed mud-rock bottoms, non-rocky shelf, canyons, and along the continental slope/basin (NMFS et al. 1998; Love and Waters 2001). Juveniles move between midwater pelagic and benthic areas with the latter forms probably occupying the shallower parts of the adult range where mixed rock and mud habitats prevail (NMFS et al. 1998). The pelagic forms occur over a wide range depth from 25 to 80 meters (Lenarz et al. 1991).

**Life History**—Information is unavailable on the migrations and movements of the bank rockfish (McCain et al. 2005). Bank rockfish are usually solitary or form aggregations at midwater depths over hardbottoms, over high-relief or on bank edges, and along the ledges of canyons (Love et al. 1990; Love et al. 2002). Spawning occurs from December to May off northern California peaking in February, and from January to April off Oregon (Love et al. 1990; Love et al. 2002). Off California, this species is a multiple brooder (Love et al. 1990). Note: some species of fish brood; brooding is a reproductive strategy that employs parental care of offspring to provide a greater chance of survival and can be employed multiple times during the breeding season with multiple sets of offspring.

**Common Prey Species**—Bank rockfish prey upon gelatinous planktonic organisms (that is, tunicates), as well as small fishes and krill (Love 1992).

### 1.4.3.2.3 Black Rockfish (Sebastes melanops)

**Distribution**—Black rockfish range from northern Baja California to the Aleutian Islands and the southern Bering Sea, but are most common from San Francisco northward to southeast Alaska (Phillips 1957; Miller and Lea 1972; Hart 1973; Stein and Hassler 1989; Kramer and O’Connell 1995; Mecklenburg et al. 2002). Black rockfish also occur in the Strait of Juan de Fuca (McCain et al. 2005).

**Habitat Preference**—Black rockfish are found at depths ranging from the surface to 366 meters but are most common at depths less than 55 meters (Stein and Hassler 1989; Love et al. 2002). Off Oregon, they are most common in waters ranging from 12 to 90 meters (ODFW 2002). Adults are semi-pelagic, inhabiting the midwater and surface areas over high-relief rocky reefs as well as in and around kelp beds, boulder fields, pinnacles, and artificial reefs (Bodkin 1988; Love 1996; Starr 1998). Larger benthic juveniles, up to 15 centimeters, may live in rocky holes (Casillas et al. 1998). Young-of-the-year are known to recruit to shallow nearshore waters after spending up to five months as pelagic larvae and juveniles in offshore waters (NMFS 2004d). Settlement into nearshore habitats depends on size and location – pelagic, offshore when less than 40 to 50 millimeter (mm) standard length (SL) in the summer; nearshore, on the bottom on sand-rock interface, high-relief rock, or kelp canopy at 40 to 70 mm SL in June, and in estuaries, bays, and tidepools when 35 to 92 mm SL from April to October, often in eelgrass.
Larvae are pelagic and have been collected as far as 266 kilometers offshore of the Oregon coast (Love et al. 2002). In shallow water, black rockfish abundances decline in the winter and increase in summer (Stein and Hassler 1989). Densities also decrease with depth during both upwelling and non-upwelling seasons (McCain et al. 2005).

**Life History**—Off northern Washington and in the outer Strait of Juan de Fuca, black rockfish exhibits no significant movement. However, they appear to move from the central Washington coast southward to the Columbia River, but not into Oregon offshore waters. From northern Oregon coast, black rockfish move northward to the Columbia River (Culver 1987). Black rockfish form mixed-aged and mixed-species, midwater schools near the bottom around kelp forests and high- and low-relief rocky terrain, along steep, dropoffs, and in high-current areas (Hart 1973; Stein and Hassler 1989). In the summer, schools of this species are seen feeding at the surface along the kelp-lined shores of the western Strait of Juan de Fuca (McCain et al. 2005). In kelp beds, larger adult black rockfish migrate outside the kelp diurnally, returning before dusk. Juveniles and small adults remain in the kelp beds closer to the bottom at night (Stein and Hassler 1989). Black rockfish usually remain in one area (Stein and Hassler 1989).

Black rockfish have internal fertilization and annual mating (Stein and Hassler 1989). Specific mating sites are unknown, but mating may occur in offshore waters (Hart 1973; Stein and Hassler 1989). Parturition occurs from January to May off California, January to March off Oregon, and February to April off British Columbia (Stein and Hassler 1989; Houk 1992a).

**Common Prey Species**—Black rockfish prey upon invertebrates such as crustaceans, polychaetes, cephalopods, various planktonic worms (chaetognaths), and jellyfish, as well as small fish, krill, and other small crustaceans during upwelling periods (Houk 1992a; Love 1996; Reilly 2001; McCain 2003).

### 1.4.3.2.4 Black-and-Yellow Rockfish (*Sebastes chrysomelas*)

**Distribution**—Black-and-yellow rockfish range from Cape Blanco, Oregon to Isla Natividad, central Baja California but are common from Sonoma County, California to near Point Conception, California (Love 1996; Love et al. 2002).

**Habitat Preference**—Black-and-yellow rockfish are considered a kelp-forest or inshore species that occur from the intertidal zone down to depths of 37 meters (Miller and Lea 1972). They are common in waters less than 18 meters (Love 1996) within kelp beds or high-relief rocky areas (Miller and Lea 1972; ODFW 2002). Adults and older juveniles are found at or near the bottom (Casillas et al. 1998) with adults spending most of their time sheltering in cracks and crevices within the rocky substratum or perching on the bottom in the open (Cailliet et al. 2000). Young juveniles and larvae are pelagic with young juveniles living in the surface kelp canopy and near drift algae (Casillas et al. 1998). Larvae initially settle out of the water column into the surface and mid-depth portions of the kelp canopies. As they mature into juveniles, they migrate down the kelp stipes to the bottom substrate in sandy areas near low-relief rock formations (Love et al. 2002).

**Life History**—Black-and-yellow rockfish are largely territorial, sedentary residents with home ranges up to 10 to 12 m² (Love et al. 2002). If artificially or naturally displaced up to one kilometer from their home site, they have the ability to navigate back to their nest (Casillas et al. 1998). Mating in the black-and-yellow rockfish occurs from late January to early February while parturition occurs from March to May (Casillas et al. 1998).

**Common Prey Species**—Black-and-yellow rockfish prey upon crustaceans such as shrimp, crabs, and isopods, mollusks, and other juvenile rockfishes (Love 1996; Lea et al. 1999; ODFW 2002).

### 1.4.3.2.5 Blackgill Rockfish (*Sebastes melanostomus*)

**Distribution**—Blackgill rockfish range from Queen Charlotte Islands, British Columbia to Punta Abreojos, southern Baja California (Love 1996; Love et al. 2002; Love et al. 2005). They are most abundant in waters off central and southern California (NMFS-NWR 2004c).
**Habitat Preference**—Blackgill rockfish occupy both midwater and benthic habitats where they are commonly found nine meters above the bottom (Love et al. 1990; Love 1996). They inhabit rocky or hard-bottom habitats along steep drop-offs, such as edges of submarine canyons and over seamounts, at depths ranging from 230 to 550 meters (Eschmeyer et al. 1983; Orr et al. 1998, 2000). Adults live offshore on deep high-relief rock outcrops in areas with extensive caves and crevices from 88 to 768 meters (Eschmeyer et al. 1983; Orr et al. 2000). Large juveniles are often found in waters deeper than 180 meters (Love 1996). Small pelagic juveniles are carried shoreward at a depth of about 200 meters, where they are commonly associated with flat rather than rocky bottoms (Love and Butler 2001). Larvae inhabit the upper mixed layer of the water column, from about 5 to 220 kilometers from shore and are seldom found below 100 meters depth. They transform to pelagic juveniles (at lengths near 16 mm) in midwater over coastal basins (McCain et al. 2005).

**Life History**—Blackgill rockfish are an aggregating species often associated with bank rockfish (Love 1996). Blackgill rockfish produce one brood per year, reproducing off central and northern California from January to June and off Oregon in April (Love et al. 1990; Love 1996; Love et al. 2002).

**Common Prey Species**—Blackgill rockfish prey upon krill, pelagic tunicates, cephalopods and juvenile rockfish, hake, anchovy, and lanternfish (Love et al. 1990).

1.4.3.2.6 Blue Rockfish (*Sebastes mystinus*)

**Distribution**—Blue rockfish range from Punta San Tomás, northern Baja California to Chatham Strait and Kruzof Island, southeastern Alaska (Miller and Lea 1972; Love et al. 2002; Love et al. 2005). They are most abundant from Eureka, California to the northern Channel Islands, California (NMFS-NWR 2004c).

**Habitat Preference**—Blue rockfish occur in depth from tidepools to 549 meters (Orr et al. 2000) but are usually found over rocky substrates at depths of 25 to 90 meters (Houk 1992b; Love et al. 2002). Adults, subadults, and older juveniles are found at or near the bottom (McCain 2003). Adults inhabit the midwater and surface areas around high-relief rocky reefs (30 to 91 meters), within and around the kelp canopy, and around artificial reefs (Feder et al. 1974; Allen 1985; Bodkin 1988; Love 1996; Starr 1998). Juveniles often appear in massive schools in the kelp canopy and shallow rocky areas by April or May (Feder et al. 1974; Bodkin 1988; Carr 1991; Houk 1992b; Love 1996). Early-stage juveniles and larvae are pelagic (McCain 2003). In the spring, small juveniles remain pelagic for three to five months until they recruit to the kelp canopy, shallow rocky areas, and the nearshore sand-rock interface (Casillas et al. 1998). Larvae live for several months in surface waters (McCain et al. 2005).

**Life History**—Blue rockfish are not considered a migratory species (Lea et al. 1999), and movements that do occur are most likely related to changes in water temperature or water turbulence (Casillas et al. 1998). Diel movements have been noted, with fish moving slightly off the bottom during the day to feed (Casillas et al. 1998). North of Point Conception, blue rockfish will school with olive and black rockfish (ODFW 2002). Early life history stages are generally found in shallower waters than adults, indicating movement towards deeper water with age (McCain et al. 2005).

Blue rockfish are ovoviviparous (McCain 2003). In southern California, the blue rockfish begins mating in November and continues through early spring producing young twice in a breeding season (Casillas et al. 1998).

**Common Prey Species**—Blue rockfish prey upon algae, pelagic tunicates, hydroids, jellyfishes, salps, crustaceans, and larval and juvenile fishes (Hart 1973; MacGregor 1983).

1.4.3.2.7 Bocaccio (*Sebastes paucispinis*)

**Distribution**—Bocaccio ranges from the western Gulf of Alaska south of Shumagin Islands and Alaska Peninsula to Punta Blanca, central Baja California (Miller and Lea 1972; Love et al. 2005), with greatest
abundance between Oregon and northern Baja California (Love et al. 2002). This species is rare in Puget Sound (Love et al. 2002).

**Habitat Preference**—Bocaccio is a middle shelf-mesobenthal species (Allen and Smith 1988) that is most abundant at depths ranging from 50 to 300 meters (Orr et al. 2000). Adults and large juveniles transition between midwater pelagic and benthic habitats over shelf and slope (Garrison and Miller 1982) in association with kelp beds, eelgrass beds, rocky substrate, and artificial structures such as piers and oil platforms at depths of 20 to 475 meters (MBC 1987; Love et al. 1990; Sakuma and Ralston 1995; Yoklavich et al. 2000; Love et al. 2005). Adults exhibit two primary habitat preferences: semi-pelagic forming loose schools above rocky areas and solitary benthic non-schooling individuals found around vertical relief, over sand-mud bottoms with little relief, and in areas with mixtures of rocks and boulders, rock ridges, and rocks and boulders among mud (Yoklavich et al. 2000). Juveniles frequently settle over the above habitats as well as rocky areas associated with algae or on to sandy areas with eelgrass or drift algae (Love et al. 2002). Small juveniles and larvae are pelagic occurring in the upper 100 meters of the water column, as far as 480 kilometers from shore (MBC 1987). Small juveniles are most abundant from the surface to depths of 18 meters (Feder et al. 1974). Young-of-the-year is found in shallow coastal waters over rocky bottoms, associated with algae (Sakuma and Ralston 1995). All life stages are found in water temperatures from 6° to 15°C and salinities from 31 to 34 psu (MBC 1987).

**Life History**—Bocaccio undergo limited movements (McCain et al. 2005). Adults undergo small vertical movements above rock habitats (Starr et al. 2002), move more than two kilometers per day in pursuit of food, and disappear from traditional commercial fishing grounds during winter spawning and reappear in the spring (MBC 1987). Young-of-the-year recruit into shallow water during their first year (Hart 1973), then move into deeper water with an increase in size and age (Garrison and Miller 1982). Bocaccio school with widow, yellowtail, vermillion, and speckled rockfishes (Love et al. 2002) and occur in large aggregations under drifting kelp beds and over firm sand-mud bottoms (MBC 1987). Bocaccio are ovoviviparous (Hart 1973; Garrison and Miller 1982) with a spawning season that lasts more than 10 months (Love et al. 1990). Parturition occurs off northern and central California from November to March (MBC 1987) with the production of two or more broods (Hart 1973; Love et al. 1990) and off British Columbia and Washington from January to April (MBC 1987).

**Common Prey Species**—Bocaccio prey upon small fish, including other species of rockfish, hake, sablefish, northern anchovy, and lanternfish associated with kelp and squid (Sumida and Moser 1984; MBC 1987; Thomas and MacCall 2001).

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**1.4.3.2.8 Bronzespotted Rockfish (Sebastes gilli)**

**Distribution**—Bronzespotted rockfish range from Punta Colnett, northern Baja California to Eureka, California (Love et al. 2002; Love et al. 2005).

**Habitat Preference**—Bronzespotted rockfish are relatively common in deeper waters (200 to 290 meters) off central and southern California (Miller and Lea 1972). Adults have been collected at depths of 75 to 413 meters in high-relief rocky outcrops (Love et al. 2002). Young-of-the-year have been reported from a boulder field at 252 meters (Love et al. 2002).

**Life History**—Information is unavailable on the migrations, movements, and reproduction of the bronzespotted rockfish (McCain et al. 2005).

**Common Prey Species**—Information is unavailable on the prey of the bronzespotted rockfish (McCain et al. 2005).

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**1.4.3.2.9 Brown Rockfish (Sebastes auriculatus)**

**Distribution**—Brown rockfish range from Bahia San Hipolito, central Baja California to Prince William Sound in the northern Gulf of Alaska (Miller and Lea 1972; Eschmeyer et al. 1983; Stein and Hassler
1989; Love et al. 2002; Love et al. 2005). They are most common in the south and central Puget Sound, and from central California to southern California (Love et al. 2002).

**Habitat Preference**—Brown rockfish inhabit low-profile hardbottom substrates (Lea et al. 1999) from the surf zone to 146 meters (Eschmeyer et al. 1983; Love et al. 2005). They are bottom dwellers, most common in waters less than 53 meters (Miller and Lea 1972; Love 1996; Love et al. 2002) aggregating in eelgrass beds, near oil platforms and sewer pipes, old tires, and around the sand-rock interfaces and rocky bottoms of artificial and natural reefs (Miller and Lea 1972; Stein and Hassler 1989; Love 1996; Love et al. 1996). Adults are common at or near the bottom and occupy high-relief portions of the above habitats (Casillas et al. 1998). Juveniles are pelagic over a wide range of depths (50 to 90 meters) usually in shallower water than adults (Lenarz et al. 1991; Love 1996). After a three-month pelagic stage, young-of-the-year recruit to hard substrate, low-relief (< 1 meter) reefs, patches of drift algae on the bottom, and walls of submarine canyons off California (Love et al. 2002; NMFS-NWR 2004c). Within the Main Basin in Puget Sound, brown rockfish occur on natural reefs, rock piles, and artificial reefs in water less than 30 meters deep (Miller and Borton 1980). Brown rockfish have a relatively broad range of seasonal temperature variations (10° to 17°C) and a broad salinity tolerance (Stein and Hassler 1989).

**Life History**—Movements greater than three kilometers are rare for brown rockfish (McCain 2003). This species has a strong homing tendency, maintaining small home ranges on artificial reefs (for example, 30 m² within Puget Sound) and large home ranges from 400 m² to 1,500 m² on low-relief reefs (Love 1996). Subadults migrate from bays to outer coastal waters (50 kilometers) (Love et al. 2002). Juveniles utilize estuaries as nursery grounds (Stein and Hassler 1989) gradually moving into deeper water during the winter as they mature (Love 1996; Palsson 1998). This species may be solitary (ODFW 2002) or live in small aggregations with vermilion, copper, and canary rockfish on deeper rock outcrops or occur with the quillback in Puget Sound (Love et al. 2002). Brown rockfish are ovoviviparous (Ashcraft and Heisdorf 2001). In Puget Sound, brown rockfish mate once per year in March and April giving birth in June (Hart 1973; Stein and Hassler 1989). Off Oregon, spawning occurs in May and June (Love 1996) and off central and northern California from December to January and May to June, respectively where mating takes place more than once per season (Love 1996; NMFS-NWR 2004c).

**Common Prey Species**—Brown rockfish prey upon larger fish, shrimp, isopods, polychaetes, crabs and other crustaceans (Carlisle et al. 1964; Quast 1968b; Feder et al. 1974; Stein and Hassler 1989; Love 1996).

### 1.4.3.2.10 Canary Rockfish (Sebastes pinniger)


**Habitat Preference**—Canary rockfish are a middle shelf-mesobenthal species (Allen and Smith 1988) that occurs from 18 to 838 meters (Hart 1973; Love 1996; Mecklenburg et al. 2002) but primarily inhabiting waters 50 to 250 meters deep (Orr et al. 2000). Canary rockfish inhabit deep water as adults (McCain 2003). Adults have two primary habitat preferences – loose semi-pelagic schools above rocky pinnacles and sharp drop-offs and non-schooling, solitary benthic individuals often associating with yellowtail, widow, bocaccio, vermilion, and silvergray rockfish (Boehlert and Kappenman 1980; Love 1996; Love et al. 2002). Off Heceta Bank, Oregon, canary rockfish are commonly found in boulder and cobble fields in association with rosethorn, sharpchin, yelloweye, and pygmy rockfish (McCain et al. 2005). Juveniles and larvae are pelagic (Boehlert and Kappenman 1980) with juveniles found just beyond the continental shelf and larvae occurring from 13 to 306 kilometers offshore (Casillas et al. 1998). Young-of-the-year are found in tide pools (Love 1996) associated with artificial reefs and floating algae, and in interfaces between mud and rocks (Cailliet et al. 2000).
**Life History**—Canary rockfish move into deeper water as they mature and are capable of major latitudinal movements (up to 704 kilometers) (Lea et al. 1999). Juveniles have been reported to be associated with rocky/sandy areas during the day and sand flats at night (Love et al. 2002). Canary rockfish are a densely aggregating fish (Love 1996). Canary rockfish are ovoviviparous with internal fertilization (Boehlert and Kappenman 1980). Off central and northern California, canary rockfish reproduce from December to March peaking in December and from January to March off Oregon, Washington, and British Columbia (Hart 1973; Love 1996).

**Common Prey Species**—Canary rockfish prey upon crustaceans, primarily plankton krill and mysids and occasionally on fish (Phillips 1964; Love 1996; Lea et al. 1999). During spring-summer upwelling periods, krill are the dominant prey (McCain 2003).

### 1.4.3.2.11 Chilipepper (*Sebastes goodei*)

**Distribution**—Chilipepper range from Magdalena Bay, southern Baja California, to as far north as Pratt and Durgin Seamounts in the Gulf of Alaska. However, they are most common between Cape Mendicino, California, and northern Baja California (Allen and Smith 1988; Love et al. 2002; Mecklenburg et al. 2002; Love et al. 2005).

**Habitat Preference**—Chilipepper are found in midwater pelagic and benthic habitats (McCain 2003) between 50 and 250 meters (Allen and Smith 1988; Orr et al. 2000). Adults and older juveniles are usually found over the continental shelf and slope to depths of 491 meters. Small juveniles and larvae occur near the surface (Love et al. 1990; Love et al. 2005). In California, chilipepper are commonly associated with high-relief, rocky areas along cliff drop-offs (Love et al. 1990), on sand and mud bottoms (MBC 1987), and occasionally over flat, hard substrates (Love et al. 1990). Juveniles and larvae are associated with kelp canopies, with juveniles primarily found in 30 to 50 meters of water (Love et al. 1990). Young-of-the-year recruit to shallow nearshore waters usually just outside of kelp beds after spending up to five months as pelagic larvae and juveniles in offshore waters (NMFS 2004d). Chilipepper occur in water temperatures of 5° to 25°C and salinities of 32 to 34 psu (MBC 1987).

**Life History**—Chilipepper is not considered a migratory species, though movements of up to 2.4 kilometers per day have been recorded with this species swimming as far as 45 meters off the bottom during the day to feed (McCain 2003). Adults form large schools over areas with boulders and rock structures (Love et al. 2002). Chilipepper are ovoviviparous with internal fertilization (McCain 2003). In central and northern California, mating occurs from September to April peaking in December through January (Oda 1992; Love 1996; Ralston and Oda 2001). Chilipepper produce multiple broods in a single season (Love et al. 1990) and school by sex just prior to mating (MBC 1987).

**Common Prey Species**—Chilipepper prey upon large krill, squid, and small fish such as anchovy, lanternfish, and young hake (Hart 1973; Love et al. 1990).

### 1.4.3.2.12 China Rockfish (*Sebastes nebulosus*)

**Distribution**—China rockfish range from Kodiak Island, western Gulf of Alaska to Redondo Beach (southern California) and offshore of San Nicholas Island (Mecklenburg et al. 2002; McCain et al. 2005). They are abundant from Prince William Sound, Alaska to northern California (Love et al. 2002).

**Habitat Preference**—China rockfish occurs both inshore and along the open coast at depths from 3 to 128 meters but are most common between depths of 18 and 92 meters (Hart 1973; Eschmeyer et al. 1983; Love 1996). Sedentary adults are found at or near the bottom and pelagic juveniles are associated with high-energy, high-relief rocky reefs or rubble, often resting on the bottom or hiding in crevices and kelp beds (Love 1996; CDFG 2002b; Love et al. 2002). Juveniles inhabit shallow subtidal waters during summer and early fall (Casillas et al. 1998) and have been observed in the Strait of Georgia, British Columbia in 9 to 18 meters of water (Love et al. 2002). Young-of-the-year settle in shallow water after a probably short pelagic stage (NMFS-NWR 2004c).
Life History—China rockfish are territorial and sedentary, traveling less than one meter from their home crevices (Eschmeyer et al. 1983; Love 1996; Lea et al. 1999). Mating of the China rockfish occurs off California from January to June peaking in January (Love et al. 2002).

Common Prey Species—China rockfish prey upon crustacean, primarily brachyuran crabs, octopus, abalones, chitons, small fish, snails, nudibranchs, red abalone (Haliotis rufescens), and brittle stars (Lea et al. 1999; Love et al. 2002).

1.4.3.2.13 Copper Rockfish (Sebastes caurinus)

Distribution—Copper rockfish range from the western Gulf of Alaska, east of Kodiak Island to Islas San Benito, central Baja California (Stein and Hassler 1989; Love 1996; Mecklenburg et al. 2002; Love et al. 2005). They are most abundant in Puget Sound throughout the San Juan Islands and the Strait of Juan de Fuca and from Valdez, Alaska to Punta Banda, northern Baja California (NMFS-NWR 2004c).

Habitat Preference—Copper rockfish occur in nearshore waters on natural rocky reefs, boulder fields, artificial reefs, rock piles, and closely associated with reefs (within one meter) (Patten 1973) and kelp beds (Lea 2001; Love et al. 2002). Adults are commonly found at depths ranging from the intertidal zone at high tide to 185 meters (Eschmeyer et al. 1983; Allen et al. 2002) but are often found in rocky areas and on rock-sand substrates in shallower waters during upwelling periods (Eschmeyer et al. 1983; Stein and Hassler 1989). They are usually found in waters shallower than 20 meters in British Columbia and less than 23 meters in Puget Sound, but occupy deeper waters in the southern part of their range (ODFW 2002). Small juveniles and larvae are pelagic for several months to a year and are frequently associated with waters containing surface-forming kelp before settling in shallow water (Stein and Hassler 1989; Carr 1991; Love 1996). Older young-of-the-year associate with drift algae near the bottom, in and around sand and low rock formations (Carr 1991).

Life History—Copper rockfish show little movement once they have settled to the bottom, though movement of up to 1.6 kilometers has been noted (Miller and Geibel 1973; Lea et al. 1999). Their home ranges are relatively small (< 10 m²) over high-relief areas and large (to 4,000 m²) over low-relief areas (Love et al. 2002). Copper rockfish mate once per year and move inshore to release their young (Love et al. 2002). Parturition occurs from April to June in Puget Sound and from February to April south of British Columbia (Love 1996). Copper rockfish may utilize bays as nursery areas (Stein and Hassler 1989).

Common Prey Species—Copper rockfish prey upon crustaceans common at or near the bottom, such as cancrid crabs, kelp crabs, and shrimp, cephalopods (Loligo sp. and octopus), and fish such as young-of-the-year rockfish, cusk eels, eelpouts, and sculpin (Carlisle et al. 1964; Stein and Hassler 1989; Love 1996; Lea et al. 1999; Lea 2001).

1.4.3.2.14 Cowcod (Sebastes levis)

Distribution—Cowcod range from Ranger Bank and Guadalupe Island, Baja California to Mendocino County, California and may infrequently occur as far north as Newport, Oregon (Love et al. 2002), but their preferred habitat is located in the Southern California Bight (Barnes 2001).

Habitat Preference—Cowcod can be found between midwater pelagic and benthic habitats in water depths between 40 and 491 meters (Love et al. 2005). Adults are common at depths of 72 to 491 meters (Orr et al. 1998, 2000) over high-relief rocky areas, in association with large white sea anemones (Casillas et al. 1998), submarine canyons, under ledges, and in crevices of isolated rock outcrops surrounded by mud (Yoklavich et al. 2000). Juveniles occur in waters 40 to 100 meters over sandy and clay (low-relief) bottoms and near oil platforms (Love et al. 2002; Butler et al. 2003; Love et al. 2005). Larvae are almost exclusively found in southern California adjacent to the northern Channel Islands at depths less than 200 meters (MacGregor 1983; Moser et al. 2000), but may occur 320 kilometers offshore over the continental shelf from northern California to northern Baja California (Love et al. 2002).
Life History—Cowcod are not migratory but may move to some extent to follow food (McCain 2003). They are generally solitary, but occasionally aggregate (Love et al. 1990). Cowcod are ovoviviparous with large females producing up to three broods per season (Love et al. 1990). In the central and northern California, a single brood is produced from December to February peaking in December (Love et al. 2002).

Common Prey Species—Cowcod prey upon fish, octopus, and squid (McCain 2003).

1.4.3.2.15 Darkblotched Rockfish (*Sebastes crameri*)

**Distribution**—Darkblotched rockfish range from Santa Catalina Island, southern California to an area southeast of Zhemchug Canyon in the eastern Bering Sea (Miller and Lea 1972) and Tanaga Island in the Aleutian Islands (Allen and Smith 1988). Distinct population groups have been found off Oregon coast between latitude 44°30' and 45°20’N. They also occur in the Strait of Juan de Fuca and Haro Strait in British Columbia (Mc Cain et al. 2005).

**Habitat Preference**—Darkblotched rockfish is an outer shelf-upper slope species occurring off Oregon, Washington, and British Columbia over soft bottoms (Eschmeyer et al. 1983) or mud near cobble or boulders (Love et al. 2002). Adults occur at depths of 25 to 915 meters but are most common between 50 and 400 meters (Allen and Smith 1988). Benthic juveniles are found at depths of 50 to 200 meters (Lenarz et al. 1991; Love et al. 2002). Larvae and pelagic juveniles are found 83 to 93 kilometers offshore in water 900 to 1,300 meters deep (McCain 2003). Off central California, young darkblotched rockfish recruit to soft substrate and low-relief (< 1 meter) reefs (McCain et al. 2005).

**Life History**—Darkblotched rockfish migrate to deeper waters with increasing size and age and make limited season movements after recruitment to adult stock (McCain 2003). This species co-occurs with Pacific ocean perch, splitnose, yellowmouth, and sharpchin rockfish (McCain et al. 2005). Darkblotched rockfish are ovoviviparous with fertilization and parturition occurring from December to March off Oregon and California, and primarily in February off Oregon and Washington (Hart 1973; Nichol and Pikitch 1994).

**Common Prey Species**—Darkblotched rockfish prey upon macroplanktonic organisms, primarily euphausiids, but also occasionally on amphipods, small salps and octopus, and infrequently on small fish (McCain 2003).

1.4.3.2.16 Dusky Rockfish (*Sebastes variabilis*)

**Distribution**—Dusky rockfish range from Hokkaido, Japan to eastern Kamchatka in the Bering Sea and along the Aleutian Islands to the central coast of Oregon (Orr and Blackburn 2004; Love et al. 2005).

**Habitat Preference**—Dusky rockfish are an off-bottom to midwater species that occurs at depths of 6 to 675 meters (Love et al. 2005), but are most commonly found at depths of 100 to 300 meters in boulder-rubble substrate (Love et al. 2002) or in areas with extensive sponge beds (NMFS et al. 1998). Juveniles inhabit shallow water areas over rocks and among algae (McCain et al. 2005). They remain above boulder-rubble substrata in the summer and hide within the substratum’s crevices during the winter (Love et al. 2002).

**Life History**—Dusky rockfish have been observed in aggregations with other northern rockfish (*Sebastes polyspinis*) and Pacific ocean perch over rocky outcroppings (Love et al. 2002). Dusky rockfish spawns in northwestern Gulf of Alaska in May and June (NMFS et al. 1998).

**Common Prey Species**—Dusky rockfish prey upon primarily on euphausiids as well as larvae, cephalopods, shrimp, and hermit crabs (NMFS et al. 1998).

1.4.3.2.17 Flag Rockfish (*Sebastes rubrivinctus*)

**Distribution**—Flag rockfish range from Heceta Bank, Oregon to off Arrecife Sacramento, central Baja California (Miller and Lea 1972; Love 1996; Love et al. 2002; Love et al. 2005).
**Habitat Preference**—Flag rockfish occur at depths from 15 to 549 meters (Miller and Lea 1972; Love 1996; Orr et al. 2000; Love et al. 2005), but are most common between 30 and 183 meters (Orr et al. 2000). Adults are solitary, bottom-dwelling reef fish over boulders and other high-relief rock substrata and are often found among large white sea anemones and in submarine canyons (CDFG 2002b). Pelagic juveniles are commonly found near the water surface in areas with drifting algae mats and plant debris, often many kilometers from shore (Love et al. 2002) and maybe associated with rocky reefs (CDFG 2002b).

**Life History**—Information is unavailable on the migrations and movements of the flag rockfish (McCain et al. 2005). Flag rockfish reproduce from July to August off northern California and from April to May off Oregon (Kendall and Lenarz 1987).

**Common Prey Species**—Flag rockfish prey upon pelagic red crabs, hermit crabs, shrimp, fishes, calanoid copepods, krill, gammarid amphipods, and octopus (Love 1996; Love et al. 2002).

### 1.4.3.2.18 Gopher Rockfish (*Sebastes carnatus*)

**Distribution**—Gopher rockfish range from Cape Blanco, Oregon, to Punta San Roque, southern Baja California (Miller and Lea 1972; Love 1996; Love et al. 2002; Love et al. 2005), but are most common from Sonoma County, California to Arrecife Sacramento, central Baja California (NMFS-NWR 2004c).

**Habitat Preference**—Gopher rockfish are a shallow-water benthic rockfish that inhabits rocky reefs, kelp beds, as well as sandy areas near reefs (Eschmeyer et al. 1983; Love 1996). They are commonly found in water depths between 12 and 37 meters (Love 1996; Orr et al. 2000) but range from intertidal zone to about 86 meters (Love et al. 2002). Adults and large juveniles are benthic, whereas small juveniles and larvae are pelagic before settling in shallow water (Casillas et al. 1998). Large juveniles are at or near the bottom, preferring low-relief rocks or sand bottoms closely associated with drift algae and the giant kelp (*Macrocystis pyrifera*) (Carr 1991).

**Life History**—Gopher rockfish are known to move from one to two kilometers in pursuit of better habitats (Lea et al. 1999; McCain 2003). They are largely territorial with home ranges of up to 10 to 12 m² (Love et al. 2002). Gopher rockfish spend the day in rocky shelters and at night on the bottom in the open (McCain et al. 2005). Gopher rockfish are ovoviviparous with eggs carried for one to two months before larvae are released (McCain 2003). Gonadal development begins in late November, mating in late January and early February, and reproduction from March through May (Casillas et al. 1998).

**Common Prey Species**—Gopher rockfish prey upon crustaceans such as crabs and caridean shrimp, juvenile sculpin and rockfish, polychaetes, brittle stars, and mollusks (Larson 1980; Love 1996; Lea et al. 1999; ODFW 2002).

### 1.4.3.2.19 Grass Rockfish (*Sebastes rastrelliger*)

**Distribution**—Grass rockfish range from Playa Maria Bay, central Baja California to Westport, Washington (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005), but are most common south of southern Oregon to about Bahia San Quintin, northern Baja California (Miller and Lea 1972; Love et al. 2002; NMFS-NWR 2004c).

**Habitat Preference**—Grass rockfish is a shallow-water rockfish that is common in nearshore rocky areas, rocky bottom tidepools, along jetties, and in vegetation (kelp and eelgrass) (Miller and Lea 1972; Eschmeyer et al. 1983). They are commonly found from the intertidal zone to 46 meters depth but frequently less than 15 meters (Miller and Lea 1972; Eschmeyer et al. 1983; Orr et al. 2000). Adults are found hiding in crevices around reef structures (Carlisle et al. 1964; Turner et al. 1969; Feder et al. 1974; Allen 1985; Love 1996; Love and Johnson 1998). Juveniles are most common in tidepools (Love 1996). Young-of-the-year settle to hard substrates in shallow water during the spring and summer after a short pelagic stage (Love 1996; Lea et al. 1999).
**Life History**—Grass rockfish are considered sedentary and residential moving less than one meter from their home range (Casillas et al. 1998). Grass rockfish have internal fertilization (McCain 2003). Parturition occurs in winter from January to March, with greatest larval abundance occurring in January (Love et al. 2002).

**Common Prey Species**—Grass rockfish prey upon crustaceans, juvenile fish such as surfperch, midshipmen, and white croaker (*Genyonemus lineatus*), crabs, pistol shrimp, cephalopods, and gastropods (Love 1996; Lea et al. 1999).

1.4.3.2.20 **Greenblotched Rockfish (Sebastes rosenblatti)**

**Distribution**—Greenblotched rockfish range from Ranger Bank, central Baja California to Point Delgada, northern California, but are most common southward from central California (Miller and Lea 1972; Love et al. 2002).

**Habitat Preference**—Greenblotched rockfish are a deep-dwelling species that occupy a depth range of 55 to 491 meters (Miller and Lea 1972; Love et al. 2002). Adults and juveniles are common at or near the bottom with adults preferring depths of 61 to 396 meters (Orr et al. 2000). Adults and large juveniles utilize high-relief rocks, caves, crevices and occasionally mixtures of mud and rock, boulders, or cobble (Love et al. 1990; Love et al. 2002). Larvae are pelagic (Love et al. 1990).

**Life History**—Information is unavailable on the migrations and movements of the greenblotched rockfish (McCain et al. 2005). Greenblotched rockfish are semi-solitary usually found singly or occasionally in very small groups (Love et al. 2002). Greenblotched rockfish are viviparous (Love 1996) producing multiple broods (two or more times per season) from December to July, with peak mating occurring in April (Love et al. 1990). Smaller mature females most likely have single broods (Love et al. 1990).

**Common Prey Species**—Greenblotched rockfish prey upon planktonic organisms such as krill, pelagic tunicates as well as small fish like hake, anchovy, and lanternfish, and squid (McCain 2003).

1.4.3.2.21 **Greenspotted Rockfish (Sebastes chlorostictus)**

**Distribution**—Greenspotted rockfish range from Barkley Canyon, southern Vancouver Island to southern Baja California but are abundant as far north as Monterey Bay, California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005).

**Habitat Preference**—Greenspotted rockfish are common, benthic inhabitants found in waters 30 to 380 meters deep (Miller and Lea 1972; Love et al. 2005) on or near the bottom, and often in caves and crevices (McCain et al. 2005). They also utilize various habitat types, such as cobble-mud, pebble-mud, boulder-mud, rock-mud, and rock ridge, associated with submarine canyons (Yoklavich et al. 2000). Adults prefer waters depths of 49 to 201 meters over high-relief rocky reefs (Love et al. 1990; Love et al. 2002) but are also common on softbottoms, such as sand or mud (Eschmeyer et al. 1983). Juveniles occur at depths between 30 to 89 meters (Love et al. 1990) and are often associated with rock outcrops (Love et al. 2002), softbottom habitats (CDFG 2002b), and oil platforms (Love et al. 2002). Solitary greenspotted rockfish are commonly found in association with large sea anemones and under ledges and crevices of isolated rock outcrops (Yoklavich et al. 2000).

**Life History**—Greenspotted rockfish are sedentary and do not undergo extensive seasonal migrations or movements, rarely moving more than three kilometers from their habit (Love 1996). Greenspotted rockfish commonly occur with greenblotched, flag, canary, and half-banded rockfishes (Love et al. 2002). Greenspotted rockfish are viviparous producing broods two or more times per season. Smaller mature females are single brooders and male rockfish may mate more than once per season (Love et al. 1990). Reproduction occurs off Oregon in April and off northern and central California from April through September, peaking in May (Love 1996; Love et al. 2002).

**Common Prey Species**—Greenspotted rockfish prey upon planktonic krill, tunicates, small fish like juvenile rockfish, hake, lanternfish, and anchovy, and squid (Love et al. 1990).
1.4.3.2.22 Greenstriped Rockfish (*Sebastes elongatus*)

*Distribution*—Greenstriped rockfish range from Cedros Island, central Baja California to Chirikof Island in the western Gulf of Alaska; but are most common between British Columbia and Punta Colnett in northern Baja California (Hart 1973; Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005).

*Habitat Preference*—Greenstriped rockfish inhabit waters from 12 to 1,145 meters deep (Hart 1973; Love et al. 2005), but commonly encountered at depths from 100 to 250 meters (Love et al. 1990; Orr et al. 2000; Johnson et al. 2001). Adults are widely distributed on rocky (boulder, cobble, pebble) and softbottoms (mud) habitats (Eschmeyer et al. 1983; Love et al. 1990; McCain et al. 2005), associated with both high-relief and low-relief reefs (Love et al. 1990), and may co-occur with the greenspotted rockfish, demosponges, and brittle stars on deep reefs (McCain 2003). Juveniles have also been observed at oil platforms and artificial reefs (Cailliet et al. 2000). Young-of-the-year settle to the bottom in water deeper than 40 meters at the interface between fine sand and clay but can also be found within sand-cobble patches and along sand-mud bottoms that surround rock outcrops (Love et al. 2002).

*Life History*—Greenstriped rockfish are primarily sedentary (McCain 2003). Greenstriped rockfish are viviparous and multiple brooders mating two or more times per season (Love et al. 1990). This species reproduces off the northern and central California from May to July, peaking in May and off Oregon, Washington, and British Columbia in late spring and early summer (Hart 1973; Love et al. 1990).

*Common Prey Species*—Greenstriped rockfish prey upon various planktonic organisms, such as euphausiids, calanoid copepods, and pelagic tunicates as well as shrimp, squid, and small fish such as hake, anchovy, and lanternfish (Love et al. 2002; McCain 2003).

1.4.3.2.23 Harlequin rockfish (*Sebastes variegates*)

*Distribution*—Harlequin rockfish range from southwest of Newport, Oregon to the southeastern Bering Sea and the Aleutian Islands at Bowers Bank (Hart 1973; Love et al. 2002; Mecklenburg et al. 2002; Love et al. 2005).

*Habitat Preference*—Harlequin rockfish inhabit the inner shelf-mesobenthal (outer shelf) zone at depths from 6 to 588 meters (Allen and Smith 1988; Love et al. 2005). Adults are found over high-relief substrata (including seamounts) at depths ranging from 100 to 350 meters and as shallow as 49 meters (Love 1996; Orr et al. 2000; Love et al. 2002). Juveniles occur in shallow waters to a depth of 6 meters (Love et al. 2002).

*Life History*—Harlequin rockfish are a sedentary benthic species that occur singly or in small aggregations usually either on the bottom or within a few meters of rocks (Love et al. 2002). Information is unavailable on the reproduction of the harlequin rockfish (McCain et al. 2005).

*Common Prey Species*—Information is unavailable on the prey of the harlequin rockfish (McCain et al. 2005).

1.4.3.2.24 Olive Rockfish (*Sebastes serranoides*)

*Distribution*—Olive rockfish range from southern Oregon to Islas San Benito in central Baja California (Miller and Lea 1972; Love et al. 2002). They are abundant from the Channels Islands off Santa Barbara northward to Cape Mendocino in northern California (Eschmeyer et al. 1983; Love 1996).

*Habitat Preference*—Olive rockfish occur at depths ranging from surface/intertidal waters to 172 meters (Eschmeyer et al. 1983), but are most common in waters less than 30 meters deep (Love 1996). Adults occupy midwater, living over hard, high-relief areas such as reefs, wrecks, oil platforms, pipes (Love 1996) and clear-water areas of dense kelp (Love et al. 2002). They are distributed evenly over all rocky substrata, preferring low-rock substratum (Carr 1991). Older juveniles tend to aggregate near the bottom along the outer edge of the kelp bed and disperse over adjacent kelp beds at night (McCain 2003). Newly settled individuals form aggregations at mid-depths along the shoreward margins of kelp beds (McCain et
al. 2005). Young-of-the-year are found hovering off the bottom around kelp beds, drifting kelp mats, oil platforms, surfgrass, artificial reefs, and other structures at depths as shallow as three meters (Carlisle et al. 1964; DeMartini 1981; Carr 1991; Love 1996; Cailliet et al. 2000; Love 2001). Young-of-the-year also aggregate in areas of reduced water movement where drift algae accumulate; whereas other juveniles recruit to both kelp-only and rock-only substrate in the lower third of the water column (Carr 1991). Larval olive rockfish are planktonic (Casillas et al. 1998).

**Life History**—Olive rockfish are sedentary (Love 1996), spending their entire life near the same reef (Watters 1992). Lea et al. (1999) reported movements of less than 1.8 kilometers. During the day, olive rockfish are found in midwaters around kelp, descending to the bottom at night (Love 1996). Movement patterns are limited by the presence or absence of kelp beds (Casillas et al. 1998). This species forms small to moderate-sized aggregations and may be found singly in schools of blue or yellowtail rockfishes (Love et al. 2002; ODFW 2002). Olive rockfish reproduce once per season (January to March, peaking in January or February) extruding fully developed larvae (Carr 1991; Love 1996; Love et al. 2002).


### 1.4.3.2.25 Pacific Ocean Perch (*Sebastes alutus*)

**Distribution**—Pacific ocean perch range from southern Japan and Sea of Okhotsk to Navarin Canyon in the Bering Sea and from the Commander and Aleutian Islands to Punta Blanca, central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005) but are common from Oregon northward (Eschmeyer et al. 1983).

**Habitat Preference**—Pacific ocean perch inhabit the edge of the upper continental slope (Archibald et al. 1983; Dark and Wilkins 1994), occurring at depths of 25 to 825 meters, but are common from depths of 55 to 350 meters (Orr et al. 2000). The majority of the population occurs in patchy, localized aggregations over the smooth bottom of the continental slope (NMFS et al. 1998). Adults and subadults are benthopelagic (McCain 2003). Adults are generally found below 122 meters depth (Eschmeyer et al. 1983) associated with gravel, rocky or boulder substrates found along gullies, submarine canyons, pinnacles, seamounts, and submarine depressions of the upper continental slope (McCain 2003). Juveniles and larvae are pelagic (Casillas et al. 1998). Juveniles are surface and can remain pelagic for two to three years (if carried offshore by currents). Those juveniles carried into shallow waters tend to live at or near the bottom in waters shallower than 250 meters (McCain 2003). Juveniles are confined to shallow portions of their bathymetric range (depths as shallow as 37 meters) over hardbottom habitats of the shelf break (Casillas et al. 1998). Larval stages initially occur at subsurface depths over the continental slope, later rising to surface depths (McCain et al. 2005). All life stages occur in euhaline waters with water temperatures of 2.5° to 6.5°C (Casillas et al. 1998), although adults off British Columbia to Oregon preferred temperatures ranging from 5° to 8°C (McCain et al. 2005).

**Life History**—Migrations and movement patterns of the Pacific ocean perch are related to summer feeding and winter spawning (NMFS et al. 1998). Pacific ocean perch winter and spawn in deeper water (> 275 meters) moving to feeding grounds in shallower water (180 to 220 meters) in the summer (June to August) (Archibald et al. 1983). In the northeast Pacific, juveniles make seasonal depth migrations (McCain 2003). Adults form large schools, including for spawning, that are 30 meters wide to 80 meters deep, and as much as 1,300 meters long (McCain et al. 2005). Juveniles form ball-shaped schools near the surface (Casillas et al. 1998). Pacific ocean perch are viviparous with internal fertilization. Reproduction takes place among seamounts and other steep areas that are associated with circulation patterns from September to October off British Columbia and Washington (McCain 2003). Actual parturition takes place months after mating, primarily from January to April off Washington (Casillas et al. 1998) with a few fish releasing larvae in August and October (Love et al. 2002). Females are reported to release larvae
at dusk, 20 to 30 meters off the bottom in depths of 360 to 400 meters, with larvae rising to midwater depths of 215 to 275 meters (Love et al. 2002).

**Common Prey Species**—Pacific ocean perch prey upon euphausiids, calanoid copepods, mysids, shrimp, and fishes (flatfishes, lanternfishes, smelts) (Love 1996; McCain et al. 2005).

### 1.4.3.2.26 Pink Rockfish (Sebastes eos)

**Distribution**—Pink rockfish range from central Oregon to southern Baja California and Isla Guadalupe, central Baja California (Love et al. 2002; Love et al. 2005).

**Habitat Preference**—Pink rockfish occur in deep waters, ranging from 45 to 366 meters (Miller and Lea 1972). Adults are found in boulder fields, resting on softbottom sediments (Love et al. 2002), or near rocky bottoms on the shelf, slope, and in canyons (CDFG 2002b). Juveniles inhabit softbottom sediments (CDFG 2002b).

**Life History, Prey**—Information is unavailable on the migrations, movements, reproduction, and common prey of the pink rockfish (McCain et al. 2005).

### 1.4.3.2.27 Quillback Rockfish (Sebastes maliger)

**Distribution**—Quillback rockfish range from Anacapa Passage, southern California to Kodiak Island in the Gulf of Alaska (Miller and Lea 1972; Love et al. 2005). They are common in the Strait of Georgia, San Juan Islands area of Puget Sound, and from southeastern Alaska to northern California (Hart 1973; Love 1996; Love et al. 2002).

**Habitat Preference**—Quillback rockfish are a common, shallow-water benthic species that occur from 5 to 275 meters (Hart 1973; Love 1996), but are found mainly at depths from 9 to 147 meters (Orr et al. 2000). This species is a solitary reef-dweller living in or close to the bottom among rocks in crevices and holes, on coarse sand or pebbles next to reefs in areas with flat-bladed kelp (Love 1996). In Puget Sound, quillback rockfish occupy a wide variety of habitats having the highest abundance on shallow (2 to 20 meters) reefs (Love et al. 2002, ODFW 2002). Adults occur in deeper waters (140 meters) associated with high-relief substrata (McCain 2003). Pelagic juveniles (young-of-the-year) settle at 18 to 25 mm total length (TL) in shallow waters along the shores within a variety of habitats (drifting aggregates of benthic macrophytes, established bull kelp (Nereocystis luetkeana) beds, natural rock configurations, and artificial reefs) (Osorio and Klingbell 2001; McCain et al. 2005). Larvae are planktonic occurring in estuaries and waters over the continental shelf (Casillas et al. 1998).

**Life History**—Quillback rockfish are residential, with movements less than 9.6 kilometers (Miller and Geibel 1973; Lea et al. 1999). They have also demonstrated homing ability and specific diurnal movement patterns (Matthews et al. 1987). Quillbacks move from artificial reefs to low-relief reefs during the summer and return to artificial reefs in the fall and winter when kelp disappears from the low-relief reefs (McCain 2003). In Puget Sound, quillbacks living over high-relief rocky reef have very limited home ranges (within 30 m²), while those living over low-relief rocky reefs roam a greater distance (400 to 1,500 m²) (Love et al. 2002). Quillbacks are viviparous. Over their geographic range, this species spawns from April to July with a peak early in the season (Love 1996). In Puget Sound, mating occurs in March and parturition in May (McCain et al. 2005).

**Common Prey Species**—Quillback rockfish prey upon crustaceans including shrimp and various crabs, small fishes including rockfish and flatfish, bivalves, polychaetes, and fish eggs (Love 1996; ODFW 2002). In Puget Sound, this species preys upon brachyuran crabs, gammarid amphipods, euphausiids, and calanoid copepods (McCain et al. 2005).

### 1.4.3.2.28 Redbanded Rockfish (Sebastes babcocki)

**Distribution**—Redbanded rockfish range from the Bering Sea (Zhemchug Canyon) and Aleutian Islands (Amchitka Island) to San Diego, southern California (Miller and Lea 1972; Hart 1973; Eschmeyer et al. 1983).
1983; Love et al. 2002; Love et al. 2005). They are most abundant from the Yakutat region of the northeast Gulf of Alaska to Oregon and fairly common into central California (Love et al. 2002).

**Habitat Preference**—Redbanded rockfish occurs in waters as shallow as 49 meters and as deep as 1,145 meters (Love et al. 2005) but are commonly found between depths of 150 to 400 meters (Allen and Smith 1988; Orr et al. 2000). Adults and juveniles typically occur over soft substrates (Eschmeyer et al. 1983; CDFG 2002b). However, they have also been associated with hardbottom substrata, generally in crevices between boulders and are occasionally observed over mixtures of mud, cobblestones, and pebbles (Love et al. 2002).

**Life History**—Information is unavailable on the migrations and movements of the redbanded rockfish (McCain et al. 2005). Redbandeds are viviparous (Love 1996). Off Oregon, parturition occurs from March to September (Love et al. 2002) and off British Columbia in April (Hart 1973).

**Common Prey Species**—Information is unavailable on the prey of the redbanded rockfish (McCain et al. 2005).

### 1.4.3.2.29 Redstripe Rockfish (*Sebastes proriger*)

**Distribution**—Redstripe rockfish range from southern Baja California to Pribilof Canyon, southeastern Bering Sea and Amchitka Island, Aleutian Islands (Hart 1973; Allen and Smith 1988; Love et al. 2002; Love et al. 2005). This species is relatively uncommon in Puget Sound (Garrison and Miller 1982) but is most abundant from southeast Alaska to central Oregon (NMFS-NWR 2004c).

**Habitat Preference**—Redstripe rockfish inhabit the outer shelf and upper continental slope (Allen and Smith 1988) in water depths between 12 and 442 meters (greatest depth frequency between 150 and 275 meters) (Allen and Smith 1988). Adults are semi-demersal (Garrison and Miller 1982) occurring at the transition zone between mud and rock habitats (Cailliet et al. 2000). Juveniles and larvae are pelagic to semi-demersal (Casillas et al. 1998). Both adults and juveniles are found slightly off the bottom (~1 meter) over both high-relief and low-relief rocky areas (CDFG 2002b).

**Life History**—Redstripe rockfish are sedentary, or occur in small groups and in schools exhibiting little (short distance) or no movement from a home habitat or range (Mathews et al. 1996). Off British Columbia, there is some evidence that redstripe rockfish form dense near-bottom schools by day that rise off the bottom and disperse at night (Love et al. 2002). Redstripe rockfish are ovoviviparous (Garrison and Miller 1982). Off northern and central California, larvae are released July through September and between April and July off Oregon (Casillas et al. 1998). In Puget Sound, larvae are released during July (Garrison and Miller 1982).

**Common Prey Species**—Redstriped rockfish prey upon krill, small fish (anchovies, herring, other rockfishes), and squid (Love et al. 2002; McCain 2003).

### 1.4.3.2.30 Rosethorn Rockfish (*Sebastes helvomaculatus*)

**Distribution**—Rosethorn rockfish range from Banco Range, central Baja California, to the western Gulf of Alaska east of Sitkinak Island (Phillips 1957; Hart 1973; Love et al. 2005). They also occur in Puget Sound (McCain et al. 2005).

**Habitat Preference**—Rosethorn rockfish most commonly occur in water depths of 59 to 1,145 meters (Johnson et al. 2003) but range from waters 25 to 549 meters deep (Phillips 1957; Hart 1973; Love et al. 2002). Adults inhabit muddy areas adjacent to boulders, cobble, or rock, in rocky areas without mud, or in association with sea lilies (Love et al. 2002). Off Heceta Bank on the central Oregon coast, adults were found in habitats consisting of boulders, cobble, demosponges, and brittle stars (McCain et al. 2005). Juveniles are found on both hard and soft substrates (CDFG 2002b).

**Life History**—Information is unavailable on the migrations and movements of the rosethorn rockfish (McCain et al. 2005). Rosethorns are solitary rarely rising more than a meter from the bottom (Love et al.
Rosethorn rockfish are viviparous (Love 1996). Parturition occurs during May and June in northern and central California (Casillas et al. 1998), and primarily in June from Oregon to British Columbia (McCain 2003).

**Common Prey Species**—Rosethorn rockfish prey upon euphausiids, crustaceans (gammarid amphipods), and fishes (Love et al. 2002; McCain et al. 2005).

### 1.4.3.2.31 Rosy Rockfish (*Sebastes rosaceus*)

**Distribution**—Rosy rockfish range from Strait of Juan de Fuca near Puget Sound, Washington to Bahia Tortugas in southern Baja California (Miller and Lea 1972; Love et al. 2002). This species has also been observed near the Cobb Seamount off Washington (Orr et al. 1998, 2000).

**Habitat Preference**—Rosy rockfish are solitary, bottom-dwelling rockfish that occur at depths of 7 to 263 meters (Love et al. 2002). Adults inhabit hard, high-relief and low-relief areas among rocks and sand between 30 and 46 meters (Love 1996, Orr et al. 2000; Love et al. 2002). Juveniles are found from 30 to 61 meters (Love 1996) and recruit to rocky areas (Love et al. 2002).

**Life History**—Information is unavailable on the migrations and movements of the rosy rockfish (McCain et al. 2005). This species occurs in small groups often rising a few meters above the bottom (Love et al. 2002). Rosy rockfish are multiple brooders. Reproduction occurs from central California northward from April to July, peaking in June (Love et al. 1990).

**Common Prey Species**—Rosy rockfish prey upon benthic crustaceans (shrimp, crabs, gammarid amphipods, krill, salps, and young-of-the-year rockfishes (Love 1996; Love et al. 2002).

### 1.4.3.2.32 Rougheye Rockfish (*Sebastes aleutianus*)

**Distribution**—Rougheye rockfish range from the Commander and Aleutian Islands to San Diego, southern California (Hart 1973; Eschmeyer et al. 1983). They are also found in Pacific waters off northern Hokkaido, Japan and Kuril Islands to Navarin Canyon in the Bering Sea (Allen and Smith 1988). This species is abundant from the Bering Sea and Gulf of Alaska to central Oregon (Love et al. 2002).

**Habitat Preference**—Rougheye rockfish commonly occur at water depths of 50 to 450 meters, but can occur as shallow as 25 meters to as deep as 900 meters (Allen and Smith 1988; Mecklenburg et al. 2002). This species is common in offshore waters, but rare in nearshore waters (Hart 1973). Adults are at or near the bottom (Eschmeyer et al. 1983) commonly observed over steeply sloped bottoms (Casillas et al. 1998). Off California, young rougheye rockfish recruit to soft substrates, frequent boulders, and rocky slopes greater than 20° (McCain 2003). Rougheyes have been found in water between minus 0.3° to 4.9°C (Love et al. 2002).

**Life History**—Information is unavailable on the migrations and movements of the rougheye rockfish (McCain et al. 2005). Small juveniles may sometimes be found in schools, whereas larger fish are either solitary or in small groups (Love et al. 1998). Fishes in the northwest Pacific may aggregate more in the fall-winter months (November to December) than May through October (Love et al. 2002).

Rougheye rockfish larvae are released during May off Oregon (McCain 2003) and from February to June off British Columbia (Love et al. 2002).

**Common Prey Species**—Rougheye rockfish prey upon crustaceans (pandalid shrimps, gammarid amphipods, mysids, and crabs) and fishes (Love et al. 2002).

### 1.4.3.2.33 Sharpchin Rockfish (*Sebastes zacentrus*)

**Distribution**—Sharpchin rockfish range from San Diego, southern California to Attu Island in the Aleutian Islands, Alaska (Allen and Smith 1988; Love et al. 2005). More specifically, it has been reported that their occurrence is from San Clemente Island, southern California (32.8°N 117.4°W) to Resurrection Bay, Alaska (60.0°N 149.4°W) in the north, and Petrel Bank near the Aleutian Island chain (52.3°N
179.8°W) to the west (McCain 2003). This species is most abundant from the Gulf of Alaska to northern California (NMFS-NWR 2004c) and off Heceta Bank, central Oregon (Love et al. 2002).

**Habitat Preference**—Sharpchin rockfish is an outer shelf-mesobenthal species that is commonly found at water depths from 25 to 610 to 660 meters (Allen and Smith 1988). This species occurs over softbottoms (Eschmeyer et al. 1983) but prefers mud and cobble or mud and boulder substrates, and are associated with boulder and cobble fields (Casillas et al. 1998). Off central Oregon on Heceta Bank, adults inhabit areas consisting of boulders, cobble, demosponges, and brittle stars (*Ophiacantha*) (McCain et al. 2005). Pelagic juveniles occur 9 to 148 kilometers offshore and larvae 46 to 148 kilometers offshore over 270 to 2,800 meters deep water (McCain et al. 2005).

**Life History**—Information is unavailable on the migrations and movements of the sharpchin rockfish (McCain et al. 2005). Sharpchin rockfish occur in small schools as well as singly on or near the seafloor (Love et al. 2002). Sharpchin rockfish undergo parturition off northern and central California from May through June and off Oregon from March through July (Casillas et al. 1998).

**Common Prey Species**—Sharpchin rockfish prey upon euphausiids, shrimps, gammarid amphipods, copepods, and small fishes (Love et al. 2002; McCain 2003).

1.4.3.2.34 Shortbelly Rockfish (*Sebastes jordani*)

**Distribution**—Shortbelly rockfish range from southern Baja California to La Perouse Bank, southern British Columbia (Eschmeyer et al. 1983; Love et al. 2005). Large concentrations occur off the Columbia River at the Oregon-Washington border (Love et al. 2002).

**Habitat Preference**—Shortbelly rockfish are a midshelf-mesobenthal and cold-temperate species inhabiting waters from 91 to 491 meters deep (Allen and Smith 1988) on the continental shelf (Chess et al. 1988) and upperslope (Stull and Tang 1996). Adults transition between midwater pelagic and benthic habitats in water ranging from 150 to 200 meters from central California to southern Vancouver Island (Casillas et al. 1998; Love et al. 2002). Adult habitats are wide ranging (Eschmeyer et al. 1983), occurring in midwater and away from underwater objects such as reefs or kelp (Casillas et al. 1998), over smooth bottom habitats near the shelf break and sharp dropoffs (McCain 2003), and along ledges of submarine canyons (Ralston et al. 2003). Juveniles are pelagic for three to five months before recruiting to kelp beds, outer margins of kelp beds, and deep rock outcrops (Love et al. 2002). Off California, young-of-the-year have been observed in the surf line (Lenarz 1992) and are known to inhabit soft substrate and low-relief (< 1 meter) reefs (Casillas et al. 1998). Larvae occur up to 278 kilometers offshore but are more common closer to shore within 19 kilometers of land (MacGregor 1986).

**Life History**—Shortbelly rockfish are an active schooling species that is found near the bottom in dense aggregations during the day, but are distributed in the mid-water column at night (Chess et al. 1988). During the summer, shortbelly rockfish tend to move into deeper waters and to the north as they grow but do not make long return migrations to the south in the winter to reproduce (Casillas et al. 1998). Off central California, shortbelly rockfish larvae make diurnal vertical migrations, where the larvae tend to stay within or above the pycnocline at all times (Casillas et al. 1998). During intense upwelling from May to June, small shortbelly rockfish stay in deep waters, presumably to avoid advection to shore (Lenarz et al. 1991). Shortbelly rockfish are viviparous, bearing advanced yolk-sac larvae at the time of parturition (Casillas et al. 1998). They reproduce off central and northern California from January to April and off Oregon from November to May, both peaking in February (Lenarz 1992; Love 1996; Starr et al. 1998; Love et al. 2002).

1.4.3.2.35 Shortraker Rockfish (*Sebastes borealis*)

**Distribution**—Shortraker rockfish range from off northern Hokkaido, Japan to Kamchatka Peninsula in the western Bering Sea (Eschmeyer et al. 1983; Allen and Smith 1988; Krieger 1992; Krieger and Ito 1999) to Navarin Canyon and Aleutian Islands south to Point Conception, California (Allen and Smith 1988).

**Habitat Preference**—Shortraker rockfish are an offshore species usually found at or near the bottom (Krieger 1992) in mid-shelf to the middle bottom slopes from 25 to 1,200 meters, but commonly occurs from 50 to 650 meters (Allen and Smith 1988) or 100 to 600 meters (Orr et al. 2000). This species is common over hard, steeply-sloped bottoms (3° to 12°), fine-grained substrata of silt or pebbles, and currents of 0.1 to 0.4 kilometers per hour (kilometers/hr) (Krieger 1992; Krieger and Ito 1999).

**Life History**—Shortraker rockfish may perform seasonal vertical migrations with depth range expanding during the months of June through November and decreasing from spring to autumn (Love et al. 2002). Migration may also occur in response to food availability with larger individuals undergoing greater movements than smaller individuals (McCain et al. 2005). Female shortraker rockfish have fully developed embryos from March through July, releasing larvae from summer through fall at depths between 300 and 500 meters (Love et al. 2002). Off British Columbia, larvae are released in April (McCain 2003).

**Common Prey Species**—Shortraker rockfish prey upon shrimp, squids, octopus, mysids, smelt, lanternfish, and mollusks (Yang and Nelson 2000; Love et al. 2002).

1.4.3.2.36 Silvergray Rockfish (*Sebastes brevispinis*)

**Distribution**—Silvergray rockfish range from Bahia de Sebastian Vizcaino, central Baja California to the southeastern Bering Sea (Hart 1973; Allen and Smith 1988; Love et al. 2005) but are most common between the central Gulf of Alaska and Oregon (Love et al. 2002).

**Habitat Preference**—Silvergray rockfish are common in open coastal regions generally inhabiting the outer shelf-mesobenthal zone (Allen and Smith 1988) at depths of 100 to 300 meters with a range from the surface to 441 meters (Allen and Smith 1988; Love et al. 2002). Adults and subadults are found on a variety of rocky-bottom habitats (Love et al. 2002). Young silvergray rockfish inhabit shallow embayments and associated kelp beds (Love et al. 2002).

**Life History**—Information is unavailable on the migrations and movements of the silvergray rockfish (McCain et al. 2005). Silvergray rockfish form loose aggregations with black, canary, dusky, Puget Sound rockfish (*Sebastes emphaeus*), and yellowtail rockfish or occur as solitary individuals resting on the bottom (Love et al. 2002). Silvergray rockfish release young between April and August off Oregon, Washington, and southeast Alaska (Hart 1973; Love et al. 2002).

**Common Prey Species**—Information is unavailable on the prey of silvergray rockfish (McCain et al. 2005).

1.4.3.2.37 Speckled Rockfish (*Sebastes ovalis*)

**Distribution**—Speckled rockfish range from northern Washington to Arrecife Sacramento, central Baja California (Love et al. 2002; Love et al. 2005) and are common from central California southward (Love 1996).

**Habitat Preference**—Speckled rockfish occur in midwater depths from 30 to 366 meters (Miller and Lea 1972) over rocks (Love et al. 1990; Love 1996), near the bottom of reefs (Love 1996), among boulders, and to a lesser degree among cobble (Love et al. 2002). Adults transition between midwater pelagic and benthic habitats over rocky substrates between 76 and 152 meters deep (Love 1996; Casillas et al. 1998). Juveniles can be found as deep as 142 meters (Love et al. 2002) but commonly occur from depths of 30 to 89 meters (Love et al. 1990; Love 1996). Off California, young rockfish recruit to hard substrate,
boulders, and high-relief (> 1 meter) reefs often in association with macrophytes and crinoids at depths from 95 to 142 meters (Love et al. 2002).

**Life History**—Speckled rockfish is an aggregating species (Love et al. 1990) that probably moves from reef to reef (Love 1996). This species often forms mixed groups with bocaccio, squarespot, and subadult or small adult widow and pygmy rockfish (Love et al. 2002). Speckled rockfish produce multiple broods (two or more times per season) releasing larvae in May off central and northern California (Love et al. 1990).

**Common Prey Species**—Speckled rockfish prey upon plankton (krill, copepods) and occasionally eat small fish (Love 1996).

### 1.4.3.2.38 Splitnose Rockfish (*Sebastes diploproa*)

**Distribution**—Splitnose rockfish range from Sanak Islands, western Gulf of Alaska to Cedros Islands, central Baja California (Miller and Lea 1972; Allen and Smith 1988; Love et al. 2005). They are most abundant from British Columbia to southern California (NMFS-NWR 2004c).

**Habitat Preference**—Splitnose rockfish inhabit the outer shelf-mesobenthal zone being common at water depths of 150 to 450 meters with extremes of 80 to 894 meters (Allen and Smith 1988). Adult and juveniles are found at or near the bottom in non-rocky shelf, continental slope and basin habitats consisting of mud near isolated rock, cobble, and boulder fields (NMFS et al. 1998; Starr et al. 1998), and occasionally in submarine canyons (CDFG 2002b). Prejuveniles and larvae are pelagic (Casillas et al. 1998). Pelagic prejuveniles recruit to soft substrate and low-relief (< 1 meter) habitat after a transitory midwater residence (Love et al. 2002). Young occur in shallow water at the surface under drifting kelp (bull kelp) (Eschmeyer et al. 1983), algae (*Fucus* spp. - dominant), and seagrasses (eelgrass) (McCain 2003).

**Life History**—Splitnose rockfish form schools that are occasionally found as high as 100 meters up in the water column (Love et al. 2002). Emigration of juvenile splitnose rockfish from surface waters occurs in May and June (Casillas et al. 1998). Small benthic juveniles appear in July and August with peaks of abundance in November and December (McCain 2003). This temporal discrepancy between disappearance from the surface and peak benthic appearance suggests that migrant juveniles may occupy an intermediate habitat of 200 to 250 meters between emigration and settlement (Casillas et al. 1998). Splitnose rockfish are ovoviviparous, reproducing and releasing larvae throughout the year (Love et al. 2002). Peak reproductive/parturition season for this species decreases incrementally northward from mid-May to June off Oregon, June to July off Washington, and July and October to December off British Columbia (Casillas et al. 1998; Love et al. 2002).

**Common Prey Species**—Splitnose rockfish prey upon midwater plankton, primarily krill, copepods, sargassid shrimp, and amphipods (McCain 2003; NMFS-NWR 2004c).

### 1.4.3.2.39 Squarespot Rockfish (*Sebastes hopkinsi*)

**Distribution**—Squarespot rockfish range from northern Baja California and Guadalupe Island, central Baja California to the southern Oregon coast (Love 1996; Casillas et al. 1998; Love et al. 2005).

**Habitat Preference**—Squarespot rockfish are a dwarf (maximum 29 centimeters total length), midwater species occurring in water depths of 18 to 305 meters, but most commonly between 30 and 150 meters (Miller and Lea 1972; Love et al. 2002). Adults move between midwater pelagic and benthic habitats (Casillas et al. 1998) occurring over rocky substrate at depths from 18 to 183 meters (Love et al. 1990; Love 1996; Love et al. 2002). Juveniles are pelagic for three to four months (Love et al. 2002). Young recruit in water greater than 30 meters (Love et al. 1990) and settle out over nearshore rocky areas as shallow as 27 meters (Love et al. 2002).

**Life History**—Squarespot rockfish tend to form large aggregations of thousands of individuals (Love 1996). This species sometimes schools with pygmy, speckled, and juvenile widow rockfish (Love et al.
2002). Squarespot rockfish are multiple brooders with reproduction occurring from February and March off central California (Love 1996).

Common Prey Species—Squarespot rockfish prey upon plankton primarily copepods, krill, arrow worms, and crab larvae (Love 1996; Love et al. 2002).

1.4.3.2.40 Stripetail Rockfish (Sebastes saxicola)

Distribution—Stripetail rockfish range from Punta Rompiente, southern Baja California to Yakutat Bay, eastern Gulf of Alaska (Miller and Lea 1972; Hart 1973; Love et al. 2002, 2005). They are most commonly found between British Columbia and southern California (Love et al. 2002).

Habitat Preference—Stripetail rockfish inhabit the outer shelf-outer slope (Stull and Tang 1996) occurring in waters from 25 to 547 meters, but most commonly between 100 and 350 meters depth (Allen and Smith 1988; Orr et al. 2000). Most adults are found at or near the bottom on substrate containing mud and scattered small rocks. Some adults transition between midwater pelagic and benthic habitats near these habitats (Love et al. 2002). Pelagic juveniles are found over a relatively narrow depth range of 50 to 60 meters (Lenarz et al. 1991), before recruiting to benthic habitats at depths of 60 to 100 meters (Johnson et al. 2001). Juvenile habitat consists of sandy substrate in association with macrophytes (kelp beds) (Love et al. 1994) and low-relief rocks and sedimentary outcrops bounded by mud and sand (Love et al. 2002).

Life History—Adult stripetail rockfish are probably nocturnally active; whereas juvenile rockfish are diurnally active (McCain et al. 2005). Once this species is recruited to shallower depths, it gradually moves to depths commonly used by the adults (Johnson et al. 2001). Adults are most often found on or very near the seafloor (Love et al. 2002).

Stripetail rockfish produce one brood per season. Young are released in northern and central California, from November through March peaking in January, off Oregon in January and February, and off British Columbia in February (Hart 1973; Love 1996; Casillas et al. 1998).

Common Prey Species—Stripetail rockfish prey upon euphausiids and copepods (Stull and Tang 1996).

1.4.3.2.41 Tiger Rockfish (Sebastes nigrocinctus)

Distribution—Tiger rockfish range from Tanner and Cortes Banks, southern California to Unalaska Island, Aleutian Islands (Love et al. 2002; Love et al. 2005). They are most common between southeast Alaska and northern California, including the northern part of Puget Sound, Washington and the Strait of Georgia, British Columbia (Love et al. 2002).

Habitat Preference—Tiger rockfish commonly occur at water depths of 55 to 274 meters (Orr et al. 2000) and have a reported range from 17 to 298 meters (Johnson et al. 2003). In the northeastern Strait of Georgia, tiger rockfish are found in waters ranging from 21 to 140 m; and in Puget Sound in less than 30 meters (McCain et al. 2005). Tiger rockfish are often associated with "wall" habitat (McCain 2003), in caves along undersea cliffs, or on the sea floor, generally in high-relief areas with strong currents (Johnson et al. 2003). Adults are found at or near the bottom (Garrison and Miller 1982). Juveniles are pelagic, commonly found near the surface and often associated with drifting algal mats and plant debris (Love et al. 2002).

Life History—Tiger rockfish are solitary and territorial (Hart 1973), defending a home crevice in the reef (ODFW 2002) and have been reported to make short storm-related movements (Love et al. 2002). Aggregations have been observed off southeast Alaska (Love et al. 2002). Tiger rockfish are ovoviviparous (McCain et al. 2005). This species mating season peaks in May and June in Puget Sound (Casillas et al. 1998) and in April and May in southeast Alaska (Love 1996; Love et al. 2002).

Common Prey Species—Tiger rockfish prey upon crustaceans (caridean shrimp, rock crab, gammarid amphipods) and small fishes like herring and juvenile rockfish (Love et al. 2002; McCain 2003).
1.4.3.2.42 Vermillion Rockfish (*Sebastes miniatus*)

**Distribution**—Vermillion rockfish range from Zaikof Bay, Montague Island, and Prince William Sound, Alaska to Islas San Benito, central Baja California, Mexico (Love 1996; Love et al. 2005). They are most abundant from northern California to northern Baja California (Love et al. 2002).

**Habitat Preference**—Vermillion rockfish are found from 12 to 439 meters and are most common between 50 and 150 meters (Love et al. 2002; Love et al. 2005). This species commonly occurs over rocks, along drop-offs, and over hardbottom (Love 1996). Adults and juveniles are benthopelagic (MBC 1987). Adults occur on or near the bottom in areas with structural diversity, such as high-relief rocky reefs and drilling platforms, and kelp beds (Love 1996; Cailliet et al. 2000; Love et al. 2002). Juveniles are secretive and often take refuge in dense algal (Ventresca 2001) and kelp beds in shallow water 6 to 27 meters deep (Cailliet et al. 2000). Larvae are pelagic and remain near the surface for three to four months before settling to soft or hardbottom substrate (Ventresca 1992) in waters between 5 and 30 meters (Love et al. 1990). Young-of-the-year recruit to soft/hard substrata such as low-relief (< 1 meter) structural habitats surrounded by sand (for example, rocky strata, worm tubes, eelgrass, and pilings) (Carr 1991; Love et al. 2002). All life stages occur in euhaline waters with salinities of 32 to 34 psu and temperatures of 6° to 20°C (MBC 1987).

**Life History**—Vermillion rockfish have strong site fidelity moving very little from its primary habitat type (Lea et al. 1999). It is thought that movements off reefs (two kilometers) may be associated with following schools of prey, primarily squid (McCain 2003). This species is usually found aggregating near or slightly above the bottom over high-relief or artificial structures (MBC 1987). Vermillion rockfish are ovoviviparous with internal fertilization and single broods (Love et al. 1990). Peak spawning months are September, December, and April to June off central and northern California (Ventresca 2001; Love et al. 2002).

**Common Prey Species**—Vermillion rockfish prey upon small fishes (northern anchovy, blue lanternfish [*Tarletonbeania crenularis*], midshipmen, rockfishes, sculpins, flatfishes), octopus, squids, pyrosomes, pelagic red crab (*Pleuroncodes planipes*), and krill (Phillips 1964; Love 1996; ODFW 2002).

1.4.3.2.43 Widow Rockfish (*Sebastes entomelas*)

**Distribution**—Widow rockfish range from Albatross Bank, western Gulf of Alaska to Todos Santos Bay, northern Baja California (Miller and Lea 1972; Eschmeyer et al. 1983). They are most abundant from British Columbia to northern California (Love et al. 2002) and most common off southern Washington and northern Oregon (MBC 1987).

**Habitat Preference**—Widow rockfish are common in water depths of 100 to 350 meters (Love et al. 1994) over hardbottom high-relief and low-relief substrata such as rocky banks, seamounts, ridges near canyons, headlands, and muddy bottoms near rocks along the continental shelf (Squire and Smith 1977; Yoklavich et al. 2000; McCain 2003). All life stages are pelagic, with adults and older juveniles often associated with benthic habitats (Casillas et al. 1998). Adults are sublittoral to bathyal from near surface to 800 meters (Eschmeyer et al. 1983; Orr et al. 1998, 2000; Love et al. 2002; Mecklenburg et al. 2002). Large juveniles occur near the bottom and inshore over depths of 9 to 37 meters (Eschmeyer et al. 1983) over hard, rocky substrate but are found as deep as 140 meters (Love et al. 2002). Small juveniles and larvae are neritic and surface, occurring from near surface waters to 20 meters depths and nearshore to 300 kilometers offshore (McCain 2003). Young-of-the-year recruit to nearshore areas containing soft substrata and low-relief (< 1 meter) in association with kelp and other algae (Love et al. 2002). All life stages occur in euhaline (31 to 34 psu) waters in water temperatures of 6° to 15°C (Eschmeyer et al. 1983; MBC 1987).

**Life History**—Widow rockfish can be solitai, but are more often found in large schools exhibiting a range of diel behaviors (Love et al. 2002). Adults form dense, irregular, mid-water and semi-demersal schools deeper than 100 meters at night and disperse in mid-water during the day (Eschmeyer et al. 1983).
Similarly, juveniles inhabit rocky areas containing macroalgae during the night and the water column during the day (Love et al. 2002). Large concentrations of widow rockfishes occur off headlands, such as Cape Blanco, Oregon and Cape Mendocino, California, whose area characteristics include extended points of land, offshore canyons, and current circulation eddies inshore of main currents (McCain et al. 2005). These oceanographic characteristics appear to be associated with widow rockfishes during their reproductive cycle (McCain 2003). In addition, aggregations have been reported around offshore seamounts such as Cobb seamount off Oregon and Bowie seamount off British Columbia (Love et al. 2002; McCain et al. 2005). Widow rockfish are ovoviviparous, have internal fertilization, and brood their eggs until released as larvae (Casillas et al. 1998). Reproduction occurs from December through April off central and northern California (peaking in February, respectively), January to March off Oregon, and January to April off British Columbia (Hart 1973; Love et al. 2002).

Common Prey Species—Widow rockfish prey upon small pelagic crustaceans (hyperiid and gammarid amphipods), euphausiids, midwater fishes (northern anchovy, juvenile Pacific hake, lanternfishes), salps (including pyrosomes), caridean shrimp, sergestid shrimp, and small squids (Hart 1973; Eschmeyer et al. 1983; Ralston and Lenarz 2001; Love et al. 2002).

1.4.3.2.44 Yelloweye Rockfish (Sebastes ruberrimus)

Distribution—Yelloweye rockfish range from south of Umnak Island, Aleutian Islands to Ensenada, northern Baja California; they are common from central California northward to the southeastern Gulf of Alaska (Phillips 1957; Miller and Lea 1972; Hart 1973; Eschmeyer et al. 1983; Mecklenburg et al. 2002). This species is considered rare in Puget Sound (Love et al. 2002).

Habitat Preference—Yelloweye rockfish are a middle-shelf, mesobenthal species (Allen and Smith 1988) that is commonly found at depths from 91 to 180 meters (Love et al. 2002) but occur in waters ranging from 15 to 549 meters (Orr et al. 1998, 2000). Adults are benthic, commonly found either on or over reefs, in submarine canyons, around steep cliffs, offshore rugged pinnacles, and cobble, continuous rock, broken rock, caves, large cracks, overhangs, and boulder habitats (Eschmeyer et al. 1983; O’Connell and Funk 1987; Love 1996; Casillas et al. 1998; CDFG 2002b; McCain 2003). Young-of-the-year are found in areas of high structural relief at depths greater than 15 meters (Love et al. 2002), on sponge beds in low-relief areas (Casillas et al. 1998), and on vertical walls (Love et al. 2002).

Life History—Yelloweye rockfish are solitary, found either on or just over reefs (Love 1996), however, aggregations of 30 or more adults have been noted on the Bowie Seamount, off British Columbia (Love et al. 2002). This species does not undergo diel movements (McCain et al. 2005). Yelloweye rockfish are ovoviviparous and a spring/summer spawner releasing young from March to July off California, in June off Washington, and April to September (peaking in May and June) off British Columbia (Love et al. 2002).

Common Prey Species—Yelloweye rockfish prey upon fish (rockfish, cods, sand lances, herrings, and lumpsuckers), crustaceans (caridean shrimp, lithodid crab), green sea urchin, and gastropods (Love 1996; McCain 2003). Off Oregon, this species preys upon cancroid crabs, cottids, righteye flounders, rockfish, and pandalid shrimp (McCain et al. 2005).

1.4.3.2.45 Yellowmouth rockfish (Sebastes reedi)

Distribution—Yellowmouth rockfish range from Sitka, southeastern Gulf of Alaska to near San Francisco, northern California; but occur most commonly between southeast Alaska and Oregon (Love et al. 2002; Love et al. 2005).

Habitat Preference—Yellowmouth rockfish occupy a depth range from 141 to 366 meters, usually 180 to 275 meters over rocky shelf on the continental slope/basin (Eschmeyer et al. 1983; NMFS et al. 1998; Love et al. 2005). Pelagic juveniles are collected off Oregon (Love et al. 2002).
Life History—Information is unavailable on migrations and movements of the yellowmouth rockfish (McCain et al. 2005). Adults have been reported to aggregate in midwater over high-relief rocks (Love et al. 2002).

Off Oregon, yellowmouth rockfish release their young from February through June (Kendall and Lenarz 1987).

Common Prey Species—Information is unavailable on the prey of the yellowmouth rockfish (McCain et al. 2005).

1.4.3.2.46 Yellowtail Rockfish (Sebastes flavidus)

Distribution—Yellowtail rockfish range from eastern Aleutian Islands south of Unalaska Island, Alaska to Isla San Martin, northern Baja California (Miller and Lea 1972; Love 1996; Love et al. 2002; Love et al. 2005). Their abundance center is from southeast Alaska to central California with the highest concentrations occurring off Washington and Oregon in Astoria Canyon near the mouth of the Columbia River (Ralston 2001; Love et al. 2002). Yellowtail rockfish are more abundant in northern than the central Puget Sound (McCain 2003).

Habitat Preference—Yellowtail rockfish, a middle–shelf mesobenthal species, commonly occurs at water depths between 50 and 250 meters with an overall depth range from the surface to 549 meters (Allen and Smith 1988; Orr et al. 1998, 2000; Love et al. 2002). This species is part of the shelf rockfish assemblage that includes Pacific ocean perch, bocaccio, chilipepper, and canary, silvergray, black, and widow rockfishes (Love 1996). From Washington to northern California, a canary-yellowtail-silvergray assemblage characterizes the area from Cape Flattery, Washington to Cape Blanco, Oregon and a yellowtail-stripetail assemblage from Cape Blanco to Cape Mendocino region in 91 to 181 meters water zone (McCain et al. 2005). Adults are semi-pelagic or pelagic (Love 1996) occurring along steep walls and cliffs, above rocky reefs (Hart 1973; Casillas et al. 1998), over mud substrates with cobble, boulder, and rock ridges, and in sand habitats (Love 1996). Off Heceta Bank (Oregon), they inhabit ridges and boulders, vase sponges, and brittle stars (McCain et al. 2005). Pelagic juveniles occur from 24 to 266 kilometers offshore, whereas benthic juveniles are found nearshore in 20 to 37 meters (Casillas et al. 1998), usually in rocky areas with giant or bull kelp (Love et al. 2002).

Life History—Yellowtail rockfish form large mid-water schools (> 1,000 fish), singly or in association with black, copper, dusky, Puget Sound, silvergray, and widow rockfishes in northern waters and with canary and vermilion rockfish off California (Ralston 2001; Love et al. 2002). Adults exhibit strong site fidelity and homing abilities (Love 1996). Stanley et al. (1999) and others have reported that yellowtail rockfish exhibit diurnal vertical migrations in behavior associated with feeding on vertically migrating prey. Young-of-the-year commonly school with olive rockfish in nearshore kelp forests (Lea et al. 1999). This species is capable of making long distance movements from 158 to 1,000 kilometers (Starr et al. 1998; Lea et al. 1999). Yellowtail rockfish are viviparous (McCain 2003). Along the west coast, months of larval release occur from January to July off northern/central California with February or March peaks, February off Oregon, and January to April in British Columbia waters (Love et al. 2002).

Common Prey Species—Yellowtail rockfish prey upon fish (small hake, Pacific herring, smelt, anchovies, lanternfish), squid, mysids and other planktonic organisms (euphausiids, salps, pyrosomes) (Love 1996; McCain 2003).

1.4.3.3 Thornyhead

1.4.3.3.1 Longspine Thornyhead (Sebastolobus altrivelis)

Distribution—Longspine thornyhead range from Cabo San Lucas, southern Baja California to Shumagin Islands, western Gulf of Alaska (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996; Love et al. 2005) but are abundant from southern California northward (Love 1996).
Habitat Preference—Longspine thornyhead are found in relatively deep water ranging from 201 to 1,756 meters (Orr et al. 2000; Love et al. 2002), but most typically between 600 and 1,000 meters in the oxygen minimum zone (Eschmeyer et al. 1983; Wakefield and Smith 1990; Love et al. 2002). They inhabit softbottoms, preferably sand or muddy areas (Eschmeyer et al. 1983; Love 1996) associated with rocks and sponges (Love et al. 2002), or on seamounts (Casillas et al. 1998). Longspine thornyheads spend their entire benthic adult and large juvenile and part of their pelagic larval phases in the oxygen minimum zone (McCain 2003). Adults and juveniles are found at or near the bottom at depths from 400 to 1,400 meters (Casillas et al. 1998). Small juveniles and larvae are pelagic for 18 to 20 months before utilizing benthic habitats (McCain 2003). Juveniles settle on the continental slope at midwater depths, approximately 600 to 1,200 meters (Casillas et al. 1998). Longspine thornyhead larvae have been collected up to 560 kilometers off the California coast, but mostly more than 32 kilometers offshore (Cross 1987).

Life History—Longspine thornyhead neither schools, aggregates, nor exhibits any ontogenetic migration pattern (McCain 2003). However, Wakefield and Smith (1990) reported that this species displays ontogenetic migration when the eggs from the bathyal bottom rise to the surface and juveniles return to the bottom. Longspine thornyhead are oviparous and multiple spawners, spawning two to four batches per seasons (Wakefield and Smith 1990; Love 1996). Off California, longspine thornyhead spawn from about January to May and off Oregon, during March and April continuing into May (Love et al. 2002; Pearson and Gunderson 2003). This species is also a determined spawner in that all of the eggs spawned are developed at the same time and released at one spawning event (Love et al. 2002). Spawning occurs at depths of 600 to 1,000 meters (Wakefield and Smith 1990), with gelatinous egg masses that are released and float into the surface waters, from March to May (Wakefield and Smith 1990). The egg masses undergo rapid development to a feeding larval stage. Approximately 90 percent of the spawning populations reside in “a stratum bounded by the 500 and 1,100 meters isobaths” (Wakefield and Smith 1990).

Common Prey Species—Longspine thornyhead prey upon fish fragments, crustaceans, bivalves, and polychaetes (Love 1996).

1.4.3.3.2 Shortspine Thornyhead (Sebastolobus alascanus)

Distribution—Shortspine thornyhead range from Seas of Okhotsk and Japan to Bering Sea off Kamchatka (Love et al. 2005) and to Navarin Canyon and Aleutian Islands to Boca de Santo Domingo, southern Baja California (Casillas et al. 1998; Love 1996; Mecklenburg et al. 2002). They are most abundant off central California to the northern Kuril Islands (NMFS-NWR 2004c).

Habitat Preference—Shortspine thornyhead inhabit areas over the continental shelf and slope (Wakefield and Smith 1990) forming a deep-water assemblage, along with Pacific ocean perch and darkblotched, splitnose, redbanded, and rougheye rockfishes (Casillas et al. 1998). Although they can occur at depths as shallow as 17 meters (Love et al. 2002) and as deep as 1,524 meters (Orr et al. 1998, 2000), shortspine thornyhead are commonly found between depths of 100 and 850 meters (Casillas et al. 1998). Adults are found at or near the bottom over mud and near cobblestones, pebbles, sponges, and sea urchins (Love et al. 2002). Juveniles occupy shallower waters than adults (Love 1996) at depths between 100 and 600 meters (Jacobson et al. 2001) over muddy bottoms near rocks (Love et al. 2002). They spend 14 to 15 months in midwater before transforming to a benthic stage (Owen and Jacobson 1992). Recently settled and adult individuals are more abundant at the deep end of their range than the shallow end, while mid-sized individuals are more abundant at the shallow end (McCain 2003). Cross (1987) suggested that juveniles recruit to the bottom regardless of depth. Larvae are pelagic for 12 to 15 months and have been collected up to 560 kilometers off the California coast (Cross 1987; McCain 2003).

Life History—Early life history stages of the shortspine thornyhead are likely widely transported, primarily via the Alaskan Gyre system and the California Current (Stepien et al. 2000) and possibly transported northward by the California Counter Current (McCain 2003). During January to June, juveniles undergo ontogenetic migration settling onto the continental shelf and then move into deeper
water as they become adults (Casillas et al. 1998). Ontogenetic migration transports particulate organic carbon from the bottom to the surface by the eggs and particulate organic matter is moved from the surface back down to the bottom as recruiting juveniles (Wakefield and Smith 1990). Shortspine thornyhead are thought to be oviparous and single spawners in oxygen minimum zone at depths between 600 to 1,000 meters (Love 1996). Spawned bi-lobed, gelatinous hollow egg masses rise to the surface between December and May off the West Coast to develop and hatch (Wakefield and Smith 1990; Pearson and Gunderson 2003). Larvae are much more common north of Point Conception, California (Love 1996).

*Common Prey Species*—Shortspine thornyhead prey upon small crustaceans (shrimp, crabs, and amphipods), worms, and fishes including shortspine and longspine thornyheads (Owen and Jacobson 1992; Barnes et al. 2001).

### 1.4.3.4 Roundfish

Species known to occur in the NWTRC are described below. The arrangement is alphabetical by common name, regardless of species.

#### 1.4.3.4.1 Cabezon (*Scorpaenichthys marmoratus*)

**Distribution**—Cabezon are sculpins that range from southeast Alaska near Sitka to Punta Abreojos, central Baja California (O'Connell 1953; Miller and Lea 1972; Hart 1973). They are abundant from Washington to southern California (Love 1996). Northern and southern substocks exist off California (Cope and Punt 2005).

**Habitat Preference**—Cabezon is abundant year round in estuarine and subtidal areas and to mid-depths (110 meters) along the continental shelf (Miller and Lea 1972; Love 1996). They are found intertidally or in shallow, subtidal areas in the vicinity of kelp beds, jetties, isolated rocky reefs or pinnacles, and in shallow tide pools (Wilson-Vandenberg 1992). Rocky bottoms and cobble substrates are utilized most frequently along with eelgrass beds and occasionally sandy bottoms (O'Connell 1953). Off California, cabezon are found in moderate to high abundance in the waters along the inner shelf (CDFG 2002b); whereas they only infrequently occur at depths over 50 meters off Washington and Oregon (McCain et al. 2005). Cabezon is a member of a nearshore assemblage of 19 fishes including several *Sebastes* species that are included in California’s nearshore FMP (CDFG 2002b). Adults and large juveniles are found at or near the bottom (O'Connell 1953), residing primarily in shallow water bays and estuarine areas (Hart 1973). Adults tend to move to deeper waters (> 9 meters) with increased size (O'Connell 1953). Small juveniles and larvae are pelagic and planktivorous with neustonic planktivorous larvae being carried offshore (> 322 kilometers) by oceanic currents (O’Connell 1953). In California, juveniles first appear in kelp canopies, tidepools, and other shallow rocky habitats, such as breakwaters from April to June (O'Connell 1953; Quast 1968b). Larvae and eggs are found in estuaries from winter through spring (Casillas et al. 1998).

**Life History**—Cabezon are not known to make any significant migrations and are considered to be sedentary (Miller and Geibel 1973). They are known to move inshore with a flood tide and retreat offshore on an ebb tide to feed (O'Connell 1953, Miller and Geibel 1973). Cabezon spend most of their time sitting in holes on reefs, in pools, or on kelp blades beneath the canopy but do not actively swim (Wilson-Vandenberg 1992). Spawning is protracted with a seasonal progression that begins off California in winter and proceeds northward to Washington by spring (O'Connell 1953). Off California, spawning takes place from late October to March, peaking in January and February, while in Puget Sound, spawning season begins in November and extends into September, peaking in March and April (Wilson-Vandenberg and Hardy 2001, NMFS 2004c). Egg masses are fertilized externally. Cabezon spawn more than once per year but absolute fecundity is not known. It has been reported that cabezon spawn their eggs on subtidal, algae-free rocky surfaces in estuaries, which can be horizontal or vertical in orientation.
Cabezon spawn in the recesses of natural and man-made objects with males exhibiting nest-guarding behavior (Garrison and Miller 1982).

**Common Prey Species**—Cabezon prey upon crabs, small lobsters, mollusks such as abalone, squid, and octopus, fish eggs, and small fish (Quast 1968b, Love 1996).

### 1.4.3.4.2 Kelp Greenling (*Hexagrammos decagrammus*)

**Distribution**—Kelp greenling range from Attu Island, Aleutian Islands and Gulf of Alaska coasts (Mecklenburg et al. 2002) to La Jolla, southern California (Hart 1973; Kendall and Vinter 1984; Love 1996), but are common north of Morro Bay, central California (Mecklenburg et al. 2002).

**Habitat Preference**—Kelp greenling are abundant in coastal waters and inland seas, including Puget Sound (Hart 1973), from the intertidal zone to 130 meters (Love et al. 2005). They inhabit rocky reefs of shallow nearshore areas near dense algae or kelp beds (Hart 1973; Kendall and Vinter 1984; Love 1996). Adults, spawning adults, and large juveniles are found at or near the bottom (Casillas et al. 1998). Adults are not commonly found below 20 meters (Love 1996), although they may range down to depths of 52 meters (Howard 1992). In Puget Sound, females are most abundant between 7 and 12 meters with males preferring water three meters deep (Garrison and Miller 1982). Juveniles are commonly associated with rocky reefs and macroalgae (CDFG 2002b). Small juveniles and larvae are pelagic occurring in the upper 45 meters of the water column in spring and summer (Kendall and Vinter 1984). They have been reported up to 965 kilometers offshore from northern California northward (Casillas et al. 1998). Eggs are found at or near the bottom and found subtidally (Garrison and Miller 1982). Adults, spawning adults, large juveniles, and eggs prefer water temperatures between 9° and 13°C and favorable salinities of 27.5 to 29.9 psu (Patten 1980).

**Life History**—Kelp greenling are not a migratory species. Most adults inhabit depths of 13 meters or less all year round, which inhibits their migration (McCain et al. 2005). However, newly hatched larval migration may take up to a year when they move out of estuaries or shallow nearshore areas and into open waters (Garrison and Miller 1982). Kelp greenling are oviparous with external fertilization (Casillas et al. 1998). Spawning occurs in Puget Sound in the fall peaking in October and November, and in California in late fall to early winter (Garrison and Miller 1982; Howard and Silberberg 2001).

**Common Prey Species**—Kelp greenling prey upon sea squirts, shrimp, crabs, worms, octopus, brittle stars, snails, and small fishes (Howard 1992; Love 1996; Howard and Silberberg 2001).

### 1.4.3.4.3 Lingcod (*Ophiodon elongatus*)

**Distribution**—Lingcod range from Punta San Carlos, northern Baja California to Shumagin Islands, southeastern Gulf of Alaska (Love et al. 2005). Highest densities occur from Point Conception, California to Cape Spencer, Alaska (Miller and Lea 1972, Mecklenburg et al. 2002) with their center of abundance off British Columbia (Starr et al. 1998; Adams and Starr 2001).

**Habitat Preference**—Lingcod occupy the estuarine-mesobenthal zone occurring from the intertidal zone to 475 meters, but most commonly are found between 100 and 150 meters over a wide range of substrates (Allen and Smith 1988). Adults, spawning adults, and eggs are common in Puget Sound, Hood Canal, and Skagit Bay in Washington and Humboldt Bay in northern California. Juveniles are common in most large estuaries between Puget Sound and San Pedro Bay, California. Larvae are common in most Washington estuaries as well as Coos Bay, Oregon and throughout San Francisco Bay in central California (Emmett et al. 1991). Adults, older juveniles, young larvae, and eggs are found at or near the bottom (Allen and Smith 1988; Shaw and Hassler 1989). The two main habitats preferred by adults are:

- Slopes of submerged banks, such as the Heceta Bank, that are 10 to 70 meters below the surface with seaweed, kelp, and eelgrass beds that form feeding grounds for small prey fish; and
Channels with swift currents that flow around rocky reefs that concentrate plankton and plankton-feeding fish (Shaw and Hassler 1989; Emmett et al. 1991; Love 1996).

Older larvae and very young juveniles are surface, primarily found in the upper three meters of the water column (Adams and Hardwick 1992) in waters greater than 150 meters deep. Off California, pelagic juveniles occur in the upper 35 meters of surface waters (Casillas et al. 1998) and prefer sandy and rocky substrates in subtidal zones and estuaries (Hart 1973; Shaw and Hassler 1989; Emmett et al. 1991; CDFG 2002b). Larvae and eggs occur in nearshore areas from winter through late spring. Egg masses are found in rocky reefs/ledges where they are wedged in rock crevices or under overhanging boulders allowing water currents of 3.5 kilometers per hour (kilometers/hr) or greater to maintain their interstitial oxygen levels (Hart 1973; Miller and Geibel 1973; Adams and Hardwick 1992). All life history stages occur in polyhaline to euhaline waters (18 to 30+ psu) that have temperatures between 5° to 15°C, although juveniles may also be found in mesohaline waters (5 to 18 psu) (Simenstad 1983; Shaw and Hassler 1989; Emmett et al. 1991).

**Life History**—Lingcod are considered a relatively sedentary species, living their whole lives associated with a single rock reef, possibly out of fidelity to a prime spawning or feeding area (Allen and Smith 1988; Shaw and Hassler 1989). Migrations greater than 100 kilometers have been reported but were typically undertaken by sexually immature fish (Smith et al. 1990). Larvae are carried by tidal currents into rearing areas within estuaries undergoing metamorphosis in early summer, while juveniles rear until winter before moving to deeper waters (Miller and Geibel 1973) Mature females live in deeper water than males and move from deep water to shallow water in the winter to spawn (Hart 1973; Casillas et al. 1998). Lingcod are oviparous, iteroparous, and gonochoristic with external fertilization (Shaw and Hassler 1989; Emmett et al. 1991). Spawning takes place from December through April in waters 3 to 10 meters below mean lower low water (MLLW) (lowest tide) over rocky reefs in areas of swift current (Adams and Hardwick 1992). Eggs masses are laid in rock crevices or on rocky reefs (Hart 1973). Males guard the nest until hatching, usually about six weeks (Shaw and Hassler 1989).

**Common Prey Species**—Lingcod prey upon fish commonly found at or near the bottom, such as spiny dogfish, Pacific herring, walleye pollock (*Theragra chalcogramma*), rockfish greenlings, small lingcods, and Pacific sand lance, and squids, octopus, and crabs (Hart 1973; Miller and Geibel 1973; Garrison and Miller 1982; Shaw and Hassler 1989).

### 1.4.3.4.4 Pacific Cod (*Gadus macrocephalus*)

**Distribution**—Pacific cod range from Yellow Sea off Manchuria, China, east to the Bering Sea, Aleutian Islands, and Gulf of Alaska, and south to Santa Monica, southern California (Miller and Lea 1972; Hart 1973; Allen and Smith 1988; Love 1996). Pacific cod in Puget Sound are generally categorized into three components: (1) North Sound: located in U.S. waters north of Deception Pass, including the San Juan Islands, Strait of Georgia, and Bellingham Bay; (2) West Sound: located west of Admiralty Inlet and Whidbey Island and in the U.S. section of the Strait of Juan de Fuca, including Port Townsend; and (3) South Sound: located south of Admiralty Inlet (Stout et al. 2001).

**Habitat Preference**—Pacific cod, a member of the inner shelf-mesobenthal community, is found near surface to a depth of 875 meters (Allen and Smith 1988), with the vast majority occurring between 50 and 300 meters depths (Hart 1973; Allen and Smith 1988; Love 1996). Pacific cods are inhabitants of shallow, softbottom habitats in marine and estuarine environments (Garrison and Miller 1982). All life stages occur in the various bays in Puget Sound and the Strait of Juan de Fuca near Vancouver Island (Garrison and Miller 1982). Adults and large juveniles transition between midwater pelagic and benthic habitats, preferring mud, sand, and clay, as well as coarse sand and gravel substrates (Garrison and Miller 1982). Small juveniles and larvae are pelagic (McCain 2003). Small juveniles usually settle between 60 and 150 meters depth, gradually moving into deeper water with increased age; whereas larvae are found in the upper 45 meters of the water column with the highest abundance occurring between 15 and 30 meters (Casillas et al. 1998). Larvae and eggs are found over the continental shelf between Washington
and central California from winter through summer (McCain 2003). Adults are found in marine waters, whereas juveniles occur in polyhaline to euhaline waters (McCain et al. 2005). Eggs are found at or near the bottom, adhesive, and occur sublittorally in polyhaline to euhaline waters at temperatures between 1° and 10°C (Hart 1973).

**Life History** — Although not typically considered a migratory species, Pacific cod have been known to move more than 1,000 kilometers (Casillas et al. 1998). Genetic analysis indicates two spawning stocks exist in North America: a seasonal bathymetric movement from deep spawning areas of the outer shelf and upper slope in fall and winter to shallow middle-upper shelf feeding grounds in the spring (Hart 1973; Casillas et al. 1998). Larvae may be transported by tidal currents to nursery areas (Casillas et al. 1998). There is also some evidence to suggest that the fish move into deeper water with age (Hart 1973), although adults are not found exclusively in deeper water (McCain 2003). Pacific cod are oviparous with external fertilization (Hart 1973). Spawning typically occurs at depths between 40 to 265 meters from late fall to early spring in Puget Sound (Garrison and Miller 1982) and in winter through spring in the Gulf of Alaska and the Bering Sea (McCain 2003). No spawning occurs below 0°C or above 10° to 13°C, speculating that eggs may experience high mortality or decreased development (Casillas et al. 1998).

**Common Prey Species** — Pacific cod prey upon various organisms depending on its size: shrimp, mysids, and amphipods (2 to 40 centimeters), crabs and amphipods (40 to 50 centimeters), Pacific sand lance (50 to 70 centimeters), and walleye pollock (70+ centimeters) (Allen and Smith 1988; McCain 2003).

### 1.4.3.4.5 Pacific Flatnose (*Antimora microlepis*)

**Distribution** — Pacific flatnose (formerly known as finescale codling) (Nelson et al. 2004) range from off southern Japan to Sea of Okhotsk, to Bering Sea and Gulf of Alaska, and south to Gulf of California (Allen and Smith 1988).

**Habitat Preference** — Pacific flatnose are mesobenthal-bathybenthal over the continental slope with a reported depth range of 175 to 3,048 meters (Allen and Smith 1988). This species has been caught at depths up to 1,275 meters, most often on the bathybenthal slope between 800 and 850 meters (Allen and Smith 1988).

**Life History** — Information is unavailable on the migrations and movements of the Pacific flatnose (McCain 2003). Sexes apparently segregate by depth with males occurring in shallower waters and females in deeper waters (McCain et al. 2005).

**Common Prey Species** — Pacific flatnose prey upon benthic macrofauna, especially crustaceans, squid, and fish (McCain et al. 2005).

### 1.4.3.4.6 Pacific Grenadier (*Coryphaenoides acrolepis*)

**Distribution** — Pacific grenadiers (formerly known as Pacific rattail) (Eschmeyer et al. 1983) range from the Sea of Okhotsk off Japan to the southern Bering Sea and Aleutian Islands to Isla Guadalupe, central Baja California (Hart 1973; Mecklenburg et al. 2002).

**Habitat Preference** — Grenadiers are among the most abundant fish of the continental slope and abyssal waters worldwide (Matsui and Kato 1990). They are benthopelagic and bathypelagic species that have been reported as shallow as 35 and 155 meters and as deep as 2,825 meters (Love et al. 2005). These species commonly occur between 600 and 2,500 meters off Oregon and Washington State in the northeast Pacific Ocean on sandy bottoms of the abyssal plain (Hart 1973; Mecklenburg et al. 2002). Specific habitat associations are unavailable for any life history stage of the Pacific grenadier (McCain et al. 2005).

**Life History** — Migrations have not been documented and it is assumed that the Pacific grenadier is a relatively sedentary species (McCain 2003). Older larvae and juveniles occur deeper suggesting a movement with increasing size, whereas larval stages have been captured in the water column at depths less than 200 meters (Casillas et al. 1998).
Pacific grenadiers are oviparous with external fertilization (Casillas et al. 1998). In more northern areas, ripe females have been collected in September, October, and April implying the possibility of two spawning seasons per year (Iwamoto 1992; McCain et al. 2005). Off southern California, spawning occurs mostly from late winter to early spring, although spent females are found throughout the year (Iwamoto 1992). Spawning depth is unavailable on the Pacific grenadier (Iwamoto 1992).

**Common Prey Species**—Pacific grenadier prey upon cephalopods, other demersal fishes (i.e., other macrourids), and sinking food particles of dead nekton (Iwamoto 1992; McCain 2003).

### 1.4.3.4.7 Pacific Hake (*Merluccius productus*)

**Distribution**—Pacific hake or Pacific whiting, of the coastal stock, range from Attu Island in the western Gulf of Alaska to Magdalena Bay, southern Baja California (Mecklenburg et al. 2002) but are most abundant in the CCS between Baja California and British Columbia (Hart 1973; Love 1996). In addition to the coastal stock, there are three much smaller stocks with reduced ranges in Puget Sound, Washington and Strait of Georgia, British Columbia; and a dwarf stock limited to waters off Baja California (Bailey et al. 1982).

**Habitat Preference**—Coastal stock of Pacific hake inhabit the continental slope and shelf within the CCS (Quirollo 1992; Mecklenburg et al. 2002). Currently, the coastal stock utilizes three habitats: (1) a narrow 30,000 square kilometers (km²) feeding habitat near the shelf break of British Columbia, Washington, Oregon and California populated six to eight months per year; (2) a broad 300,000 km² open-sea area of California and Baja California populated by spawning adults in the winter and embryos and larvae for four to six months a year; and (3) a continental shelf area of unknown size off California and Baja California, where juveniles brood (P.E. Smith 1995).

Adults, juveniles, larvae, and eggs are pelagic (MBC 1987) ranging in depths from 12 to 1,400 meters (Love et al. 2005). Adults are surface-subsurface (Sumida and Moser 1980) occurring as deep as 920 meters with highest densities between 50 and 500 meters and as far offshore as 400 kilometers (Hart 1973; Bailey et al. 1982; Dark and Wilkins 1994; Dorn 1995). Juveniles reside in shallow coastal waters, bays, and estuaries at depths less than 200 meters (Bailey et al. 1982; P.E. Smith 1995); are less abundant in upwelled nearshore coastal waters compared to non-upwelled water (Sakuma and Ralston 1995); and have their highest densities in submarine canyons at depths of 150 to 200 meters (McCain 2003). Larvae of 8 to 12 mm are found at 100 to 300 meters, whereas those greater than 12 mm occur primarily below 200 meters (Bailey et al. 1982). Abundance and distribution of hake larvae are strongly influenced by prevailing currents (Horne and Smith 1997) and aggregate near the base of the thermocline or mixed layer of low-salinity water on top on well-mixed marine waters (McCain 2003). The majority of eggs occur at depths ranging between 50 to 150 meters, with early-stage eggs usually occurring at 75 to 150 meters and later-stage eggs occurring at 50 to 100 meters) (Moser et al. 1997). All life stages are found in water with salinities of 29.3 to 33.6 psu and temperatures from 9° to 17°C (Garrison and Miller 1982; MBC 1987).

**Life History**—Pacific hake are highly migratory moving between the nearshore shelf, shelf break, and slope (McCain et al. 2005). In April, the coastal stocks undertake extensive annual migrations from offshore spawning areas in Baja California (Saunders and McFarlane 1997), moving inshore, following food supply and Davidson Current to summer feeding grounds off northern California, Oregon, and Washington, and Vancouver Island, British Columbia (Quirollo 1992). By late summer or fall, Pacific hake move offshore from their feeding grounds and undergo a southern migration to their spawning grounds utilizing the southward flowing California Current (Bailey et al. 1982; Dorn 1995; P.E. Smith 1995). Stocks in the Strait of Georgia and Puget Sound undergo similar migration patterns, but on a greatly reduced scale (McCain et al. 2005). During the summer, Pacific hake form extensive midwater aggregations (22 kilometers long x 14 kilometers wide) near the continental shelf break, with highest densities located over bottom depths of 200 to 300 meters (Quirollo 1992). Pacific hakes school at depth during the day, then move to the surface and disband at night for feeding (Sumida and Moser 1984).
Pacific hake are oviparous, pelagic spawners with external fertilization, spawning at least once per season (Casillas et al. 1998). The coastal stock (Magdalena Bay, Baja California to Cape Mendocino, California) spawns from December through March, peaking in late January (P.E. Smith 1995). Spawning aggregations begin a month prior to gamete release, with spawning occurring at depths between 130 and 500 meters (Bailey et al. 1982; P.E. Smith 1995). The interior Pacific hake stocks spawn and live their entire lives within Puget Sound (Quirollo 1992). Spawning in the Strait of Georgia occurs from March through May, peaking in late April, and in Puget Sound, from February through April, peaking in March (McCain et al. 2005). In both areas, spawning occurs in locations proximate to major sources of freshwater inflow near the Frazier River in the Strait of Georgia and near the Skagit and Snohomish rivers in Port Susan (McCain et al. 2005).

Common Prey Species—Pacific hake prey on euphausiids, amphipods, squid, pandalid shrimp, smelt, crabs, and occasionally on Pacific hake and pelagic schooling fish (eulachon and herring) (Bailey et al. 1982; Dark and Wilkins 1994). The diet of the Pacific hake varies:

- With latitude, with northern anchovy and rockfish as primary prey species in central California, and Pacific herring as primary prey off Vancouver Island, British Columbia, Washington, and Oregon.
- By season, with euphausiids representing an important food source off Oregon and Washington in the summer, compared to fish and shrimp in the autumn and fish in the spring. Off California, there is considerable autumn cannibalization of Pacific hake (Buckley and Livingston 1997).

### 1.4.3.4.8 Sablefish (Anoplopoma fimbria)

**Distribution**—Sablefish range from off central Honshu, Japan, to Aleutian Islands and Bower Banks to Bering Sea, south of St. Lawrence Island, Alaska, and southeast to Cedros Island, central Baja California. This species is uncommon south of Point Conception, California, and most abundant in the Gulf of Alaska (Hart 1973; McFarlane and Beamish 1983a, 1983b; MBC 1987; Love 1996). There are at least three genetically distinct stocks: (1) south of Monterey Bay characterized by slower growth rates and smaller average size; (2) northern California to Washington that is characterized by moderate growth rates and sizes; and (3) off British Columbia and Gulf of Alaska characterized by fast growth rates and larger sizes. Only the northern California to Washington stock occurs within the NWTRC (Schirripa and Colbert 2005).

**Habitat Preference**—Sablefish is an inner shelf-bathybenthal species that is found over soft substrates in deep marine waters (Love 1996). Adults and larger juveniles are benthopelagic (Hart 1973). Adults occur as deep as 2,700 meters but are most abundant at depths between 200 and 1,200 meters; whereas juveniles are rarely found at depths less than 200 meters (Mason et al. 1983; Love 1996; Jacobson et al. 2001). Adults and large juveniles form schools over sand and mud (McFarlane and Beamish 1983a), occur on hard-packed mud and clay bottoms in the vicinity of submarine canyons (MBC 1987), and are associated with seamounts, such as the Heeeta Bank (McCain 2003). Small juveniles, larvae, and eggs are pelagic (Hart 1973). Small juveniles inhabit the upper 100 meters of the water column (MBC 1987) and newly hatched larvae and eggs usually occur deeper than 300 meters (Hart 1973). Small juveniles and larvae are found up to 370 kilometers offshore, often near drifting kelp (McCain 2003). The distribution of larvae in the water column is strongly influenced by the onset of upwelling conditions (McFarlane et al. 1997). All life stages occur in euhaline waters at temperatures of 2.9° to 21.0°C: adults/large juveniles - 2.9° to 6.5°C; small juveniles - 11.7° to 16.5°C; larvae - 5.6° to 16.5°C; and eggs - 3.8° to 6.5°C (Mason et al. 1983; MBC 1987).

**Life History**—Sablefish are a non-migratory species, although some individuals have been recorded moving up to 2,735 kilometers to mid-ocean seamounts (Love 1996). Sexually mature adults do not undergo any spawning migration (Hart 1973; Mason et al. 1983; McFarlane and Beamish 1983a). Small juveniles descend to the bottom during the fall and remain in relatively shallow water for about a year.
before moving into deeper water (MBC 1987). Sablefish seem to have a deeper, lower limit to their distribution off the West Coast as compared with their distribution off Alaska (McCain 2003). Hart (1973) recognized localized movement from shallow summer waters to deeper waters in the winter. Sablefish are batch spawners and oviparous with external fertilization (Love 1996; Casillas et al. 1998). Spawning occurs annually in waters deeper than 300 meters along the continental slope (Hart 1973) from late fall through winter but varies with latitude (Monterey Bay in central California: November to February; and Canadian Pacific coast: January through April, peaking in February) (Mason et al. 1983; MBC 1987). The peak spawning biomass of sablefish is located within the deep waters of the oxygen minimum zone (Casillas et al. 1998). The ontogenetic movement of sablefish into deep water to spawn is more strongly correlated with age than with size (Schirripa and Colbert 2005).

**Common Prey Species**—Sablefish prey on fish (including rockfish, northern anchovy, and Pacific herring), shrimp, crabs, and octopus, but their predominant prey includes euphausiids (Hart 1973; McFarlane and Beamish 1983a; McCain 2003).

1.4.3.5 Skates, Sharks, and Chimeras

This group includes three species of skates (big, California, and longnose), three species of sharks (leopard, soupfin, and spiny dogfish), and one species of chimeras (spotted ratfish). Information on each of these species is provided below.

1.4.3.5.1 Big Skate (*Raja binoculata*)

**Distribution**—Big skate range from Bering Sea and Aleutian Islands, at least as far west as Unalaska Island, to eastern Gulf of Alaska, south to Cabo Falsa, southern Baja California, and the Gulf of California (Love et al. 2005). They are uncommon south of Point Conception, California, but relatively abundant in northern and central California (Roedel and Ripley 1950; Allen and Smith 1988; Ebert 2003; NMFS-NWR 2004c; FLMNH).

**Habitat Preference**—Big skate occupies inner and outer shelf areas (Allen and Smith 1988) at depths up to 800 m. They inhabit inner shelf waters as shallow as two meters or less in bays but are found most frequently on the outer shelf in waters 50 to 200 meters deep (Allen and Smith 1988). Big skates have also been associated with silty sediment or with sediment consisting of a mixture of mud, sand, gravel, and cobble as well as in habitats, such as the Heceta Bank that consist of mud and sea urchins (*Allocentrotus*; McCain et al. 2005). Juveniles are associated with softbottom sediments (CDFG 2002b).

**Life History**—Information is unavailable on the migrations and movements of the big skate (McCain et al. 2005). Big skates are oviparous with fertilized internal eggs that are deposited on the bottom to hatch and develop (Casillas et al. 1998). Eggs are covered with a thick leathery membrane (case) and can measure up to 30 centimeters in length (Eschmeyer et al. 1983). Egg cases are laid year round or possibly seasonal, containing up to seven eggs per case with an average of three to four (Eschmeyer et al. 1983; McCain 2003).

**Common Prey Species**—Big skates prey upon crustaceans, small benthic fishes, polychaete worms, and mollusks (Hart 1973; Eschmeyer et al. 1983; Ebert 2003).

1.4.3.5.2 California Skate (*Raja inornata*)

**Distribution**—California skate range from the Strait of Juan de Fuca, Canada to Cedros Island, central Baja California and the Gulf of California (Roedel and Ripley 1950; Ebert 2003). This species is common off most of the California coast (Roedel and Ripley 1950).

**Habitat Preference**—California skate occur inshore and in shallow bays (13 meters) (Eschmeyer et al. 1983). This species has been caught as deep as 1,600 meters (Eschmeyer et al. 1983) but typically inhabits a depth range of 17 to 671 meters (Ebert 2003). Adults and juveniles inhabit inshore soft muddy
bottoms sediments (Roedel and Ripley 1950; CDFG 2002b) and habitats, such as the Heceta Bank, that consist of mud and sea urchins (Allocentrotus) (McCain et al. 2005).

**Life History**—Information is unavailable on the migrations and movements of the California skate (McCain et al. 2005). California skates are oviparous, have internal fertilization, and deposit their eggs on the bottom to develop and hatch (Casillas et al. 1998). Eggs are encased in a distinctive smooth-surfaced leathery case with horns (Roedel and Ripley 1950; Eschmeyer et al. 1983). Upon hatching, the young are fully developed, although they do have a yolk sac that is gradually absorbed (Casillas et al. 1998).

**Common Prey Species**—California skate feeds on shrimp and other invertebrates such as polychaete worms (Ebert 2003).

### 1.4.3.5.3 Longnose Skate (*Raja rhina*)

**Distribution**—Longnose skate range from southeastern Bering Sea to just below Punta San Juanico, southern Baja California and the Gulf of California (Allen and Smith 1988; Ebert 2003).

**Habitat Preference**—Longnose skate is one of the more common skates (Roedel and Ripley 1950) occurring on the bottom of the inner and outer shelf areas from 9 to 1,069 meters depths (Ebert 2003). It is most commonly found at depths ranging from 100 to 150 meters (Allen and Smith 1988). Adults and juveniles are typically associated with softbottom sediments and with combinations of mud and cobble near high-relief structures (CDFG 2002b; Ebert 2003).

**Life History**—Information is unavailable on the migrations and movements of the longnose skate (McCain et al. 2005). Longnose skates are oviparous with internal fertilization depositing their eggs on the bottom to develop and hatch. Eggs are laid in an enclosed rough, leathery shell with a loose covering of fibers and short horns (Eschmeyer et al. 1983). The egg cases generally contain one egg per case (Roedel and Ripley 1950; Hart 1973). The young are fully developed when the eggs hatch, although they do contain a yolk sac that is gradually absorbed (Casillas et al. 1998).

**Common Prey Species**—Longnose skates less than 60 centimeters prey upon crustaceans and those greater than 60 centimeters prey upon bony fishes (Ebert 2003).

### 1.4.3.5.4 Leopard Shark (*Triakis semifasciata*)

**Distribution**—Leopard shark range from southern Oregon to Mazatlan, Mexico, including the Gulf of California (Eschmeyer et al. 1983; Ebert 2003; FLMNH). This species is most abundant in northern California bays and estuaries and along southern California beaches (Ebert 2003).

**Habitat Preference**—Leopard shark is a coastal species that is common in enclosed, muddy bays and sloughs (northern California) as well as flat, sandy areas, mud flats, sandy and muddy bottoms strewn with rocks near rocky reefs, and kelp beds (southern California) from the surf zone to 156 meters (Eschmeyer et al. 1983; Compagno 1984b; Emmett et al. 1991; Smith 2001; Love et al. 2005). This species also inhabits littoral waters (Castro 1983; Eschmeyer et al. 1983; Compagno 1984b; Emmett et al. 1991), areas around jetties and piers (Emmett et al. 1991), and congregates around warm water outfalls of power plants (Smith 2001). Leopard sharks are most common on or near the bottom in waters less than 20 meters deep but have been collected in waters greater than 91 meters (Emmett et al. 1991). Estuaries (Monterey Bay) (Emmett et al. 1991; Starr et al. 1998) and shallow coastal waters (Smith 2001) are used as pupping and feeding/reeing grounds. Neonate pups occur in and just beyond the surf zone in Santa Monica Bay (Smith 2001) and near eel grass beds in other bays such as San Francisco and Humboldt (Ebert 2003). This species occurs in polyhaline to euhaline waters (NMFS-NWR 2004c).

**Life History**—Leopard shark often enters shallow bays and intertidal flats during high tides, retreating on ebb tides. Unlike other nocturnal sharks, this species is active during the day, (Eschmeyer et al. 1983; Emmett et al. 1991). They may form large nomadic schools composed of single sexes or size cohorts that may be mixed with gray (*Mustelus californicus*) or brown (*M. henlei*) smoothhounds, sevengill sharks (*Notorynchus cepedianus*), bat rays, or spiny dogfish (Castro 1983; Compagno 1984b; Emmett et al. 1991).
Leopard sharks are gonochoristic, ovoviviparous, and iteroparous (Emmett et al. 1991). Internal fertilization and embryogenesis occur within the female; there is no yolk-sac placenta (Castro 1983; Emmett et al. 1991). This species has a gestation period lasting 10 to 12 months (Castro 1983; Emmett et al. 1991). Mating occurs soon after the females give birth, primarily in April and May. Females give birth to 7 to 36 pups (Smith 2001) from March to August (Compagno 1984b; Love 1996).

**Common Prey Species**—Leopard shark prey upon cancrid crabs, clam siphons, fishes, polychaetes, echiuroid worm (*Urechis caupo*), and fish eggs from herring, topsmelt, jacksmelt (*Atherinopsis californiensis*), and midshipmen fish (genus *Porichthys*) (Compagno 1984b; Love 1996).

### 1.4.3.5.5 Soupfin Shark (*Galeorhinus zyopterus*)

**Distribution**—Soupfin shark range from northern British Columbia to Gulf of California and Ecuador to Chile (Roedel and Ripley 1950; Hart 1973; Compagno 1984b).

**Habitat Preference**—Soupfin shark is an abundant coastal-pelagic species of temperate continental and insular waters that is often associated with bottom habitats (Compagno 1984b) such as bays and muddy shallows (Eschmeyer et al. 1983). Soupfin sharks often occur at depths as shallow as two meters but are also found in submarine canyons up to 1,100 meters deep (Compagno 1984b). Male and female soupfin sharks segregate by sex (Casillas et al. 1998), with adult males favoring deep waters and females, shallow waters (Compagno 1984b). The proportion of males is greater in northern waters off California with females occurring mostly in southern California waters and a mixture of sexes in central California waters (Roedel and Ripley 1950; Castro 1983; Eschmeyer et al. 1983; Ebert 2003). Young soupfin sharks are abundant in southern California waters, probably as a result of the larger female population in the area (Casillas et al. 1998).

**Life History**—Soupfin shark forms dense schools exhibiting a coastwide movement, migrating north in the summer and southward in the winter (Castro 1983). This species has extensive movements, without recognizable patterns, of up to 56 kilometers/day, with sustained speeds of 16 kilometers/day for 1,600 kilometers (Hart 1973; Eschmeyer et al. 1983; Compagno 1984b). Soupfins are ovoviviparous with mating occurring during the spring (Ebert 2003). After a gestation period of approximately one year, females move into bays to bear their live young in litters ranging in size from 6 to 52 pups (Roedel and Ripley 1950; Hart 1973; Castro 1983; Eschmeyer et al. 1983; Compagno 1984b) averaging 35 pups (Ebert 2003). The primary nursery grounds are south of the NWTRC in inshore areas south of Point Conception. In central California, San Francisco and Tomales bays are utilized to a certain extent as pupping grounds (Compagno 1984b).

**Common Prey Species**—Soupfin shark prey upon herrings, sardines and other clupeids, anchovies, salmon, smelt, hake, cod, lingcod, midshipmen fish (genus *Porichthys*), flying squid (*Ommastrephes bartrami*), mackerel and small tuna, barracuda (*Sphyraena argentea*), croakers, wrasses, opaleye (*Girella nigricans*), surfperches, damselfishes, gobies, kelp fish, halibut and other flatfishes, rockfishes and scorpionfish, sculpins, sablefish, cephhalopods, marine snails, crab, shrimp, annelid worms, echinoderms and uncommonly on other chondrichthyians such as ratfish, sharks, and small stingrays and skates (Compagno 1984b; Ebert 2003).

### 1.4.3.5.6 Spiny Dogfish (*Squalus acanthias*)

**Distribution**—Spiny dogfish sharks are found in temperate and subarctic latitudes in both the northern and southern hemispheres. In the northern and central Pacific Ocean, they range from Yellow Sea off China to Bering Sea and southeastern Chukchi Sea, Alaska to Gulf of California (Castro 1983; Eschmeyer et al. 1983; Allen and Smith 1988; Mecklenburg et al. 2002; FLMNH). This species is common in inlands seas, such as the San Francisco Bay and Puget Sound (Castro 1983; Allen and Smith 1988) and in shallow bays from Alaska to central California (Eschmeyer et al. 1983).
Habitat Preference—Spiny dogfish is an inner shelf-mesobenthal species that occurs from the surface and intertidal areas at depths ranging from intertidal zone to 1,244 meters and perhaps as deep as 1,446 meters (Love et al. 2005) but is commonly found in waters less than 350 meters (Castro 1983; Allen and Smith 1988). Adults and subadults are mostly sublittoral-bathyal (Ebert 2003). Adults occur at depths less than 350 m; whereas subadults are found on muddy bottoms, when not found in the water column less than 200 meters depth (Casillas et al. 1998). Small juveniles (< 10 years old) are pelagic occurring at depths less than 100 meters (Ebert 2003). All life stages occur in euhaline waters at temperature ranges of 7° to 15°C (Ebert 2003; McCain et al. 2005).

Life History—Seasonal migrations of offshore populations of spiny dogfish sharks result from a desire to stay within their preferred temperature range (Castro 1983). Schooling occurs with inshore populations and with migratory offshore populations (Eschmeyer et al. 1983). The schools, numbering in the hundreds, exhibit north-south coastal movements and onshore-offshore movements (Castro 1983). These schools tend to divide up according to size and sex, although young males and females tend to stay together (Casillas et al. 1998). Spiny dogfish also make diel migrations from near bottom habitats during the day to near surface habitats at night (McCain 2003). Spiny dogfish are viviparous and have internal fertilization (Castro 1983; Eschmeyer et al. 1983; Ebert 2003) with males and females mating annually on the ocean bottom between September and January (Casillas et al. 1998). The spiny dogfish’s gestation period lasts 18 to 24 months, one of the longest of any aquatic vertebrate (Nammack et al. 1985). The long gestation period of the spiny dogfish contributes to their vulnerability to overfishing. Adult females move inshore to shallow waters during the spring to release their young in the midwater zone over depths of 165 to 300 meters with the litter size ranging from 2 to 20 pups (Ebert 2003).

Common Prey Species—Spiny dogfish prey primarily on fish (including Pacific sand lance, herring, smelts, cods, capelin, hake, and ratfish) and invertebrates like shrimp, crabs, worms, krill, squid, octopus, jellyfish, and sea cucumbers (Castro 1983; Ebert 2003; McCain et al. 2005).

1.4.3.5.7 Spotted Ratfish (Hydrolagus colliei)

Distribution—Spotted ratfish, a shortnose chimaeras, range from the western Gulf of Alaska to near Punta Prieta, southern Baja California and northern Gulf of California (Miller and Lea 1972; Allen and Smith 1988; Mecklenburg et al. 2002).

Habitat Preference—Spotted ratfish is a middle-shelf-mesobenthal species that is found from the intertidal zone to almost 1,000 meters, but occurs most frequently between depths of 100 and 150 meters (Allen and Smith 1988). This species is a deepwater fish that prefers low-relief rocky bottoms, exposed gravel and cobble, and mud and sea urchins (Allocentrotus), such as those that occur along the Heceta Banks, as a habitat (McCain et al. 2005). All free-swimming life history stages are at or near the bottom and share essentially the same habitat with no partitioning by age or size (Casillas et al. 1998). Spotted ratfish inhabit larger estuaries for feeding and mating throughout its range, especially from early winter to late spring (Love 1996). They are more common in shallow waters (intertidal/subtidal) to the north (bays and sounds) and in deeper waters (> 30 meters) to the south (southern California) (Love 1996; Ebert 2003). All life stages occur in waters temperature of 7.2° to 8.9°C (Ebert 2003).

Life History—Spotted ratfish occur singly, in small groups or in large aggregations (Love 1996). They make significant seasonal and diel migrations (Love 1996). In the winter, they move into shallow nearshore waters and estuaries, for feeding and pre-spawn mate selection (Casillas et al. 1998). In Puget Sound and other estuaries, spotted ratfish move from deep water by day to shallower water at night, which is undertaken mostly by smaller fish. This type of diel migration suggests that deep water is the preferred feeding ground for young spotted ratfish or a means of predator avoidance (Casillas et al. 1998). Spotted ratfish are oviparous with internal fertilization (Love 1996). Mating occurs at all times throughout the year but seems to peak from late summer to early fall. Spotted ratfish, regardless of size or age, produce only two egg cases per year (Kato 1992). Eggs are attached by the mother to rocks or placed
upright in the sand (Hart 1973). In the summer and fall, ratfish move offshore into deep waters to deposit egg cases (Casillas et al. 1998).

**Common Prey Species**—Spotted ratfish prey upon isospondylous (herring-like) fishes, mollusks, squid, nudibranchs, opistobranchs, annelids, and small crustaceans such gammarid amphipods (Hart 1973; Allen and Smith 1988; Love 1996; Ebert 2003).

### 1.4.4 Highly Migratory Species

Within the NWTRC, highly migratory species with designated EFH include the following: common thresher shark (*Alopias vulpinus*), bigeye thresher shark (*Alopias superciliosus*), shortfin mako shark (*Isurus oxyrinchus*), blue shark (*Prionace glauca*), albacore tuna (*Thunnus alalunga*), northern bluefin tuna (*Thunnus orientalis*), and broadbill swordfish (*Xiphias gladius*). These species are distributed over wide areas of the open ocean, waters of the continental shelf, and coastal waters (PFMC 2003c). Only the common thresher shark and blue shark have been reported as rare sightings around San Juan Islands (1972) and in Puget Sound (1881, 1882, and 1917), respectively (DeLacy et al. 1972; Miller and Borton 1980; DeVaney). As a group, highly migratory species are managed by the PFMC under the supervision of the NMFS-Southwest Region (NMFS 2004h). In the NWTRC, the only highly migratory species harvested in significant quantities is the albacore tuna (PFMC 2005d).

The PFMC monitors other species for informational purposes, and some species including great white sharks, megamouth sharks, basking sharks, Pacific halibut, and Pacific salmon are designated as prohibited. If fishers targeting highly migratory species catch these species, they must release them immediately.

Highly migratory species are not correlated with the areas or features that typify most fish habitat, such as bottom substrate or submerged vegetation, but rather are associated with physiographic and hydrographic features, such as ocean fronts, current boundaries, the continental shelf margin, or seamounts. These characteristics, along with the fact that these fishes generally occur in the open ocean and frequent nearshore waters, complicate the process of identifying essential habitat except in a broad context. They exhibit both horizontal and vertical movements, as well as travel great distances inshore, offshore, and for seasonal migrations. The distributions of the various life stages are also constrained by temperature, salinity, and oxygen concentrations. The majority of the resulting habitat parameters are dynamic, changing both spatially and temporally. EFH has not been designated for the highly migratory species in the marine and estuarine waters of Puget Sound’s inshore basins (PFMC 2003c), and no habitat areas of particular concern in the NWTRC have been designated (Moncada et al. 2004).

### 1.4.4.1 Sharks

Sharks are highly mobile predators that rely on their non-visual senses – electroreception, have slow metabolism, grow and mature slowly, and produce small numbers of young. These factors make them extremely susceptible to commercial exploitation and environmental degradation precipitating rapid stock declines or collapses from which recovery may take decades (Helfman et al. 1999; Musick 1999). The PFMC manages five species of Pacific sharks to protect them from overfishing and finning, the practice of removing the fins from a shark’s body and dumping the remainder of the fish back into the water (Allen 1999; NMFS 2002a; PFMC 2003c).

The four shark species found in the NWTRC have EFH described for their three life stages – neonate/early juvenile, late juvenile/subadult, and adult (PFMC 2003c). All four species presented in this section are pelagic sharks. Pelagic sharks occupy large portions of the marine environment that include surface, subsurface, oceanic, and neritic zones. Pelagic sharks are widely distributed over the upper oceanic zones and are capable of traveling over entire ocean basins (PFMC 2003c).
1.4.4.1.1 Common Thresher Shark (*Alopias vulpinus*)

**Status**—Common thresher shark is not managed internationally and there are no quotas. The common thresher shark is considered data deficient by the IUCN Red List due to the lack of adequate information necessary to make a direct or indirect assessment of its risk of extinction based on its distribution or population status. The FAO lists this species as category 4 (exploited species) due to the low reproductive potential of the species and the fact that it is a target of many intensive fisheries throughout the world (Castro et al. 1999). This species is not overfished, nor is overfishing occurring (PFMC 2003c; NMFS 2005k).

**Distribution**—Common thresher shark is circumglobal occurring in temperate and warm oceans, penetrating into tropical waters. It is found in the Atlantic Ocean, Mediterranean Sea, Indian Ocean, and central and western Pacific. In the eastern Pacific, this species ranges from southeastern Alaska and Goose Bay, British Columbia to Chile but may include the Gulf of California (Eschmeyer et al. 1983; Compagno 1984b, 2002).

**Habitat Preference**—Common thresher sharks are most abundant over continental and insular shelves in neritic and oceanic waters out to 161 kilometers (Compagno 1984b, 2002). Adult and juveniles are surface with adults occurring from the surface to depths of 366 meters or more (Ebert 2003) and juveniles preferring open coast and semi-enclosed bays (Eschmeyer et al. 1983) with high concentrations of schooling prey. This species is often associated with areas of high biological productivity and the presence of strong frontal zones that separate regions of upwelling and adjacent waters, as well as areas with strong horizontal and vertical mixing of surface and subsurface waters (NMFS-NWR 2004c). These effects create habitats conducive to the production and maintenance of schooling pelagic prey (PFMC 2003c). Common thresher sharks occur in waters with salinities of 32 to 36 psu and temperatures of 14° to 29°C (MBC 1987).

**Life History**—Common thresher sharks undergo active transboundary seasonal north-south migration from San Diego/Baja California-Mexico to Oregon and Washington following warm water masses and schools of prey (Ebert 2003; PFMC 2003c). In early spring, adults remain in offshore southern California waters (366 to 549 meters) from one to two months during which time pupping occurs followed by the pups moving to inshore nursery areas (PFMC 2003c). Adults, mostly males, move as far north as Vancouver Island in late summer and early fall (Ebert 2003). Subadults tend to remain in the Southern California Bight, which is an important nursery area, rarely venturing further north than Cape Mendocino, California (Ebert 2003) except during warm-water years where they are found by the Columbia River mouth and as far as 48°N (PFMC 2003c). In fall, subadults are thought to move south again, arriving in the Channel Islands area. Little is known about the presumed southward migration of large adults, which do not appear along the coast until spring (PFMC 2003c). Reproduction in the common thresher shark is ovoviviparous and oophagous with a normal brood size of two to four pups per litter (Bedford 1992; Smith and Aseltine-Neilson 2001). Mating presumably takes place in mid-summer (July to August) along the U.S. West Coast EEZ, with a gestation period of about nine months, with parturition occurring most likely in the spring months (March to June) off California (PFMC 2003c).


**EFH Designations**—(PFMC 2003c) EFH is shown in Figure 1-9.

- **Neonate/early juveniles (< 102 centimeters fork length [FL])**—EFH is not designated in the NWTRC. EFH includes surface, neritic, and oceanic waters off beaches, in shallow bays, and in near surface waters from the U.S./Mexico EEZ border north to Santa Cruz (37°N latitude). These
habitats are primarily over bottom depths of 11 to 732 meters, particularly in water less than 183 meters deep and to a lesser extent further offshore between 366 and 549 m.

- **Late juveniles/subadults (> 101 centimeters FL and < 167 centimeters FL)**—EFH is not designated in the NWTRC. EFH consists of the surface, neritic, and oceanic waters off beaches and open-coast bays, as well as offshore in near-surface waters. These waters range from the U.S./Mexico EEZ border north to off Pigeon Point, California (37°N10’ latitude), from the 11 to 2,560 meters isobaths.

- **Adults (> 166 centimeters FL)**—EFH is located in the surface, neritic, and oceanic waters off beaches and open-coast bays in near-surface waters. Within the Pacific Northwest OPAREA, these waters range from the U.S./Mexico EEZ border north (seasonally) to Cape Flattery, Washington from the 73 meters isobath westward to about 127°30’W longitude north of the Mendocino Escarpment and from the 73 to 3,475 meters isobath south of the Mendocino Escarpment.

1.4.4.1.2 Bigeye Thresher Shark (*Alopias superciliosus*)

**Status**—Bigeye thresher shark is not managed internationally and there are no quotas. This species is thought to be more vulnerable to overfishing than the common thresher shark but little is known of the bigeye thresher shark’s abundance and stock structure (PFMC 2003c; NMFS 2005k). The FAO lists this species as category 3 (exploited species) due to its slow growth, limited reproductive potential, and the fact that it is caught in large numbers in numerous tuna and swordfish fisheries throughout its range (Castro et al. 1999).

**Distribution**—Bigeye thresher is circumglobal in tropical and temperate seas. It occurs in the Atlantic Ocean, western Mediterranean Sea, western Indian Ocean, and central and western Pacific. In the eastern Pacific, this species ranges from Vancouver, British Columbia, south to the Gulf of California and Islas Galapagos and possibly off Peru and northern Chile; usually south of 45°N latitude (Compagno 1984b, 2002; PFMC 2003c).

**Habitat Preference**—Bigeye thresher sharks are found in oceanic and neritic waters over continental and insular shelves, occasionally in shallow areas (Compagno 1984b). This species ranges from surface and subsurface water to depths down to a recorded maximum of 723 meters (Nakano et al. 2003). This species occurs in deeper (200 to 550 meters) and cooler (6° to 11°C) waters during the day, shifting upwards to the mixed layer (at about 50 to 130 meters) and warmer water temperatures (15° to 26°C) at night (PFMC 2003c). Bigeye threshers can reportedly stay in cooler water for longer periods of time than other pelagic sharks (PFMC 2003c). The population off California and Oregon appears to be predominately adult males. Immature females occur primarily south of Monterey Bay. Juveniles off the West Coast appear to associate with a broader range of SST (15° to 25°C) than adult males (15° to 19°C) (PFMC 2003c). Bigeye thresher sharks are frequently caught off southern California from August to November, peaking in September (Hanan et al. 1993; Ebert 2003).

**Life History**—Data are unavailable on long-term movements and migrations of the bigeye thresher shark (PFMC 2003c). In the eastern Pacific off Central and South America, recent studies on this species suggest diel vertical migration for night feeding in the area of the thermocline and adjustment to water temperatures ranging from 6° to 26°C (PFMC 2003c). Reproduction in the bigeye thresher shark is ovoviviparous and oophagous with a normal brood size of one to four pups, usually one per litter (Compagno 2002; Ebert 2003). A probable period of gestation has been estimated at 12 months (PFMC 2003c).
Source: Map adapted from Shepard and Emery (1941) and PFMC (2003b).

**Figure 1-9:** EFH for the Adult Lifestage of the Common Thresher Shark (73 meters to 127°W Longitude North of the Mendocino Escarpment and 73 to 3,475 meters South of the Mendocino Escarpment)
Common Prey Species—Bigeye thresher sharks prey upon bottom fishes (Pacific hake) and pelagic fishes such as longnose lancetfish (*Alepisaurus ferox*), herring (*Clupeidae*), mackerel (*Scomber* spp.), small billfishes (*Istiophoridae*), and king-of-the-salmon (*Trachipterus altivelis*), squids (*Teuthoidea*), and crustaceans (Compagno 2002; Ebert 2003; PFMC 2003c; FLMNH).

**EFH Designations**—(PFMC 2003c) EFH is shown in Figure 1-10.

- **Neonate/early juveniles (~90 to 115 centimeters FL, 0 to 2 and 3 year old)**—EFH is not designated in the NWTRC. These size classes are not known to occur in the U.S. West Coast EEZ.

- **Late juveniles/subadults (> 115 centimeters FL and < 155 centimeters FL males and < 189 centimeters females)**—EFH is not designated in the NWTRC. EFH consists of coastal and oceanic waters in the surface and subsurface zones from the U.S./Mexico border north to 37°N latitude of Davenport, California. This early life history stage occurs south of 34°N latitude from the 183 to 3,658 meters isobath and north of 34°N latitude from the 1,463 to 4,023 meters isobath.

- **Adults (> 154 centimeters FL males and > 188 FL females)**—EFH is located within the Pacific Northwest OPAREA in coastal and oceanic waters in the surface and subsurface zones from the U.S./Mexico border north seasonally to 45°N latitude off Cascade Head, Oregon. In southern California, this life stage is found south of 34°N latitude, from the 183 to 3,658 meters isobath and north of 34°N latitude from the 1,463 meters isobath toward the outer EEZ boundary.

### 1.4.4.1.3 Shortfin Mako Shark (*Isurus oxyrinchus*)

**Status**—Shortfin mako is not managed internationally and there are no quotas. Significant effects of exploitation have not been shown, and the local stock is not currently considered overfished, nor is overfishing occurring (PFMC 2003c; NMFS 2005k). Information is unavailable on the population structure of the shortfin mako in the eastern North Pacific (Ebert 2003). The FAO lists this species as category 4 (exploited species), as it has shown historical declines due to swordfish and tuna bycatch operations (Castro et al. 1999). The IUCN red list of threatened species lists the shortfin mako as a lower risk but near threatened.

**Distribution**—Shortfin mako is circumglobal occurring in warm-temperate and tropical seas. In the eastern Pacific, it ranges found from Chile and Islas Galapagos, northward to British Columbia, occurring most commonly off southern California (Hanan et al. 1993; Holts and Bedford 1993; Ebert 2003).

**Habitat Preference**—Shortfin mako shark, an offshore littoral and surface species, is known to occur in the water column from the surface to depths of at least 500 meters or more (Compagno 2002; PFMC 2003c). This species is endothermic and thus able to maintain higher temperatures than the surrounding waters in their body musculature, brains, eyes, and viscera with countercurrent vascular heat exchangers (Compagno 2002). Adults are less common on the outer banks of the Southern California Bight around the Channel Islands during late summer (Ebert 2003). Juveniles are abundant in the summer months off southern California near the surface above the thermocline in the mixed layer utilizing these offshore continental waters as a nursery area (Holts and Bedford 1993) for at least two years (Cailliet and Bedford 1983). Off California, shortfin makos are associated with SSTs ranging from 15° to 25°C (PFMC 2003c).

**Life History**—Shortfin mako is highly migratory (Ebert 2003). In the extreme northern and southern part of its range, this species has a tendency to follow movements of warm water masses poleward in the summer at temperatures ranging from 17.2° to 22.2°C (Compagno 2002) then retreating when temperature cools (Ebert 2003). Water column preference of adult fish is unknown except from one study that tracked one adult in the Atlantic Ocean, noting large vertical movements between the surface and 450 meters during the day, with small excursions down to the thermocline at night (PFMC 2003c).
Figure 1-10: EFH for the Adult Lifestage of the Bigeye Thresher Shark (1,463 meters to EEZ)

Source: Map adapted from PFMC (2003b).

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Reproduction in the shortfin mako shark is ovoviviparous and oophagous with a normal brood size of 4 to 25 and possibly 30 pups (average 10 to 18 pups) in a litter (Love 1996; Compagno 2002). This species has a three-year reproductive cycle, which includes a 15- to 18-month gestation period, a late winter to mid-spring pupping season, followed by an 18-month resting period before females become fertile again (Mollet et al. 2000; Ebert 2003). The bight is an important pupping and nursery area (Taylor and Bedford 2001; Compagno 2002; Ebert 2003).

Common Prey Species—Shortfin mako sharks prey upon mackerel, tuna, bonito, anchovies, herring, lancetfishes, rockfish, lingcod, yellowtail jacket (*Seriola lalandi*), seabass, swordfish, juvenile blue, requiem, and hammerhead sharks, cephalopods, dolphins, and sea turtles (Strasburg 1958; Taylor and Bedford 2001; Compagno 2002; Ebert 2003; FLMNH).

**EFH Designation**—(PFMC 2003c) EFH is shown in Figure 1-11.

- **Neonate/early juveniles (< 101 centimeters FL)**—EFH is located in oceanic and surface waters of the West Coast from the 183 to 3,658 meters isobath (and possibly beyond), from the Mexico border to Point Pinos, California, especially from the 1,829 to 3,658 meter isobaths from Monterey Bay north to Cape Mendocino, and within the Pacific Northwest OPAREA from the 1,829 meter subsurface contour (isobath) out to the EEZ boundary north of Cape Mendocino to 46°30’N latitude. This early life history stage occupies northerly habitats during warm water years.

- **Late juveniles/subadults (> 100 centimeters FL and < 180 centimeters FL males and < 249 centimeters females)**—EFH is identified as oceanic and surface waters from the U.S./Mexico EEZ border north to 46°30’N latitude from the 100 meters isobath out to the EEZ boundary north to San Francisco (38°N latitude) and within the Pacific Northwest OPAREA from the 1,829 meters isobath out to the EEZ boundary north of San Francisco.

- **Adults (> 179 centimeters FL males and < 248 centimeters FL females. Most adults within the U.S. West Coast EEZ are males)**—EFH consists of surface oceanic waters from the U.S./Mexico EEZ border north to 46°30’N latitude extending from the 732 meters isobath out to the EEZ boundary south of Point Conception, California and within the Pacific Northwest OPAREA from the 1,829 meter subsurface contour (isobath) out to the EEZ boundary and beyond, north of Point Conception.

### 1.4.4.1.4 Blue Shark (*Prionace glauca*)

**Status**—Blue shark is not actively managed internationally and there are no quotas. Recent studies indicate that the species, which may comprise a single stock, is abundant and healthy in spite of being incidentally fished by high-seas, longline fleets for over 50 years (PFMC 2003c). This species is not undergoing overfishing, nor is it consider overfished on the West Coast (PFMC 2003c; NMFS 2005k; FLMNH). The FAO lists this species as category 3 (exploited) species because it is caught in significant numbers in the bycatch of numerous longline fisheries (Castro et al. 1999). The IUCN red list of threatened species lists the blue shark as a lower risk but near threatened.

**Distribution**—Blue shark is primarily circumglobal in its distribution occurring in temperate and tropical waters from 60°N to 50°S latitude (Compagno 1984a). In the eastern Pacific, this species ranges from Kodiak Island, western Gulf of Alaska to Chile including Gulf of California and Islas Galapagos, being abundant in offshore and coastal waters of the western U.S. and Mexico (Compagno 1984a; Holts 1992).
Source: Map adapted from Shepard and Emery (1941) and PFMC (2003b).

Figure 1-11: EFH for the Lifestages of Shortfin Mako Shark – Neonate and Small Juvenile (1,829 to 3,658 meters South of Cape Mendocino and 1,829 meters to EEZ North of Cape Mendocino) and Large Juvenile, Subadult and Adult (1,829 meters to EEZ)
**Habitat Preference**—Blue shark is an oceanic-surface and fringe-littoral species occurring from the surface to about 350 meters (Holts et al. 2001). Considered an offshore species, it sometimes occurs near the coast at night often where the continental shelf narrows or is cut by submarine canyons close to shore (Compagno 1984a; Ebert 2003). In the Pacific, blue sharks are present in greatest abundance between 20°N to 50°N with females more abundant at higher latitudes than males (PFMC 2003c). Within the U.S. West Coast EEZ, this species is common and one of the most frequently encountered sharks along the entire California coast (Ebert 2003). Juveniles are abundant off California, especially in the Southern California Bight, which is a major birthing and nursery area, and Monterey Bay from May to October (Sciarrotta and Nelson 1977; Hanan et al. 1993; Holts et al. 2001). Strasburg (1958) found that north of 30°N latitude, blue sharks preferred shallower depths (<85 meters). Off California, this species spends the majority of its time in water depths ranging from 16.0 to 25.9 meters (Klimley et al. 2002).

Blue sharks are tolerant of a relatively wide range of water temperatures. According to Compagno (1984a) and Eschmeyer et al. (1983), this species apparently prefers relatively cool water at 7° to 16°C but can tolerate water of 21°C or warmer. SSTs associated with blue shark drift catches off the West Coast ranged from 12° to 25°C (Sciarrotta and Nelson 1977) and off California from 10° to 15°C (Klimley et al. 2002).

**Life History**—In the north Pacific, seasonal migrations occur between latitudes 20°N and 50°N, with northward movements extending into the Gulf of Alaska as waters warm during the summer months, and southward movements occurring during the winter months (Strasburg 1958). Along the west coast, mature females are thought to start their northward journey in early spring as warm water moves northward, while juveniles of both sexes follow closely; large males start later and tend to stay further offshore (Holts 1992; Hanan et al. 1993). Nakano (1994) has proposed a migration model for the blue shark in the north Pacific, where birth occurs in early summer in nursery areas located at 35° to 45°N, with one to five year old females moving north of these latitudes and two to four year old males moving south. Upon reaching maturity, this species apparently migrates to the subtropics and tropics to join a reproductively active population (PFMC 2003c). Within the U.S. West Coast EEZ, a larger nursery area extends from 31° to 47°N (PFMC 2003c). This species is known to undertake extensive trans-oceanic migrations, sometimes moving over 6,678 kilometers (Kohler et al. 1998; Ebert 2003).

Diel movements of blue sharks off southern California indicate that adults increase their activity at night and make shallower dives during the day. This cyclical diving behavior is thought to serve as a hunting, orientation, or thermo-regulatory function (Holts et al. 2001). Blue sharks appear to aggregate in loose schools (Holts et al. 2001).

Blue shark is viviparous with 4 to 135 young per litter (average 20 to 40) and a gestation period lasting 9 to 12 months (Compagno 1984a; Ebert 2003). Reproduction for blue sharks has been reported as seasonal in most areas, with birth often occurring in spring or summer (Nakano 1994; PFMC 2003c). Off California, mating reportedly occurs from late spring to early winter, and parturition takes place in early spring (Hanan et al. 1993). The nursery habitat may extend northward from the Southern California Bight to off the Columbia River and primarily offshore of the 183 meters isobath (PFMC 2003c).

**Common Prey Species**—Blue sharks prey upon relatively small bony fishes such as Pacific herring, sardines, northern anchovy, blacksmith (*Chromis punctipinnis*), salmon, lancetfishes, flying fishes, pipefishes, hake, rock cod, jack mackerel, tunas, sea bass, flatfishes, and spiny dogfish and invertebrates including squid (Histiotethid and market squid), red crab, and euphasiid swarms (*T. spinifera*) (Compagno 1984a; Love 1996; Ebert 2003; PFMC 2003c; FLMNH).

**EFH Designations**—(PFMC 2003c) EFH is shown in Figure 1-12.

- **Neonates and early juveniles (<83 centimeters FL)**—EFH is located in surface, oceanic waters from the U.S./Mexico border north to the U.S./Canada border from the 1,829 meters isobath.
seaward to the outer boundary of the EEZ and beyond; extending inshore to the 183 meters isobath south of 34°N’ latitude.

- **Late juveniles and subadults (> 82 centimeters FL and < 167 centimeters FL males and < 153 centimeters females)—EFH is identified as surface, oceanic waters from the U.S./Mexico EEZ border north to 37°N latitude (off Santa Cruz, California) from the 183 meters isobath seaward to the outer boundary of the EEZ and beyond; and within the Pacific Northwest OPAREA north to the U.S./Canada border from 1,829 meters isobath seaward to the EEZ outer boundary.

- **Adults (> 166 centimeters FL males and < 152 centimeters FL females)—EFH consists of surface, oceanic waters from the U.S./Mexico EEZ border north to the U.S./Canada border from the 1,829 meters isobath seaward to the outer boundary of the EEZ and beyond in the Pacific Northwest OPAREA; extending inshore to the 366 meter subsurface contour (isobath) south of 37°N latitude off Santa Cruz.

### 1.4.4.2 Tuna

The family Scombridae, the mackerels, tunas, and bonitos, includes some of the world’s most popular food and sport fishes. Within this family, members of the genus *Thunnus* are unique in possessing a high metabolic rate and vascular heat exchange allowing thermo-regulation and endothermy. They are predaceous, swift-swimming, and powerful fishes that occur in tropical and temperate waters. Two of the five EFH designated tuna species occur in the Pacific Northwest OPAREA (PFMC 2003c).

#### 1.4.4.2.1 Albacore Tuna (*Thunnus alalunga*)

**Status**—Albacore tuna stock is healthy and it is not known if it is overfished, or if is overfishing occurring (PFMC 2003c). No quotas are being considered and no regional harvest guidelines have been recommended at the present time (NMFS 2005k). The albacore tuna is listed as data deficient by the IUCN red list of threatened species, due to the lack of adequate information necessary to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.

**Distribution**—Albacore tuna are circumglobal in tropical and subtropical oceanic regions between latitudes 40° to 58°N and 25° to 43°S occurring in the Atlantic, Pacific, and Indian oceans and in the Mediterranean Sea (Collette and Nauen 1983). In the northeastern Pacific, they range from northern and eastern Gulf of Alaska to Chile including Islas Galapagos and entrance to Gulf of California (Squire and Smith 1977; Collette and Nauen 1983; Eschmeyer et al. 1983; Mecklenburg et al. 2002). Albacore tuna are generally distributed in a band centered at 35°N in the Kuroshio Current off Japan, the North Pacific Transition Zone (NPTZ), and the California Current (IATTC 2001).

**Habitat Preference**—All life stages of the albacore tuna are pelagic with temperature being the most influential factor in determining their distribution (Collette and Nauen 1983). Adults and subadults occur as deep as 600 meters, but primarily from 27 to 180 m; whereas small juveniles, larvae, and eggs are found from the surface to 50 meters (primarily 20 to 30 meters) (Collette and Nauen 1983). Depth distribution of deep-swimming adults is dependent upon vertical thermal structure and dissolved oxygen levels greater than 60 percent. Juveniles are often found near oceanic fronts or in regions of temperature discontinuities (PFMC 2003c). Deep-swimming adults occur in waters between 13.5° to 25.2°C, while the 15.6° to 19.4°C SST isotherms appear to delimit the habitat of juveniles (PFMC 2003c). While very young juveniles and larvae are not known to occur within the U.S. Pacific Coast EEZ, sizable concentrations of juveniles (< 85 centimeters FL) and adults (> 85 centimeters FL) occur from Cedros Island, Baja California to Oregon in the area of the Columbia River Plume and from 80 to 482 kilometers offshore (MBC 1987). Albacore tuna are found in euhaline waters with salinities of 32.7 to 38.8 psu and at temperatures of 9° to 30°C: adults – 13.5° to 25.2°C; juveniles - 13.9° to 22.2°C; larvae - 24° to 27°C; and eggs - 24° to 30°C (Hart 1973; Collette and Nauen 1983; MBC 1987).
Figure 1-12: EFH for All Lifestages of the Blue Shark (1,829 meters to EEZ)

Source: Map adapted from PFMC (2003b).
**Life History**—Albacore tuna have a complex migration pattern, with the north and south Pacific stocks having similar patterns. Most migrations are undertaken by subadults (two to four years old). A given year class migrates west to east in a band between 30° to 45°N, leaving the northwest Pacific in springtime. Albacore move into the eastern portion of the NPTZ 1,000 to 1,500 kilometers offshore waters off North America by early summer. When surface waters warm, they migrate into coastal waters by mid-summer off Baja California and California. This onshore migration continues throughout the summer months extending northward during late summer then westward in the fall entering into subtropical waters to reproduce (Kimura et al. 1997; Moyle and Cech 2000). Migrations may also be influenced by large-scale climate events that affect the Kuroshio Current regime off Japan. Albacore tuna may migrate more intensely to the eastern Pacific when the Kuroshio Current takes a large meandering path (Kimura et al. 1997).

Similar size albacore travel together in school groups (young: small, loose, and broadly scattered and old: compact), which collectively can be up 320 to 480 kilometers wide (MBC 1987; Crone 2001). In North American waters, albacore tuna are generally associated with coastal frontal boundaries and tend to aggregate in the vicinity of local upwelling fronts (MBC 1987; Laurs and Dotson 1992). Spawning does not occur in the Pacific Northwest OPAREA, instead taking place in the North Pacific between latitudes 10° and 30°N from Japan to Hawaii between April and July in oceanic waters (MBC 1987). Albacore tuna is oviparous with eggs released in two batches per year (Collette and Nauen 1983).

**Common Prey Species**—Albacore tuna prey on small fish (including northern anchovies, Pacific saury (*Cololabis saira*), rockfish spp., myctophids, and barracudina (*Magnisudis atlantica*)); squids (for example, opalescent inshore, armhook (*Gonatus anonychus*), boreatlantic armhook (*G. fabracil*), and clubhook (*Onychoteuthis* spp.); and crustaceans (such as sergestid shrimp, pelagic red crab, amphipods (*Phronima sedentaria*), and euphausiids) (Hart 1973; Collette and Nauen 1983; Bernard et al. 1985; PFMC 2003c).

**EFH Designations**—(PFMC 2003c) EFH is shown in Figure 1-13.

- **Eggs and Larvae**—EFH is not designated in the NWTRC. No habitat within the U.S. West Coast EEZ.

- **Juveniles (<85 centimeters FL)/Adults (> 84 centimeters FL)**—EFH is identified in the Pacific Northwest OPAREA as oceanic, surface waters generally beyond the 183 meters isobath, from the U.S./Mexico border north to the U.S./Canada border, and westward to the outer edge of the U.S. EEZ boundary.

### 1.4.4.2.2 Northern Bluefin Tuna (*Thunnus orientalis*)

**Status**—Evidence for overfishing or for persisting decline in the stock of northern bluefin tuna is lacking (NMFS 2005g). The bluefin tuna is treated as a vulnerable species due to the fact that this species is the least productive and has the most restricted spawning conditions among tunas. Its population status is also considered problematic because no indices reliably reflect overall stock abundance. No regional harvest guidelines are recommended in view of the stock being primarily western Pacific, the lack of international agreement on stock status relative to maximum sustainable yield (MSY), and the West Coast fishery not directly affecting the spawning stock (PFMC 2003c).

**Distribution**—Northern bluefin tuna originates in the western Pacific, especially west of 180° and the Hawaiian Islands. Their distribution ranges from southward to off New Zealand, eastern Australia, and New Guinea, and westward to Japan, East China Sea, and Philippines. In the eastern Pacific, this species is found from about 20°N and 42°N, sometimes extending northward in warm-water years to 48°N and beyond (Bayliff 2001). Within the U.S. West Coast EEZ, the northern bluefin tuna occurs from the below U.S./Mexico border (tip of Baja California) (Love et al. 2005) to Point Conception, California and intermittently north to the U.S./Canada border and beyond (Shelikof Strait, Gulf of Alaska) (Mecklenburg et al. 2002) when SST are above normal (Bayliff 1993).
Figure 1-13: EFH for the Juvenile and Adult Lifestages of the Albacore Tuna (183 meters to EEZ)
Habitat Preference—Northern bluefin tuna occur in oceanic, surface waters usually beyond the 183 to 732 meters isobath out to the U.S. EEZ boundary, but occasionally inhabit inshore waters (Collette and Nauen 1983). Research suggests that the most suitable habitat off Baja California and along the West Coast exists from May through October, when the bluefin tuna’s preferred SSTs (17° and 23°C) tend to prevail in those areas (PFMC 2003c). There appears to be no consistently utilized habitat within the U.S. West Coast EEZ for adult fish over 150 centimeters FL, although some of these large fish have been caught in the Southern California Bight in the vicinity of the Channel Islands (Bayliff 1993). In addition to the preferred temperature range defined by SSTs, northern bluefin tuna can also be found associated with the following habitat features: California Current in the eastern Pacific and the NPTZ, North Pacific Subarctic Boundary, and Kuroshio Current off Japan (Bayliff 1993).

Life History—Research suggests that the northern bluefin tuna’s migratory path is within the North Pacific Subarctic-Subtropical Transition Zone. Recent studies have documented the migration of juveniles from the western Pacific to the eastern Pacific. Tagged individuals off Japan made the trans-Pacific migration in about two months, then resided in the eastern Pacific for about eight months before being recaptured (Itoh et al. 2003a). Off the west coast, Domeier et al. (2005) reported a seasonal movement pattern of young northern bluefin tuna spending winter and spring off central Baja California, moving northward to Oregon from summer through fall, then returning southward into Mexican waters by winter where they remained until the following spring.

Northern bluefin tuna (40 to 80 kilograms [kg]) school by size with other tunas such as albacore, yellowfin (T. albacares), bigeye (T. obesus), skipjack, frigate tuna (Auxis rochei), eastern Pacific bonito (Sarda chiliensis) and yellowtail (Collette and Nauen 1983). Itoh et al. (2003b) reported a diurnal and seasonal change in swimming depth and vertical swimming behavior at dawn and dusk. The majority of northern bluefin tuna spawn in the northwest Pacific ocean in area from the Philippines past Taiwan to Okinawa from April to June. Small numbers also spawn off southern Honshu in the Pacific Ocean in July and in the Sea of Japan in August (Bayliff 2001; Itoh et al. 2003a). This species is oviparous producing as many as 10 million eggs per year (Love 1996).

Common Prey Species—Northern bluefin tuna prey upon northern anchovy, herring, sanddabs, white croakers, pompanos, mackerel, Pacific saury, squid, Pacific hake, and other tuna (Collette and Nauen 1983; Bayliff 1993; Love 1996; FLMNH).

EFH Designations—(PFMC 2003c) EFH is shown in Figure 1-14.

- Eggs and Larvae—EFH is not designated in the NWTRC. No habitat within the U.S. West Coast EEZ.
- Juveniles (< 150 centimeters FL and 60 kg)—EFH is identified in the Pacific Northwest OPAREA as oceanic, surface waters beyond the 183 meters isobath from the U.S./Mexico EEZ border north to the U.S./Canada border, and westward to the outer edge of the EEZ boundary. The northerly migration extension appears dependent on position of the North Pacific Subarctic Boundary.
- Adults (> 150 centimeters FL and 60 kg)—EFH is not designated in the NWTRC. No regular habitat within the U.S. West Coast EEZ exists, although large fish are occasionally caught in the vicinity of the Channel Islands off southern California but rarely off central California.
Figure 1-14: EFH for the Juvenile Lifestage of the Northern Bluefin Tuna (183 meters to EEZ)

Source: Map adapted from PFMC (2003b).
1.4.4.3 Billfish

The family Istiophoridae, which includes marlins and sailfish, consists of gamefish that have a prolonged snout and upper jaw that forms a sword. Billfish are exceptional foodfish and are regarded as excellent and exciting targets by sport fishermen (Nakamura 1985). One species of billfish, the broadbill swordfish, has EFH designated within the Pacific Northwest OPAREA (PFMC 2003c).

1.4.4.3.1 Broadbill Swordfish (Xiphias gladius)

**Status**—Recent studies indicate that the EPO broadbill swordfish population is healthy and currently no regional harvest guideline is recommended (PFMC 2003c). The swordfish is listed as data deficient by the IUCN red list of threatened species, due to the lack of adequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution or population status.

**Distribution**—Broadbill swordfish are circumglobal in distribution occurring in all tropical, subtropical, and temperate seas ranging from around 50°N to 50°S (Nakamura 1985; PFMC 2003c). In the eastern Pacific, this species ranges from south of Vancouver Island, British Columbia to Valdivia, Chile including southernmost part of Gulf of California and Islas Galapagos (Palko et al. 1981; Love et al. 2005). Broadbill swordfish are most abundant off northwestern Mexico (south of Baja California), common off California but uncommon north of Point Conception, California (Miller and Lea 1972; Squire and Smith 1977; Palko et al. 1981).

**Habitat Preference**—All life stages of the swordfish are pelagic (Palko et al. 1981; Nakamura 1985). Adults and subadults occur from the surface to 2,878 meters (Nakamura 1985; Love et al. 2005). Small juveniles, larvae, and eggs are surface with small juveniles occurring in the upper 29 meters, larvae from 1 to 15 meters, and eggs from the surface to 75 meters (MBC 1987). Adults and juveniles are most abundant near current boundaries, frontal zones, submarine escarpments, and boundary zones, where there are sharp gradients of temperature and salinity, and in areas of high productivity where forage species such as squid are abundant (Palko et al. 1981). This association with cephalopod prey, concentrated near frontal boundaries, appears significant in determining their distribution in the north Pacific (PFMC 2003c).

Broadbill swordfish adults and juveniles can tolerate a wide range of water temperature ranging from 5° to 27°C but are normally found in areas with SSTs above 13°C (Nakamura 1985). Larvae occur in water temperatures of 22.4° to 30.7°C and eggs at 22.4° to 30.7°C (Palko et al. 1981). Most large-sized fish are female, which appear to be more common in cooler waters. According to Palko et al. (1981) few males tend to occur in waters below 18°C and make up the majority of warm water landings. Research suggests that adult swordfish spend 75 percent of their time in or just below the upper mixed layer, at depths of 10 to 50 meters in water temperatures around 14°C, and make excursions to approximately 300 meters depths in water temperatures close to 8°C (PFMC 2003c). Adults are found over a broad range of salinities (6 to 39 psu), whereas earlier life history stages occur only in euhaline water with salinities of 33.8 to 37.4 psu (MBC 1987).

Dewees (1992) states that like adults, juveniles tend to concentrate along productive thermal boundaries, between cold, upwelled water and warm water masses where they feed on fishes and squids. In the Pacific, juvenile swordfish are restricted to areas of upwelling and high productivity and do not move far during the first year of life. Young swordfish originate in tropical and subtropical regions and migrate to higher latitudes as they increase in size (PFMC 2003c).

**Life History**—Little is known about migration in Pacific swordfish, although limited tagging data support a general west-to-east movement from Hawaii toward continental North America (PFMC 2003c). This species does not migrate long distances, although individuals occasionally wander more than 1,000 kilometers. In general, they move into temperate waters during the summer to feed and return to warmer waters to over-winter and spawn (Palko et al. 1981). Adults, juveniles, and larvae undertake diel vertical migration from deeper depths (up to 600 meters) during the daytime (related to feeding or to light) and
moving into the mixed surface layer (upper 200 meters) at night for feeding (Palko et al. 1981; Holts 2001).

Research suggests that swordfish do not seem to have a discrete spawning ground or spawning season (PFMC 2003c). Larvae and juveniles tend to occur in warmer tropical and subtropical regions. No egg and larval habitats have been reported for the U.S. West Coast EEZ, although larvae have been reported as far north as 35°N latitude in late summer (Grall and de Sylva 1983). Spawning occurs throughout the year in equatorial waters but is progressively restricted to spring-summer at higher latitudes. In the eastern Pacific, the distribution narrows, probably because of lower water temperatures associated with the Peru Current and upwelling in that region (PFMC 2003c). Swordfish are oviparous and are believed to spawn inshore from the surface to 75 meters (MBC 1987). There is some evidence for pairing of spawning adults, as this species apparently does not school (Palko et al. 1981). Peak spawning occurs in the north Pacific between May and August, from December to January in the south Pacific, and from March to July in the central Pacific (Palko et al. 1981). It is probable that some degree of spawning occurs throughout the year in tropical waters between 20°N and 20°S, due to the distribution of larvae associated with SSTs between 24° and 29°C (PFMC 2003c).

**Common Prey Species**—Swordfish prey upon squid and pelagic fishes including dorado, barracuda, flying fish, clupeids, sauries, Pacific hake, gadids, jack mackerel, shortbelly rockfish, and small scombrids (Squire and Smith 1977; Palko et al. 1981; Nakamura 1985; FLMNH).

**EFH Designations**—(PFMC 2003b) EFH is shown in Figure 1-15.

- **Eggs and Larvae**—EFH is not designated in the NWTRC. No habitat within the U.S. West Coast EEZ.

- **Juveniles—males (males < 102 EFL or 118 centimeters JFL; females < 144 centimeters EFL or < 163 JFL)**—EFH is identified as oceanic surface and subsurface waters from the U.S./Mexico EEZ border north to 41°N latitude; in the Southern California Bight primarily south of the Santa Barbara Channel Islands from the 732 meter isobath out to the EEZ boundary, and north of Point Conception, California from the 1,829 meters isobath westward to the EEZ outer boundary and northward to 41°N latitude in the Pacific Northwest OPAREA.

- **Adults—males (males > 102 centimeters EFL or 117 JFL; females > 144 centimeters EFL or 162 JFL)**—EFH includes oceanic surface and subsurface waters out to the EEZ boundary, inshore to the 732 meters isobath in southern and central California from the U.S./Mexico EEZ border north to 37°N latitude, and in the Pacific Northwest OPAREA beyond the 1,829 meters isobath northward to 46°40’N latitude.
Figure 1-15: EFH for the Juvenile and Adult Lifestages of the Broadbill Swordfish (1,829 meters to EEZ)

Source: Map adapted from PFMC (2003b).
2 PROPOSED ACTION

The purpose of the Proposed Action is to achieve and maintain Fleet readiness using the Northwest Training Range Complex (NWTRC) to support and conduct current, emerging, and future training and research, development, test and evaluation (RDT&E) operations, while enhancing training resources through investment on the ranges. The Navy proposes to implement actions within the NWTRC to:

- Maintain baseline training and RDT&E operations at current levels;
- Increase certain training and RDT&E operations from current levels as necessary to support the Fleet Readiness Training Plan (FRTP);
- Accommodate mission requirements associated with force structure changes and introduction of new weapons and systems to the Fleet; and
- Implement enhanced range complex capabilities.

Three alternatives are analyzed in this EIS/OEIS:

1) The No Action Alternative – Current Activities;
2) Alternative 1 – Increase Operational Training and Accommodate Force Structure Changes; and

2.1 NWTRC

The NWTRC serves as a backyard range for those units homeported in the Pacific Northwest area, including those aviation, surface ship, submarine, and Explosive Ordnance Disposal (EOD) units homeported at Naval Air Station (NAS) Whidbey Island, Naval Station (NAVSTA) Everett, Puget Sound Naval Shipyard, and Naval Base Kitsap (NBK) Bremerton, NBK-Bangor, formerly known as SUBBASE Bangor. Additionally, the NWTRC supports other non-resident users and their training requirements to include Naval Special Warfare (NSW) units. The Navy’s Proposed Action is a step toward ensuring the continued vitality of this essential naval training resource.

2.1.1 Primary Components

The NWTRC consists of four primary components: ocean operating areas, the Puget Sound operating areas, special-use airspace, and training land areas. The range complex includes ranges and airspace that extend west to 250 nautical miles (nm) (463 kilometers [km]) beyond the coast of Northern California, Oregon, and Washington and east to Idaho. The components of the NWTRC encompass 122,400 nm² (420,163 km²) of surface/subsurface ocean OPAREAs, 46,048 nm² (157,928 km²) of special use airspace, and 875 acres (354 hectares) of land. For range management and scheduling purposes, the NWTRC is divided into numerous sub-component ranges or training areas used to conduct training and RDT&E activities, as described in detail in Chapter 2.

NWTRC Ocean OPAREAS. The ocean areas of the Range Complex include surface and subsurface operating areas extending generally west from the coastline of Northern California, Oregon, and Washington for a distance of approximately 250 nm (463 km) into international waters (see Figure 2-1).

Puget Sound Surface/Subsurface Areas. There are several areas within Puget Sound routinely used by the Navy for a variety of surface and underwater activities. These areas are depicted on Figure 2-2 and include:

- Navy 3. Navy 3 is a polygon of water space used by Navy ships for training. This 46 nm² (158 km²) area is located 8 nm (15 km) west of Ault Field, NAS Whidbey Island, in the Strait of Juan de Fuca.
- Navy 7. Navy 7 is defined as the sea surface and subsurface area beneath R-6701.
Figure 2-1: Northwest Training Range Complex (NWTRC)
Figure 2-2: Puget Sound Training Areas of the NWTRC
Crescent Harbor Underwater EOD Range. This EOD underwater range is located in Crescent Harbor off of the Seaplane Base at Whidbey Island.

Indian Island EOD Underwater Range. This area is located offshore, just west of Naval Magazine Indian Island.

Bangor EOD Underwater Range. This area, also known as the Floral Point EOD Underwater Range, is located within a Navy operating area in Hood Canal, near NBK-Bangor.

**Airspace.** The NWTRC study area includes airspace used either exclusively by the military, or co-use with civilian and commercial aircraft. Some of this airspace is special use airspace, military airspace designated by the Federal Aviation Administration as Warning Areas, Restricted Areas, and Military Operating Areas (MOAs). The airspace included in the NWTRC study area is depicted in Figures 2-1 and 2-2 and includes:

- **Warning Area 237.** W-237 comprises 33,997 nm² (116,606 km²) of airspace that generally overlays the NWTRC Ocean OPAREAS off the coast of Washington, W-237 begins approximately 3 nm (5 km) off the coast and extends westward in international waters and airspace for a distance of approximately 250 nm (463 km) from the ocean surface up to several specified altitudes depending upon which sub-area is used. The floor of W-237 airspace begins at the ocean surface, and the ceiling varies between 27,000 ft (8,230 m) and unlimited.

- **Olympic MOAs.** The Olympic A and B MOAs are located over the northwest coast of the Olympic Peninsula in Washington and extends out 3 nm to join with W-237. The MOAs cover 1,641 nm² (5,628 km²) of area. Olympic A and B have a floor of 6,000 feet (ft) (1,829 meters [m]) and a ceiling of 18,000 ft (5,486 m). Olympic B air traffic controlled assigned airspace (ATCAA) has a floor of 18,000 ft (5,486 m) and a ceiling of 50,000 ft (15,240 m).

- **The Chinook A and B MOAs are adjacent to R-6701 over the eastern portion of the Strait of Juan de Fuca and Admiralty Inlet respectively. Both Chinook MOAs cover 56 nm² (192 km²) of surface area and have a floor of 300 ft (91 m) and a ceiling of 5,000 ft (1,524 m).**

- **Restricted Area 6701.** R-6701 is a 22 nm² (75 km²) area over Admiralty bay that extends from the surface to 5,000 ft (1,524 m).

- **Okanogan MOA.** The Okanogan MOA is located above north central Washington and covers 4,364 nm² (14,968 km²) in area. This MOA is divided into A, B, and C sections. Okanogan A is available from 9,000 ft (2,743 m) to 18,000 ft (5,486 m). Okanogan B and C have a floor of 300 ft (91 m) above the ground and a ceiling of 9,000 ft (2,743 m). The ATCAAs corresponding to the Okanogan MOA extends the airspace to 50,000 ft (15,240 m).

- **Roosevelt MOA.** The Roosevelt MOA is located just east of the Okanogan MOA and covers an area of 5,413 nm² (18,566 km²). This MOA is divided into two sections. Roosevelt A has a floor of 9,000 ft (2,743 m) and a ceiling of 18,000 ft (5,486 m). Roosevelt B has a floor of 300 ft (91 m) above the ground and a ceiling of 9,000 ft (2,743 m). ATCAAs associated with the Roosevelt MOA extends its airspace to 50,000 ft (15,240 m).

- **W-570, located off the central coast of Oregon, is 4,470 nm² (15,330 km²) in size. The airspace begins at the ocean’s surface and extends to 50,000 ft (15,240 m). This area is used by P-3 aircraft for reconnaissance training.**

- **W-93 is located south of W-570, off the coast of Oregon and northern California. The 4,652 nm² (15,960 km²) of airspace in W-570 is also used for P-3 reconnaissance training and extends from the surface to 50,000 ft (15,240 m).**

**Land Range.** The land areas of the NWTRC study area, all of which are on Navy property, include the Seaplane Base Survival Area, Lake Hancock Target Range, OLF Coupeville, the EOD detonation training range at NBK-Bangor, and Indian Island. Seaplane Base Survival Area comprises approximately 875 acres (354 hectares) of undeveloped Navy property, located adjacent to Crescent Harbor. It provides a
robust suite of range capabilities for use in small unit amphibious and land tactical maneuvers, land navigation, and survival training. Additionally, Seaplane Base Survival Area has several unimproved helicopter landing zones, small boat landing beaches, and a parachute drop zone. Indian Island is located west of Marrowstone Island between the waters of Port Townsend and Whidbey Island. It is approximately 4.2 miles (6.7 km) long and oriented on a north-south axis. Indian Island is used by NSW to conduct insertion/extraction activities. All activities at Indian Island are covert in nature, and no live fire weapons or other ordnance are used.

2.2 ALTERNATIVES

The NWTRC EIS/OEIS analyzes three alternatives: the No Action Alternative, Alternative 1 and Alternative 2. The following sections provide brief descriptions of these alternatives.

2.2.1 No Action Alternative

The Navy has been operating in the NWTRC since the early 1900’s. Under the No Action Alternative, training activities and major range events would continue at current levels. The NWTRC would not accommodate an increase in training activities required to execute the FRTP or implement proposed force structure changes, nor would it implement range enhancements as necessary by the Navy. Evaluation of the No Action Alternative in this EIS/OEIS provides a baseline for assessing environmental impacts of Alternative 1 and Alternative 2 (Preferred Alternative), as described in the following subsections.

Training activities currently conducted in the NWTRC are described below. Each military activity described in this EIS/OEIS meets a requirement that can be ultimately traced to requirements from the National Command Authority. Training activities in the NWTRC vary from basic individual or unit level events of relatively short duration involving few participants to integrated major range training events, which may involve hundreds of participants over several days.

Over the years, the tempo and types of activities have fluctuated within the NWTRC due to changing requirements, the dynamic nature of international events, the introduction of advances in warfighting doctrine and procedures, and force structure changes. Such developments have influenced the frequency, duration, intensity, and location of required training. The factors influencing tempo and types of activities are variable by nature, and will continue to cause fluctuations in training activities within the NWTRC. Accordingly, operational data used throughout this EIS/OEIS are a representative baseline for evaluating impacts that may result from the proposed training activities.

2.2.2 Alternative 1 – Increase Training Activities and Accommodate Force Structure Changes

Alternative 1 is a proposal designed to meet Navy and Department of Defense current and near-term operational training requirements. If Alternative 1 were to be selected, in addition to accommodating training activities currently conducted, the NWTRC would support an increase in training activities to include force structure changes associated with the introduction of new weapon systems, vessels, and aircraft into the Fleet. Under Alternative 1, baseline-training activities would be increased. In addition, training activities associated with force structure changes would be implemented for the EA-18G Growler, Guided Missile Submarine (SSGN), P-8 Multimission Maritime Aircraft (MMA), and unmanned aerial systems. Force structure changes associated with new weapons systems would include new A-A missiles, and new sonobuoys.

2.2.3 Alternative 2 – Increase Training Activities, Accommodate Force Structure Changes, and Implement Range Enhancements

Implementation of this alternative would include all elements of Alternative 1 (accommodating training activities currently conducted, increasing training activities, and accommodating force structure changes). In addition, under Alternative 2:
• In order to optimize training throughput and meet the FRTP, training activities of the types currently conducted would be increased over levels identified in Alternative 1 (see Table 2-6);

• Range enhancements would be implemented, to include new electronic combat threat simulators/targets, development of a small scale underwater training minefield, and development of air and surface target services.

Alternative 2 is the Preferred Alternative, because it would optimize the training capability of the NWTRC and meet Navy minimum required capabilities as documented in the Navy Ranges Required Capabilities Document of September 8, 2005.
### Table 2-1: Current and Proposed Activities in the NWTRC Study Area

<table>
<thead>
<tr>
<th>Range Activity</th>
<th>Platform</th>
<th>System or Ordnance</th>
<th>No Action Alternative</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANTI-AIR WARFARE (AAW)</strong></td>
<td></td>
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</tr>
<tr>
<td>Aircraft Combat Maneuvers</td>
<td>EA-6B, EA-18G*, FA-18, F-16</td>
<td>None</td>
<td>1,353 sorties</td>
<td>2,000 sorties</td>
<td>2,000 sorties</td>
<td>W-237*, Okanogan, Olympic, and Roosevelt MOAs/ATCAAs, Darrington OPAREA</td>
</tr>
<tr>
<td>Air-to-Air (A-A) Missile Exercise*</td>
<td>EA-18G</td>
<td>AIM-7, AIM-9, AIM-120 AMRAAM</td>
<td>0</td>
<td>12</td>
<td>24</td>
<td>W-237</td>
</tr>
<tr>
<td>Surface-to-Air (S-A) Gunnery Exercise</td>
<td>DDG, FFG, AOE</td>
<td>5'/54 BLP, 20mm CIWS, 7.62mm TDU-34 towed targets</td>
<td>72</td>
<td>80</td>
<td>160</td>
<td>W-237, PACNW OPAREA</td>
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<tr>
<td>S-A Missile Exercise**</td>
<td>CVN</td>
<td>Sea Sparrow Missile or RAM BQM-74E target</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>W-237, PACNW OPAREA</td>
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<td><strong>ANTI-SURFACE WARFARE (ASUW)</strong></td>
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<tr>
<td>Surface-to-Surface (S-S) Gunnery Exercise</td>
<td>CVN, DDG, FFG, AOE</td>
<td>5'/54 BLP, 20mm CIWS, 25 mm, 7.62mm, 57mm, 50 cal Targets: HSMST, Trimaran, SPAR, Surface Target Balloon</td>
<td>90</td>
<td>100</td>
<td>180</td>
<td>W-237, PACNW OPAREA</td>
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<tr>
<td>Air-to-Surface (A-S) Bombing Exercise</td>
<td>MK-82 (live) BDU-45 (inert)</td>
<td>MK-58 marine marker</td>
<td>24</td>
<td>30</td>
<td>30</td>
<td>W-237, PACNW OPAREA</td>
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<tr>
<td>HARM Exercise</td>
<td>EA-6B, EA-18G*</td>
<td>CATM-88C (not released)</td>
<td>See STW</td>
<td>See STW</td>
<td>See STW</td>
<td>Okanogan, Olympic, and Roosevelt MOAs/ATCAAs, W-237</td>
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Table 2-1: Current and Proposed Activities in the NWTRC Study Area (cont’d)

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<tr>
<th>Range Activity</th>
<th>Platform</th>
<th>System or Ordnance</th>
<th>No Action Alternative</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Location</th>
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<tr>
<td><strong>ANTI-SUBMARINE WARFARE (ASW)</strong></td>
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<td>ASW Tracking Exercise - Extended Echo Ranging (EER)</td>
<td>P-3C, P-8 MMA*</td>
<td>SSQ-110A EER, SSQ-77 VLAD</td>
<td>10</td>
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<td>ASW Tracking Exercise - Surface Ship</td>
<td>DDG, FFG</td>
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<td>60</td>
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<td>PACNW OPAREA</td>
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<td>ASW Tracking Exercise - Submarine</td>
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<td>Targets: MK-39 EMATT</td>
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<td><strong>MINE WARFARE (MIW)</strong></td>
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<td>Mine Countermeasures</td>
<td>EOD Pers. H-60, Rigid Hull Inflatable Boat (RHIB)</td>
<td>2.5 lb C-4</td>
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<td>Land Demolitions</td>
<td>EOD Pers. Truck</td>
<td>C-4 (various sizes), various igniters and fuses, smoke grenades</td>
<td>102</td>
<td>110</td>
<td>110</td>
<td>Bangor DTR, Seaplane Base DTR</td>
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Table 2-1: Current and Proposed Activities in the NWTRC Study Area (cont’d)

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<th>NAVAL SPECIAL WARFARE (NSW)</th>
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<td>Insertion/Extraction</td>
<td>C-130, H-60, NSW Pers.</td>
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<td>108</td>
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<td>NSW Training</td>
<td>SDV, RHIB, NSW Pers.</td>
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<tr>
<td>HARM Exercise (Non-firing)</td>
<td>EA-6B, EA-18G*</td>
<td>CATM-88C (not released)</td>
<td>2,724</td>
<td>3,000</td>
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<th>SUPPORT OPERATIONS</th>
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<tbody>
<tr>
<td>Intelligence, Surveillance, and Reconnaissance</td>
<td>P-3, EP-3, EA-6B, EA-18G*</td>
<td>SSQ-53 DIFAR sonobuoys</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>Unmanned Aerial System Research, Development, Test and Evaluation (RDT&amp;E) and Training</td>
<td>Scan Eagle, Global Hawk*, BAMS*</td>
<td>None</td>
<td>12</td>
<td>112</td>
</tr>
</tbody>
</table>

Notes: * This activity, ordnance, or location is only applicable under Alternative 1 and 2.
* This activity, ordnance, or location is only applicable under Alternative 2.
3  **RESOURCE ANALYSIS**

Potential effects on EFH and managed species from NWTRC training activities and range enhancements are described in the following section. Effects on EFH and managed species could be associated with vessel movement, aircraft over-flight, expended materials, hazardous chemicals, detonation of explosive ordnance, weapons training, and sonar use. Navy training activities could have direct and indirect effects on individual species, modify their habitats, or alter water quality. The EFH assessment focuses on activities and effects common to offshore events, but also discusses individual exercises, such as underwater detonations, with unique aspects. Mitigation measures and cumulative impacts are described in the final two sections.

3.1  **IMPACT DEFINITION**

Essential fish habitat regulations require analysis of potential impacts that could have an adverse effect on EFH and managed species (NMFS 2007b). An adverse effect on EFH is defined as any impact that reduces the quality or quantity of EFH (50 CFR 600.910[a]). The Navy has determined that temporary or minimal impacts are not considered to adversely affect EFH. Federal regulations were used as guidance for this determination (50 CFR 600.815(a)(2)(ii); EFH Final Rule, 67 Fed. Reg. 2354). Temporary effects are those that are limited in duration and allow the particular environment to recover without measurable impact. Minimal effects are those that may result in relatively small changes in the affected environment and insignificant changes in ecological functions (NMFS, 2002b).

3.2  **VESSEL MOVEMENTS**

Vessels performing training exercises in the NWTRC are primarily large ocean going ships and submarines operating in waters greater than 328 feet (100 m), transiting through the OPAREA. The noise from Navy vessels could affect fish behavior. However, Navy vessels are quiet compared to commercial vessels of comparable size. Bubble screens are commonly used to reduce propeller noise and other sound reduction mechanisms may be employed (Richardson et al. 1998).

Misund (1997) found that fish ahead of a ship, that showed avoidance reactions, did so at ranges of 160 to 490 feet (50 to 350 m). When the vessel passed over them, some species of fish responded with sudden escape responses that included lateral avoidance or downward compression of the school. Studies documenting behavioral responses of fish to vessels show that fish may exhibit avoidance responses to engine noise, sonar, depth finders, and fish finders (Jorgensen et al. 2004, Acoustic Ecology 2007). Avoidance reactions are quite variable depending on the type of fish, its life history stage, behavior, time of day, and the sound propagation characteristics of the water (Schwartz 1985).

The low-frequency sounds of large vessels or accelerating small vessels caused avoidance responses among the herring (Chapman and Hawkins 1973). Avoidance ended within 10 seconds after the vessel departed. Twenty-five percent of the fish groups habituated to the sound of the large vessel and 75 percent of the responsive fish groups habituated to the sound small boats.

Adult fish are capable of active avoidance so ship strikes would be a rare event. Some eggs, larvae, and juvenile fish may presumably be killed or injured by contact with a ship or its’ propellers. Behavioral impacts, as discussed above, would be transient with return to normal behavior after the ship passes.

The magnitude and extent of impacts on fish from vessel movement in the NWTRC can only be expressed in qualitative terms. The density and the distribution of managed species in specific areas is not known, and, reliable, quantitative predictions of population-level effects are simply beyond the capacity of contemporary ocean science (Bryant 2005, 2006, NRC 2007, Watkins 2007). Even large fisheries databases are insufficient for hypothesis testing given the background variability in ecosystem dynamics induced by changes in natural conditions (NRC 2002a, 2004, PFMC and NMFS 2006). It is not possible to establish confidence limits on impact estimates or define precise thresholds between significant and insignificant impacts. However, Navy vessels traversing an area of 126,630 square nautical miles of sea
space would be very unlikely to substantially affect fish stocks or their pelagic habitats. Thus, there would not be adverse effects of vessel movement on managed species or EFH. While this conclusion is based on qualitative judgment, it incorporates the best scientific information available and reflects the highest level of technical assessment currently supportable. This qualification applies to all determinations made in this section.

3.3 **AIRCRAFT OVERFLIGHTS**

Aircraft flyovers will be a routine event during training exercises. Most high-performance would fly at altitudes over 5,000 feet (1,524 meters). However, aviation exercises can involve aircraft operating at low altitude (less than 1,500 feet [457 meters]), at high speeds, for a brief periods, over relatively small areas in vicinity of practice targets. Otherwise, low-level flights are usually restricted to take-offs and landings, and flights by helicopters and observation aircraft.

Airborne sound from a low-flying airplanes or helicopters may be heard by marine animals at the surface or underwater but the acoustic intensity would not be likely to cause physical damage since sound does not transmit well from air to water (Department of the Navy [DoN] 2007a,d).

The sounds from aircraft flying over the ocean could trigger startle responses and swimming away from the aircraft track in some sensitive species of fish in the upper portion of the water column. The primary factor causing abrupt movements of animals is engine noise, specifically changes in engine noise (Richardson et al.1995, Hain et al. 1999). Responses to aircraft noise would be within the range of normal behavior and highly transitory.

Aircraft flown in warfare training areas may fly at supersonic speeds (that is, faster than the speed of sound). At supersonic speeds, air pressure waves combine and produce shock waves known as sonic booms. The penetration of sound pressure waves including sonic booms through an air/water interface is relatively inefficient (Yagla and Stiegler 2003, DoN 2007b). The sound wave would have to enter the air-water interface at an angle of 13 degrees or less, otherwise the sound wave will be reflected from the water's surface. The sound introduced into the water from a sonic boom would be narrow, and sonic booms would be infrequent.

Impacts to fish from aircraft overflights would be minimal and temporary, and thus have no adverse effects on managed species or EFH.

3.4 **FUEL SPILLS**

Fish could be harmed by petroleum hydrocarbons spilled as a result of ship or aircraft accidents and weapons and target use (DoN 2007a, b, c, and d). Oil and diesel fuel pose less risk than jet fuel which is particularly toxic. However, jet fuel floats on sea water and vaporizes quickly so it would not be likely to contact many fish. Assuming that an aerial target disintegrates on contact with the water, toxic components of the fuel would evaporate within several hours to days or be degraded by bacteria, phytoplankton, zooplankton, and similar organisms (NRC 1985). Small petro-chemical releases from weapons and targets would be spatially separated and occur at different times, even in areas of highest use.

If a fuel spill occurs, the effects would be mitigated through compliance with standard spill-control responses and wildlife rescue procedures. Fuel dumping by aircraft rarely occurs. Navy aircrews are prohibited from dumping fuel below 6,000 feet (1,829 meters), except in an emergency situation. Above that altitude, the fuel has enough time to completely vaporize and dissipate and would therefore have no effect on the sea below.

Impacts to fish from fuel spills would be minimal and temporary, and thus have no adverse effects on managed species or EFH.
3.5 **DISCHARGES FROM SHIPS**

The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) prohibits certain discharges of oil, garbage, and other substances from vessels. The MARPOL Convention and its Annexes are implemented by US federal laws, including the Act to Prevent Pollution from Ships (33 USC 1901 to 1915) and the Federal Water Pollution Control Act (33 USC 1321 to 1322). These statutes are further implemented and amplified by DoN and the Office of the Chief of Naval Operations Environmental and Natural Resources Program Manual (Chief of Naval Operations Instruction [OPNAVINST] 5090.1 series), which establishes U.S. Navy policy, guidance, and requirements for the operation of U.S. Navy vessels. The vessels operating in the NWTRC would comply with the discharge requirements established in OPNAVINST 5090.1 (series), minimizing or eliminating potential impacts from the discharges of ships.

3.6 **EXPENDED MATERIALS**

The Navy uses a variety of materials expended during training exercises conducted in the NWTRC, including:

- ordnance of various sizes, both non-explosive and explosive;
- fuels, propellants, explosives, and chemicals contained in ordnance, targets, and sonobuoys;
- various targets, whether inflatable, towed by aircraft, airborne drones, or automated torpedoes; and
- marine markers that produce chemical flames and surface smoke.

Implementation of the proposed action would result in expended ordnance in the NWTRC. The majority of expended ordnance rounds would be expended in W-237, which is 33,997 square nautical miles (116,606 square kilometers) in size. W-237 extends from 3 nautical miles offshore to approximately 250 nautical miles from the Washington coast. Assuming all ordnance would be expended evenly throughout W-237, the concentration of expended rounds under the proposed action would be approximately 6 per square nautical mile (1.6 per square kilometer).

Fish could be exposed to materials expended during training in the following ways:

- surface or subsurface impact from inert ordnance or fragments of exploded ordnance;
- ingestion of expended materials, such as fragments of ordnance or targets; and
- ingestion of or contact with unexpended fuels, propellants, explosives, and chemicals.

The analyses presented here predict that the majority of the expended materials would have no significant impact on fish or essential fish habitat in territorial or non-territorial waters. The reasoning for that prediction is presented below.

**Surface and subsurface impacts.** Most missiles hit their target or are disabled before hitting the water. Thus, most of these missiles and targets hit the water as fragments, which quickly dissipate their kinetic energy within a short distance from the surface. Similarly, expended small-arms rounds may also strike the water surface with sufficient force to cause injury. Most fish swim some distance below the surface of the water. Therefore, fewer fish are exposed to mortality from falling fragments whose effects are limited to the near surface than mortality from intact missiles and targets whose effects can extend well below the water surface. Impacts of falling debris and small arms rounds on fish would be minimal and thus have no adverse effects on managed species or EFH.

**Ingestion of expended materials.** The majority of the expended materials would rapidly sink to the sea floor. In the near term, these materials could be available for ingestion by foraging fish or other animals.
that become food for other predators. The probability of fish ingesting expended ordnance would depend on factors such as the location of the spent materials, size of the materials, and the level benthic foraging that occurs in the impact area, which is a function of benthic habitat quality, prey availability, and species-specific foraging strategies. It is possible that persistent expended ordnance could be colonized by benthic organisms (such as clams and oysters) and mistaken for prey, or that expended ordnance could be accidentally ingested while foraging for natural prey items.

In the mid- and long-term, these items are expected to become encrusted by natural processes, and incorporated into the sea floor, with no significant accumulations in any particular area and no adverse effects to water quality or marine benthic communities.

**Ingestion of or contact with fuels, propellants, explosives, and chemicals.** Chemical constituents can be released from:

- explosions associated with sonobuoys, submarine targets, torpedoes, missiles, aerial targets, and underwater explosions; and
- petroleum hydrocarbons, including jet fuel, released during an accident.

Assuming that a target disintegrates on contact with the water, its fuel will be spread over a large area and dissipate quickly. In addition, fuel spills and material released from weapons and targets would occur at different locations and at different times.

Potential impacts from Navy explosion testing include degradation of substrate and introduction of toxic chemicals into the water column. The water quality effects of the explosions would be infrequent, temporary, and localized, and would have no long-term adverse effect on water quality. Furthermore, charges at the Port Townsend, Crescent Harbor and Holmes Harbor sites are raised off the bottom to minimize impacts to the sea floor. At the NBK-Bangor site, testing involves placing smaller charges onto a stationary steel frame, raising the charge off the sea floor and therefore minimizing impacts to the substrate. Effects on marine fish associated with the release of munitions constituents, carbon, and Kevlar pieces and other materials are expected to be minimal.

MK-58 marine markers produce chemical flames and regions of surface smoke and are used in various training exercises to mark a surface position to simulate divers, ships, and points of contact on the surface of the ocean. The smoke dissipates in the air having little effect on the marine environment. The marker burns similar to a flare, producing a flame until all burn components have been used. While the light generated from the marker is bright enough to be seen up to three miles away in ideal conditions, the resulting light would either be reflected off the water’s surface or would enter the water and attenuate in brightness over depth. Approximately 300 marine markers would be used in the NWTRC under the Preferred Alternative. Given the size of the NWTRC and the low number of markers used, impacts to fish from marine markers would be minimal and thus have no adverse effects on managed species or EFH.

### 3.7 Radio Frequency Emissions

Aircraft, surface ships, and land-based centers use radio frequency (RF) emissions to transmit data, track targets, and communicate with other personnel. Biological effects of high intensity, long-duration exposure to RF emissions include deep tissue heating, degradation of eye faculties, damage to reproductive organs, and, changes in behavior (DoN 2007a, b). Unlike sonar which propagates well in sea water, RF wavelengths are shorter and quickly attenuate. Impacts to fish from exposure to high intensity RF emissions would be minimal and temporary and thus would have no adverse effects on managed species or EFH.

### 3.8 Lasers

Lasers are used to guide missiles and other munitions to their targets, for mine identification, and to re-acquire mines. Lasers are not pointed toward aircraft, ships, or personnel. The AQS Mine-hunting Sonar
System is a helicopter towed Class 4 laser device used for reacquisition of mines during high-speed reconnaissance in waters with mine threat. It can be harmful to human eyes and no unprotected divers or other personnel are to be within 60 feet of the laser while in operation; reference to possible effects upon fish were not found (refer to Naval Laser Safety Review Board 5100 Ser 360/lsrb 04 April 2007 for details). Because of the narrow effective beam of lasers, the rapid diffusion of light in water (typically less than 2 meters in diameter), and the high speed at which the AQS System is towed, marine life in the water would have limited possible exposure to lasers. The impacts of laser use on fish would be minimal and temporary and thus have no adverse effects on managed species or EFH.

### 3.9 UNDERWATER DETONATIONS

Underwater detonations (UNDETs) conducted in the NWTRC would be associated with explosive ordnance disposal (EOD) training in the Puget Sound region. The training consists of using explosive charges to destroy or disable inert mines at established underwater locations in Crescent Harbor and Port Townsend Bay (on the west side of Naval Magazine Indian Island).

Potential effects of explosive charge detonations on fish and EFH include: 1) disruption of habitat, 2) exposure to chemical by-products, 3) disturbance, injury, or death from the shock (pressure) wave, 4) acoustic impacts, and 5) indirect effects including those on prey species and other components of the food web.

#### 3.9.1 Habitat Disruption

The underwater detonation of explosives may result in temporary physical alteration of fish habitats (Wright and Hopky 1998). Live hard-bottom, artificial reefs, seagrass beds, and kelp beds harbor a wide variety of marine organisms (Cahoon et al. 1990). These habitats support productive biological assemblages and dense aggregations of fish (Thompson et al. 1999). The Navy selects UNDET areas to avoid these key habitats (DoN 2005b). NWTRC underwater detonations would only take place in waters overlying unconsolidated sediment (sandy or muddy bottoms). Thus, the cratering of soft-bottom seafloor is the only habitat disruption that could result. Typically, detonations occur in 50 to 60 feet of water, at least 1000 feet from the nearest shoreline. The weight of explosive used in each detonation ranges from 5 to 20 pounds. Each exercise entails placement of an inert mine on the seafloor, location of the mine using hand-held sonar, placement of the charge on or near the mine, attachment of detonating equipment, detonation, retrieval of debris, and in-water inspection of the detonation site. Disabled mines are recovered.

Prior to detonation, the mine and detonation charge are lifted approximately 10 feet above the sea floor using a float. This procedure reduces potential seafloor disruption.

Underwater detonations would temporarily disturb surface sediments and displace organisms living on and in the substrate, and in the overlying water column. Mobile species are expected to rapidly move back into the area following detonations, whereas sedentary species may or may not recover to previous abundances depending on the spatial overlap and time interval between detonations. Turbidity increases following explosions would be brief, lasting a few minutes to a few hours, and are not expected to extend a substantial distance away. The local sediments are expected to fall out of suspension or be dispersed by waves and currents. Effects on sediment-dwelling organisms, which are regularly exposed to high turbidity as a result of waves and currents, would be minimal. Increased turbidity could temporarily decrease the foraging efficiency of fish, however, given the dynamic nature of the habitat and the grain size of the material, turbidity is expected to be minimal and localized.

#### 3.9.2 Chemical By-Products

Combustion products from the detonation of high explosives – carbon monoxide (CO), carbon dioxide (CO₂), hydrogen (H₂), water (H₂O), nitrogen (N₂), and ammonia (NH₃) - are commonly found in sea water. The primary constituents that would be released from explosives training are nitroaromatic
compounds such as trinitrotoluene (TNT), cyclonite (Research Department composition X or RDX), and octogen (High Melting Explosive or HMX) (URS et al. 2000). Initial concentrations of explosion by-products are not expected to be hazardous to marine life (DoN 2001a) and would not accumulate in the training area because exercises are spread out over time and the chemicals will rapidly disperse in the ocean. Impacts to fish from chemical by-products of detonation would be minimal and temporary and those have no adverse effects on managed species or EFH.

3.9.3 Pressure Effects

An underwater explosion generates a shock wave that produces a sudden, intense change in local pressure as it passes through the water (DoN 1998, 2001a). Pressure waves extend to a greater distance than the heat and light produced by the explosion and are, therefore the most likely source of adverse impacts on marine life (Craig 2001, SIO 2005, DoN 2006a).

The shock wave from an underwater explosion is lethal to fish at close range, causing massive organ and tissue damage and internal bleeding (Keevin and Hempen 1997). At greater distance from the detonation point, the extent of mortality or injury depends on a number of factors including fish size, body shape, orientation, and species (Wright 1982, Keevin and Hempen 1997). At the same distance from the source, larger fish are generally less susceptible to death or injury, elongated forms that are round in cross-section are less at risk than deep-bodied forms, and fish oriented sideways to the blast suffer the greatest impact (Yelverton et al. 1975, Wiley et al. 1981, O’Keefe and Young 1984a, b, Edds-Walton and Finneran 2006). Species with gas-filled organs have higher mortality than those without them (Goertner et al. 1994, CSA 2004).

Two aspects of the shock wave appear most responsible for injury and death to fish: the received peak pressure and the time required for the pressure to rise and decay (Dzwilewski and Fenton 2003). Higher peak pressure and abrupt rise and decay times are more likely to cause acute pathological effects (Wright and Hopky 1998). Rapidly oscillating pressure waves may rupture the kidney, liver, spleen, and sinus and cause venous hemorrhaging (Keevin and Hempen 1997). They can also generate bubbles in blood and other tissues, possibly causing embolism damage (Ketten 1998). Oscillating pressure waves may also burst gas-containing organs. The swim bladder, the gas-filled organ used by many pelagic fish to control buoyancy, is the primary site of damage from explosives (Yelverton et al. 1975, Wright 1982). Gas-filled fish swim bladders resonate at different frequencies than surrounding tissue and can be torn by rapid oscillation between high- and low-pressure waves. Swim bladders are a characteristic of bony fish and are not present in sharks and rays. However, hemorrhaging of the liver in sharks exposed to the shock waves from explosives could have deleterious effects on the buoyancy function provided by the livers of these species (Edds-Walton and Finneran 2006). Delayed lethality could result from the accumulation of sub-lethal injuries (DoN 200a).

Studies that have documented fish killed during planned underwater explosions indicate that most fish that die do so within one to four hours, and almost all die within a day (Hubbs and Rechnizer 1952, Yelverton et al. 1975). Fitch and Young (1948) found that the type of fish killed changed when blasting was repeated at the same marine location within 24 hours of previous blasting. They observed that most fish killed on the second day were scavengers, presumably attracted by the victims of the previous day’s blasts. However, fish collected during these types of studies have mostly been recovered floating on the waters surface. Gitschlag et al. (2000) collected both floating fish and those that were sinking or lying on the bottom after explosive removal of nine oil platforms in the northern Gulf of Mexico. They found that as few as 3 percent of the specimens killed during a blast may float to the surface. Other impediments to accurately characterizing the magnitude of fish kills included currents and winds that transported floating fish out of the sampling area and predation by seabirds or other fish.

There have been few studies of the impact of underwater explosions on early life stages of fish (eggs, larvae, juveniles). Fitch and Young (1948) reported the demise of larval anchovies exposed to underwater blasts off California, and Nix and Chapman (1985) found that anchovy and smelt larvae died following
the detonation of buried charges. Similar to adult fish, the presence of a swim bladder contributes to shock wave-induced internal damage in larval and juvenile fish (Settle et al. 2002). Shock wave trauma to internal organs of larval Pinfish and Spot from shock waves was documented by Govoni et al. (2003). These were laboratory studies, however, and have not been verified in the field.

Data on the effects of underwater explosions on aquatic plants are extremely limited. The potential for injury and mortality to aquatic invertebrates from underwater blasts is a little better known (Keevin and Hempen 1997). These studies indicate that invertebrates are relatively insensitive to pressure-related damage from underwater explosions, perhaps because they lack gas-containing organs which have been implicated in internal damage and mortality in vertebrates.

The variety of environmental parameters and biological features that can modify the impact of underwater explosions complicates the effort to predict lethal effect ranges in the field (Wright 1982, Keevin and Hempen 1997). Predictive models have, however, been developed over the past three decades (Wiley et al. 1981, Goertner 1982, Young 1991). These are based on measurements of the pressure produced by underwater explosions at increasing distance from the detonation point (O’Keefe and Young 1984, Wright and Hopky 1998, Dzwilewski and Fenton 2003). Different types of explosive materials are normalized in effect range models by establishing an equivalent weight of TNT known as the "Net Explosive Weight" or "NEW."

Young (1991) provides equations that allow estimation of the potential effect on swim bladder fish using a damage prediction method developed by Goertner (1982). Young’s parameters include the size of the fish and its location relative to the explosive source, but are independent of environmental conditions, such as depth of the fish and explosive shot frequency. An example of such model predictions is shown in Table 3-1 which lists estimated fish-effects ranges using Young’s (1991) method for swim bladder fish exposed to a 60-lb explosion at depth of 10 feet (3.3 meters). The 10 percent mortality range is the distance beyond which 90 percent of the fish present would be expected to survive. It is difficult to predict the range of more subtle effects causing injury but not mortality (CSA 2004).

<table>
<thead>
<tr>
<th>Weight of Fish</th>
<th>10% Mortality Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>feet</td>
</tr>
<tr>
<td>1 oz</td>
<td>712</td>
</tr>
<tr>
<td>1 pound</td>
<td>496</td>
</tr>
<tr>
<td>30 pounds</td>
<td>319</td>
</tr>
</tbody>
</table>

Young’s model for 90 percent fish survivability applies to simple explosives. In addition, Young’s model was based on open, deep-water conditions, where blast effects are predicted more easily. Explosives used in the NWTRC are detonated in shallow water, just off the shoreline. This restricts the effected area to a small nearshore wedge, rather than a large circular area. Given the difficulty determining the areas of influence in these shallow-water conditions and the lack of definitive estimates of the size of fish populations in such small, nearshore areas, site-specific modeling of fish mortality was not done. However, field studies indicate that previous demolition activities have not diminished or altered the composition of the fish populations (Kushner and Rich 2004).

To summarize, a limited number of fish would be killed in the immediate proximity of explosive charges detonated during EOD training. Additional fish would be injured and could subsequently die or suffer greater rates of predation. Beyond the range of direct physical impacts, there would be short-term, behavioral responses to fish within a relatively small area. When exercises are completed, the fish stock should repopulate the affected areas. The regional abundance and diversity of fish are unlikely to measurably decrease. While this conclusion is primarily based on qualitative judgments, it is supported by
the best scientific information currently available. Reliable, quantitative predictions of population level effects are simply beyond the capacity of contemporary ocean science.

3.9.4 Acoustic Impacts

Sound is the only form of energy that propagates well underwater and is used by many aquatic animals for imaging, navigation, and communication. Light, so commonly employed in sensory perception by terrestrial animals, does not penetrate far in seawater, especially in turbid coastal environments. Sound is a wave of energy from an impulse or vibration that alternately compresses and decompresses a medium like air or water. A sound wave moves through the medium causing two types of actions; an oscillation of the pressure of the medium and an oscillating movement of particles in the medium.

A sound wave has three basic attributes; frequency, wavelength, and amplitude. Frequency is the number of cycles of compression and decompression per second – expressed in units called Hertz (Hz) equal to one cycle per second. The human voice can generate frequencies between 100 and 10,000 Hz and the human ear can detect frequencies of 20 to 20,000 Hz. Some animals like dogs and bats can hear sounds at much higher frequencies - up to 160,000 Hz. At the other end of the spectrum, whales and elephants can produce and detect sounds at frequencies in the range of 15 to 35 Hz.

Wavelength is the distance between two successive compressions or the distance the wave travels in one cycle of vibration. The amplitude of a sound wave is the distance a vibrating particle is displaced. Small variations in amplitude produce weak or quiet sounds, while large variations produce strong or loud sounds. The amplitude of a sound is directly related to the amount of energy transmitted.

A number of factors determine the energy level of a sound received at a distance from the source. As sound travels through the ocean, the intensity associated with the wavefront diminishes, or attenuates. This decrease in intensity, called propagation or transmission loss, results from absorption, spreading, and scattering. Sound wave frequency determines the distance the waves travel before losing enough energy to no longer cause the medium to oscillate. High frequencies are more readily absorbed and thus travel shorter distances than low frequencies. The spreading of a wavefront causes the total power associated with the wavefront to be distributed over an increasingly large area with a concomitant decrease in intensity. Sound waves can also be diminished by striking boundaries, such as the sea surface, thermocline, seafloor, or biota in the water column.

Ambient noise in the ocean is persistent, world-wide, and comes from all directions (NRDC 1999, NRC 2003, NOAA 2007c, d, e). Background environmental noise has been measured over frequency ranges from below 1 Hz to over 100,000 Hz (100 kHz) (Cato and McCauley 2001, Andrew et al. 2002). The levels and frequencies of ambient noise in coastal waters are subject to wide variations depending on time and location. Anthropogenic (man-made) noise is produced by watercraft (from jet skis to supertankers), offshore oil/gas exploration and production, sonar, underwater telemetry and communication, construction projects, and ocean research (Richardson et al. 1995, NRDC 1999, Stocker 2002). Naturally occurring environmental noises include the sound of wind and waves, tides and currents, rain, thunder and lightning, tectonic and volcanic activity, as well as sounds produced by marine animals. At any given time and place, the ambient noise level is a mixture of these noise types with higher sound levels over consolidated substrate than sand or mud.

Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans (NOAA 2007e). The radiated noise spectrum of merchant ships ranges from 20 to 500 Hz with higher frequencies produced by sonar activities (Richardson et al. 1995). Most ocean going vessels have sonar systems for navigating, depth sounding, and sometimes “fish finding”. Depth sounding sonar usually operate in the 15 kHz to 200 kHz frequency range, while locating, positioning, and navigational sonar use the mid frequency band of 1 kHz to 20 kHz (Stocker 2002). Long-range sonar generally operate in the 100 Hz to 3 kHz range. Commercial fishing boats may also use pingers to prevent seals, dolphins, and turtles from being caught in nets (Gearin et al. 2000). There are two basic types of pinger devices,
harassment devices and deterrent devices. “Acoustic Harassment Devices” are pingers specifically used to
deter pinnipeds from preying on captured fish. These devices use high intensity signals in the middle to
high frequencies (5-30 kHz; Reeves et al. 2001). “Acoustic Deterrent Device” pingers use low intensity
sound signals in the middle to high frequencies (2.5 – 10 kHz) with higher harmonic frequencies (up to
160-180 kHz). They are designed to prevent bycatch of small cetaceans (Reeves et al. 1996, 2001).

3.9.4.1 Hearing in Marine Fish

Marine fish spend at least part of their life in salt water. All fish have two sensory systems that are used to
detect sound in the water including the inner ear, which functions very much like the inner ear found in
other vertebrates, and the lateral line, which consists of a series of receptors along the body of the fish
(Popper, 2008). The inner ear generally detects higher frequency sounds while the lateral line detects
water motion at low frequencies (below a few hundred Hz) (Hastings and Popper, 2005). A sound source
produces both a pressure wave and motion of the medium particles (water molecules in this case), both of
which may be important to fish. Fish detect particle motion with the inner ear. Pressure signals are
initially detected by the gas-filled swim bladder or other air pockets in the body, which then re-radiate the
signal to the inner ear (Popper, 2008). Because particle motion attenuates relatively quickly, the pressure
component of sound usually dominates as distance from the source increases. A more detailed discussion
of the lateral line can be found at the end of this section. Broadly, fishes can be categorized as either
hearing specialists or hearing generalists (Scholik and Yan, 2002). Fishes in the hearing specialist
category have a broad frequency range with a low auditory threshold due to a mechanical connection
between an air filled cavity, such as a swimbladder, and the inner ear. Specialists detect both the particle
motion and pressure components of sound and can hear at levels above 1 kHz. Generalists are limited to
detection of the particle motion component of low frequency sounds at relatively high sound intensities
(Amoser and Ladich, 2005). It is possible that a species will exhibit characteristics of generalists and
specialists and will sometimes be referred to as an “intermediate” hearing specialist. For example, most
damselfish are typically categorized as generalists, but because some larger damselfish have demonstrated
the ability to hear higher frequencies expected of specialists, they are sometimes categorized as
intermediate.

Although hearing capability data only exists for fewer than 100 of the 29,000 fish species (Popper, 2008),
current data suggest that most species of fish detect sounds from 0.05 to 1.0 kHz, with few fish hearing
sounds above 4 kHz (Popper, 2008; NRC, 2003). Moreover, studies indicate that hearing specializations
in marine species are quite rare and that most marine fish are considered hearing generalists (Popper,
2003; Amoser and Ladich, 2005). Specifically, the following species are all believed to be hearing
generalists: elasmobranchs (i.e., sharks and rays) (Casper et al., 2003; Casper and Mann, 2006; Myrberg,
2001), scorpaeiniforms (i.e., scorpionfishes, searobins, sculpins) (Lovell et al., 2005), scombrids (i.e.,
albacores, bonitos, mackerels, tunas) (Iversen, 1967; Iversen, 1969; Popper, 1981; Song et al., 2006),
damselfishes (Egner and Mann, 2005; Kenyon, 1996; Wright et al., 2005; Wright et al., 2007), and more
specifically, midshipman fish (Porichthys notatus) (Sisneros and Bass, 2003), Atlantic salmon (Salmo
salar) (Hawkins and Johnstone, 1978), and Gulf toadfish (Opsanus beta) (Remage-Healey et al., 2006).
Moreover, it is believed that the majority of marine fish have their best hearing sensitivity at or below 0.3
kHz (Popper, 2003). However, it has been demonstrated that marine hearing specialists, such as some
Clupeidae, can detect sounds above 100 kHz. Refer to Table 3-2 for a list of marine fish hearing
sensitivities.
<table>
<thead>
<tr>
<th>Family</th>
<th>Description of Family</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Hearing Range (kHz)</th>
<th>Greatest Sensitivity (kHz)</th>
<th>Sensitivity Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albulidae</td>
<td>Bonefishes</td>
<td>Bonefish</td>
<td><em>Albula vulpes</em></td>
<td>0.1 0.7</td>
<td>0.3</td>
<td>generalist</td>
</tr>
<tr>
<td>Anguillidae</td>
<td>Eels</td>
<td>European eel</td>
<td><em>Anguilla anguilla</em></td>
<td>0.01 0.3</td>
<td>0.04-0.1</td>
<td>generalist</td>
</tr>
<tr>
<td>Ariidae</td>
<td>Catfish</td>
<td>Hardhead sea catfish</td>
<td><em>Ariopsis (Arius) felis</em></td>
<td>0.05 1</td>
<td>0.1</td>
<td>generalist</td>
</tr>
<tr>
<td>Batrachoididae</td>
<td>Toadfishes</td>
<td>Midshipman</td>
<td><em>Porichthys notatus</em></td>
<td>0.065 0.385</td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gulf toadfish</td>
<td><em>Opsanus beta</em></td>
<td>&lt; 1</td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td>Clupeidae</td>
<td>Herrings, shads, menhadens, sardines</td>
<td>Alewife</td>
<td><em>Alosa psuedoharengus</em></td>
<td>0.12</td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blueback herring</td>
<td><em>Alosa aestivalis</em></td>
<td>0.12</td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>American shad</td>
<td><em>Alosa sapidissima</em></td>
<td>0.1 0.18</td>
<td>0.2-0.8 and 0.025-0.15</td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gulf menhaden</td>
<td><em>Brevoortia patronus</em></td>
<td>0.1</td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bay anchovy</td>
<td><em>Anchoa mitchilli</em></td>
<td>4</td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scaled sardine</td>
<td><em>Harengula jaguana</em></td>
<td>4</td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spanish sardine</td>
<td><em>Sardinella aurita</em></td>
<td>4</td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pacific herring</td>
<td><em>Clupea pallasi</em></td>
<td>0.1 5</td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td>Chondrichthyes [Class]</td>
<td>Cartilaginous fishes, rays, sharks, skates</td>
<td></td>
<td></td>
<td>0.2 1</td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td>Gadidae</td>
<td>Cods, gadiforms, grenadiers, hakes</td>
<td>Cod</td>
<td><em>Gadus morhua</em></td>
<td>0.002 0.5</td>
<td>0.02</td>
<td>generalist</td>
</tr>
<tr>
<td>Gobidae</td>
<td>Gobies</td>
<td>Black goby</td>
<td><em>Gobius niger</em></td>
<td>0.1 0.8</td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td>Holocentridae</td>
<td>Squirrelfish and soldierfish</td>
<td>Shoulderbar soldierfish</td>
<td><em>Myripristis kuntee</em></td>
<td>0.1 3.0</td>
<td>0.4-0.5</td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hawaiian squirrelfish</td>
<td><em>Adioryx xantherythus</em></td>
<td>0.1 0.8</td>
<td></td>
<td>generalist</td>
</tr>
</tbody>
</table>
Table 3-2. Marine Fish Hearing Sensitivities (continued)

<table>
<thead>
<tr>
<th>Family</th>
<th>Description of Family</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Hearing Range (kHz)</th>
<th>Greatest Sensitivity (kHz)</th>
<th>Sensitivity Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labridae</td>
<td>Wrasses</td>
<td>Tautog</td>
<td>Tautoga onitis</td>
<td>Low 0.01 High 0.5</td>
<td>0.037-0.050</td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blue-head wrasse</td>
<td>Thalassoma bifasciatum</td>
<td>Low 0.1 High 1.3</td>
<td>0.3-0.6</td>
<td>generalist</td>
</tr>
<tr>
<td>Lutjanidae</td>
<td>Snappers</td>
<td>Schoolmaster snapper</td>
<td>Lutjanus apodus</td>
<td>Low 0.1 High 1.0</td>
<td>0.3</td>
<td>generalist</td>
</tr>
<tr>
<td>Myctophidae</td>
<td>Lanternfishes</td>
<td>Warming’s lanternfish</td>
<td>Ceratoscopeulus warmingii</td>
<td></td>
<td></td>
<td>specialist</td>
</tr>
<tr>
<td>Pleuronectidae</td>
<td>Flatfish</td>
<td>Dab</td>
<td>Limanda limanda</td>
<td>Low 0.03 High 0.27</td>
<td>0.1</td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>European plaice</td>
<td>Pleuronetes platessa</td>
<td>Low 0.03 High 0.2</td>
<td>0.11</td>
<td>generalist</td>
</tr>
<tr>
<td>Pomadasyidae</td>
<td>Grunts</td>
<td>Blue striped grunts</td>
<td>Haemulon sciuurs</td>
<td>Low 0.1 High 1.0</td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td>Pomacentridae</td>
<td>Damselfish</td>
<td>Sergeant major damselfish</td>
<td>Abudefauf saxatilis</td>
<td>Low 0.1 High 1.6</td>
<td>0.1-0.4</td>
<td>Generalist/intermediate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bicolor damselfish</td>
<td>Stegastes partitus</td>
<td>Low 0.1 High 1.0</td>
<td>0.5</td>
<td>Generalist/intermediate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nagasaki damselfish</td>
<td>Pomacentrus nagasakiensis</td>
<td>Low 0.1 High 2.0</td>
<td>&lt;0.3</td>
<td>Generalist/intermediate</td>
</tr>
<tr>
<td>Salmonidae</td>
<td>Salmons</td>
<td>Atlantic salmon</td>
<td>Salmo salar</td>
<td>Low &lt;0.1 High 0.58</td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td>Sciaenidae</td>
<td>Drums, weakfish, croakers</td>
<td>Atlantic croaker</td>
<td>Micropogonias undulates</td>
<td>Low 0.1 High 1.0</td>
<td>0.3</td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spotted sea trout</td>
<td>Cynoscion nebulosus</td>
<td></td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kingfish</td>
<td>Menticirrhus americanus</td>
<td></td>
<td></td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spot</td>
<td>Leiostomus xanthurus</td>
<td>Low 0.2 High 0.7</td>
<td>0.4</td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Black drum</td>
<td>Pogonias cromis</td>
<td>Low 0.1 High 0.8</td>
<td>0.1-0.5</td>
<td>generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weakfish</td>
<td>Cynoscion regalis</td>
<td>Low 0.2 High 2.0</td>
<td>0.5</td>
<td>specialist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silver perch</td>
<td>Bairdiella chrysoura</td>
<td>Low 0.1 High 4.0</td>
<td>0.6-0.8</td>
<td>specialist</td>
</tr>
</tbody>
</table>
### Table 3-2. Marine Fish Hearing Sensitivities (continued)

<table>
<thead>
<tr>
<th>Family</th>
<th>Description of Family</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Hearing Range (kHz)</th>
<th>Greatest Sensitivity (kHz)</th>
<th>Sensitivity Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scombridae</td>
<td>Albacores, bonitos, mackerels, tunas</td>
<td>Bluefin tuna</td>
<td><em>Thunnus thynnus</em></td>
<td>Low: 1.0</td>
<td>Generalist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yellowfin tuna</td>
<td><em>Thunnus albacares</em></td>
<td>High: 1.1</td>
<td>Generalist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kawakawa</td>
<td><em>Euthynnus affinis</em></td>
<td>Low: 0.1</td>
<td>0.5</td>
<td>Generalist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Skipjack tuna</td>
<td><em>Katsuwonus pelamis</em></td>
<td>High: 1.1</td>
<td>Generalist</td>
<td></td>
</tr>
<tr>
<td>Scorpaenidae</td>
<td>Scorpionfishes, searobins, sculpins</td>
<td>Sea scorpion</td>
<td><em>Taurulus bubalis</em></td>
<td>Low: 0.1</td>
<td>Generalist</td>
<td></td>
</tr>
<tr>
<td>Serranidae</td>
<td>Seabasses, groupers</td>
<td>Red hind</td>
<td><em>Epinephelus guttatus</em></td>
<td>Low: 0.1</td>
<td>0.2</td>
<td>Generalist</td>
</tr>
<tr>
<td>Sparidae</td>
<td>Porgies</td>
<td>Pinfish</td>
<td><em>Lagodon rhomboides</em></td>
<td>Low: 0.1</td>
<td>0.3</td>
<td>Generalist</td>
</tr>
<tr>
<td>Triglidae</td>
<td>Scorpionfish, searobins, sculpins</td>
<td>Leopard searobin</td>
<td><em>Prionotus scutulatus</em></td>
<td>Low: 0.1</td>
<td>0.39</td>
<td>Generalist</td>
</tr>
</tbody>
</table>

* Referenced as *Arius felis* by Popper and Tavolga, 1981.

Sources: Astrup, 1999; Astrup and Mohl, 1993; Casper and Mann, 2006; Casper et al., 2003; Coombs and Popper, 1979; Dunning et al., 1992; Egner and Mann, 2005; Gregory and Clabburn, 2003; Hawkins and Johnstone, 1978; Higgs et al., 2004; Iversen, 1967, 1969; Jorgensen et al., 2004; Kenyon, 1996; Lovell et al., 2005; Mann et al., 1997, 2001, 2005; Myrberg, 2001; Nestler et al., 2002; Popper, 1981; Popper and Carlson, 1998; Popper and Tavolga, 1981; Ramcharitar and Popper, 2004; Ramcharitar et al., 2001, 2004, 2006, Remage-Healey et al., 2006; Ross et al., 1996; Sisneros and Bass, 2003; Song et al., 2006; Wright et al., 2005, 2007; Popper, 2008

In contrast to marine fish, several thousand freshwater species are thought to be hearing specialists. Nelson (1994) estimates that 6,600 of 10,000 freshwater species are otophysans (catfish and minnows), which are hearing specialists. Interestingly, many generalist freshwater species, such as perciforms (percids, gobiids) and scorpaeniforms (sculpins) are thought to have derived from marine habitats (Amoser and Ladich, 2005). It is also thought that Clupeidae may have evolved from freshwater habitats (Popper et al., 2004). This supports the theory that hearing specializations likely evolved in quiet habitats common to freshwater and the deep sea because only in such habitats can hearing specialists use their excellent hearing abilities (Amoser and Ladich, 2005).

Some investigators (e.g., Amoser and Ladich, 2005) hypothesize that, within a family of fish, different species can live under different ambient noise conditions, which requires them to adapt their hearing abilities. Under this scenario, a species’ probability of survival would be greater if it increased the range over which the acoustic environment, consisting of various biotic (sounds from other aquatic animals) and abiotic (wind, waves, precipitation) sources, could be detected. In the marine environment, Amoser and Ladich (2005) cite the differences in the hearing ability of two species of Holocentridae as a possible example of such environmentally-derived specialization. Both the shoulderbar soldierfish (*Myripristis kuntee*) and the Hawaiian squirrelfish (*Adioryx xantherythrus*) can detect sounds at 0.1 kHz. However, the
high frequency end of the auditory range extends towards 3 kHz for the shoulderbar soldierfish but only to 0.8 kHz for the Hawaiian squirrelfish (Coombs and Popper, 1979). However, as these two species live in close proximity on the same reefs, it is not certain that differing environmental conditions cause the hearing variations (Popper, 2008). Generally, a clear correlation between hearing capability and the environment cannot be asserted or refuted due to limited knowledge of ambient noise levels in marine habitats and a lack of comparative studies.

Susceptibility to anthropogenic sound can be influenced by developmental and genetic differences in the same species of fish. In an exposure experiment, Popper et al. (2007) found that experimental groups of rainbow trout (Oncorhynchus mykiss) had substantial differences in hearing thresholds. While fish were attained from the same supplier, it is possible different husbandry techniques may be the reason for the differences in hearing sensitivity. These results emphasize that caution should be used in extrapolating data beyond their intent.

Among all fishes studied to date, perhaps the greatest variability is found within the family Sciaenidae (i.e., drumfish, weakfish, croaker), where there is extensive diversity in inner ear structure and the relationship between the swim bladder and the inner ear. Specifically, the Atlantic croaker’s (Micropogonias undulatus) swim bladder has forwardly directed diverticulae that come near the ear but do not actually touch it. However, the swim bladders in the spot (Leiostomus xanthurus) and black drum (Pogonias cromis) are further from the ear and lack anterior horns or diverticulae. These differences are associated with variation in both sound production and hearing capabilities (Ladich and Popper, 2004, Ramcharitar et al., 2006b). Ramcharitar and Popper (2004) discovered that the black drum responded to sounds from 0.1 to 0.8 kHz and was most sensitive between 0.1 and 0.5 kHz, while the Atlantic croaker responded to sounds from 0.1 to 1 kHz and was most sensitive at 0.3 kHz. Additional sciaenid research by Ramcharitar et al. (2006) investigated the hearing sensitivity of weakfish (Cynoscion regalis) and spot. Weakfish were found to detect frequencies up to 2 kHz, while spot detected frequencies only up to 0.7 kHz.

The sciaenid with the greatest hearing sensitivity discovered thus far is the silver perch (Bairdiella chrysoura), which has demonstrated auditory thresholds similar to goldfish, responding to sounds up to 4 kHz (Ramcharitar et al., 2004). Silver perch swim bladders have anterior horns that terminate close to the ear. The Ramcharitar et al. (2004) research supports the suggestion that the swim bladder can potentially expand the frequency range of sound detection. Furthermore, Sprague and Luczkovich (2004) calculated silver perch are capable of producing drumming sounds ranging from 128 to 135 dB. Since drumming sounds are produced by males during courtship, it can be inferred that silver perch detect sounds within this range.

The most widely noted hearing specialists are otophysans, which have bony Weberian ossicles (bones that connect the swim bladder to the ear), along which vibrations are transmitted from the swim bladder to the inner ear (Amoser and Ladich, 2003; Ladich and Wysocki, 2003). However, only a few otophysans inhabit marine waters. In an investigation of a marine otophysan, the hardhead sea catfish (Ariopsis felis), Popper and Tavolga (1981) determined that this species was able to detect sounds from 0.05 to 1 kHz, which is considered a much lower and narrower frequency range than that common to freshwater otophysans (i.e., above 3 kHz) (Ladich and Bass, 2003). The difference in hearing capabilities in the respective freshwater and marine catfish appears to be related to the inner ear structure (Popper and Tavolga, 1981).

Experiments on marine fish have obtained responses to frequencies up to the range of ultrasound; that is, sounds between 40 to 180 kHz (University of South Florida, 2007). These responses were from several species of the Clupeidae (i.e., herrings, shads, and menhadens) (Astrup, 1999); however, not all clupeid species tested have responded to ultrasound. Astrup (1999) and Mann et al. (1998) hypothesized that these ultrasound detecting species may have developed such high sensitivities to avoid predation by odontocetes. Studies conducted on the following species showed avoidance to sound at frequencies over
100 kHz: alewife (*Alosa pseudoharengus*) (Dunning et al., 1992; Ross et al., 1996), blueback herring (*A. aestivalis*) (Nestler et al., 2002), Gulf menhaden (*Brevoortia patronus*) (Mann et al., 2001) and American shad (*A. sapidissima*) (Popper and Carlson, 1998). The highest frequency to solicit a response in any marine fish was 180 kHz for the American shad (Gregory and Clabburn, 2003; Higgs et al., 2004). The *Alosa* species have relatively low thresholds (about 145 dB re 1 μPa), which should enable the fish to detect odontocete clicks at distances up to about 200 meters (656 feet) (Mann et al., 1997). For example, echolocation clicks ranging from 200 to 220 dB could be detected by shad with a hearing threshold of 170 dB at distances from 25 to 180 meters (82 to 591 feet) (University of South Florida, 2007). In contrast, the Clupeidae bay anchovy (*Anchoa mitchilli*), scaled sardine (*Harengula jaguana*), and Spanish sardine (*Sardinella aurita*) did not respond to frequencies over 4 kHz (Gregor y and Clabburn, 2003; Mann et al., 2001).

Wilson and Dill (2002) demonstrated that there was a behavioral response seen in Pacific herring (*Clupea pallasii*) to energy levels associated with frequencies from 1.3 to 140 kHz, although it was not clear whether the herring were responding to the lower-frequency components of the experiment or to the ultrasound. However, Mann et al. (2005) advised that acoustic signals used in the Wilson and Dill (2002) study were broadband and contained energy of less than 4 kHz to ultrasonic frequencies. Contrary to the Wilson and Dill (2002) conclusions, Mann et al. (2005) found that Pacific herring could not detect ultrasonic signals at received levels up to 185 dB re 1 μPa. Pacific herring had hearing thresholds (0.1 to 5 kHz) that are typical of Clupeidae that do not detect ultrasound signals.

Species that can detect ultrasound do not perceive sound equally well at all detectable frequencies. Mann et al. (1998) reported that the American shad can detect sounds from 0.1 to 180 kHz with two regions of best sensitivity: one from 0.2 to 0.8 kHz, and the other from 25 to 150 kHz. The poorest sensitivity was found from 3.2 to 12.5 kHz.

Although few non-clupeid species have been tested for ultrasound (Mann et al., 2001), the only other non-clupeid species shown to possibly be able to detect ultrasound is the cod (*Gadus morhua*) (Astrup and Mohl, 1993). However, in Astrup and Moh’s (1993) study it is feasible that the cod was detecting the stimulus using touch receptors that were over driven by very intense fish-finding sonar emissions (Astrup, 1999; Ladich and Popper, 2004). Nevertheless, Astrup and Mohl (1993) indicated that cod have ultrasound thresholds of up to 38 kHz at 185 to 200 dB re 1 μPa, which likely only allows for detection of odontocete’s clicks at distances no greater than 10 to 30 meters (33 to 98 feet) (Astrup, 1999).

As mentioned above, investigations into the hearing ability of marine fishes have most often yielded results exhibiting poor hearing sensitivity. Experiments on elasmobranch fish (i.e., sharks and rays) have demonstrated poor hearing abilities and frequency sensitivity from 0.02 to 1 kHz, with best sensitivity at lower ranges (Casper et al., 2003; Casper and Mann, 2006; Myrberg, 2001). Though only five elasmobranch species have been tested for hearing thresholds, it is believed that all elasmobranchs will only detect low-frequency sounds because they lack a swim bladder, which resonates sound to the inner ear. Theoretically, fishes without an air-filled cavity are limited to detecting particle motion and not pressure and therefore have poor hearing abilities (Casper and Mann, 2006).

By examining the morphology of the inner ear of bluefin tuna (*Thunnus thynnus*), Song et al. (2006) hypothesized that bluefin tuna probably do not detect sounds to much over 1 kHz (if that high). This research concurred with the few other studies conducted on tuna species. Iversen (1967) found that yellowfin tuna (*T. albacares*) can detect sounds from 0.05 to 1.1 kHz, with best sensitivity of 89 dB (re 1 μPa) at 0.5 kHz. Kawakawa (*Euthynnus affinis*) appear to be able to detect sounds from 0.1 to 1.1 kHz but with best sensitivity of 107 dB (re 1 μPa) at 0.5 kHz (Iversen, 1969). Additionally, Popper (1981) looked at the inner ear structure of a skipjack tuna (*Katsuwonus pelamis*) and found it to be typical of a hearing generalist. While only a few species of tuna have been studied, and in a number of fish groups both generalists and specialists exist, it is reasonable to suggest that unless bluefin tuna are exposed to
very high intensity sounds from which they cannot swim away, short- and long-term effects may be minimal or nonexistent (Song et al., 2006).

Some damselfish have been shown to be able to hear frequencies of up to 2 kHz, with best sensitivity well below 1 kHz. Egner and Mann (2005) found that juvenile sergeant major damselfish (Abudefduf saxatilis) were most sensitive to lower frequencies (0.1 to 0.4 kHz); however, larger fish (greater than 50 millimeters) responded to sounds up to 1.6 kHz. Still, the sergeant major damselfish is considered to have poor sensitivity in comparison even to other hearing generalists (Egner and Mann, 2005). Kenyon (1996) studied another marine generalist, the bicolor damselfish (Stegastes partitus), and found the bicolor damselfish responded to sounds up to 1.6 kHz with the most sensitive frequency at 0.5 kHz. Further, larval and juvenile Nagasaki damselfish (Pomacentrus nagasakiensis) have been found to hear at frequencies between 0.1 and 2 kHz, however, they are most sensitive to frequencies less than 0.3 kHz (Wright et al., 2005; Wright et al., 2007). Thus, damselfish appear to be primarily generalists with some ability to hear slightly higher frequencies expected of specialists (Popper, 2008).

Female midshipman fish apparently use the auditory sense to detect and locate vocalizing males during the breeding season. Interestingly, female midshipman fish go through a shift in hearing sensitivity depending on their reproductive status. Reproductive females showed temporal encoding up to 0.34 kHz, while nonreproductive females showed comparable encoding only up to 0.1 kHz (Sisneros and Bass, 2003).

The hearing capability of Atlantic salmon indicates a rather low sensitivity to sound (Hawkins and Johnstone, 1978). Laboratory experiments yielded responses only to 0.58 kHz and only at high sound levels. Salmon’s poor hearing is likely due to the lack of a link between the swim bladder and inner ear (Jorgensen et al., 2004).

Furthermore, investigations into the inner ear structure of fishes belonging to the order Scorpaeniformes have suggested that these fishes have generalist hearing abilities (Lovell et al., 2005). Although an audiogram (which provides a measure of hearing sensitivity) has yet to be performed, the lack of a swimbladder is indicative of these species having poor hearing ability (Lovell et al., 2005). However, studies of the leopard robin (Prionotus scitulus), another species in this order that do contain swim bladders, indicated that they are hearing generalists as well (Tavolga and Wodinski, 1963) which makes extrapolation on hearing from this species to all members of the group very difficult to do (Popper, 2008).

As mentioned above, the lateral line is the second component of the sensory system used by fish to detect acoustic signals. The lateral line system of a fish allows for sensitivity to sound (Hastings and Popper, 2005). This system is a series of receptors along the body of the fish that detects water motion relative to the fish that arise from sources within a few body lengths of the animal. The sensitivity of the lateral line system is generally from below 1 Hz to a few hundred Hertz (Coombs and Montgomery, 1999; Webb et al., 2008). The only study on the effect of exposure to sound on the lateral line system (conducted on one freshwater species) suggests no effect on these sensory cells by intense pure tone signals (Hastings et al., 1996). While studies on the effect of sound on the lateral line are limited, Hastings et al.’s (1996) work, showing limited sensitivity to within a few body lengths and to sounds below a few hundred Hertz, make the effect of the mid-frequency sonar of the Proposed Action unlikely to affect a fish’s lateral line system. Therefore, further discussion of the lateral line in this analysis is unwarranted.

Of the fish species with distributions overlapping the NWTRC for which hearing sensitivities are known, most are hearing generalists.

3.10 WEAPONS TRAINING

EFH and managed species could be affected from shock waves and noise associated with weapons use, from sound generated as the projectile travels to the target, and from shock waves, sound, and debris created by impact and explosion of the weapon.
3.10.1 Bombing

Typically, bombing exercises (BOMBEX) at sea involve one or more aircraft bombing a target simulating a hostile surface vessel (DoN 2005c). Weapons with non-explosive warheads would generate physical shock entering the water but would not explode. The shock from practice bombs hitting the sea surface would cause a small number of fish kills or injuries and minor acoustic displacement but would not jeopardize fish populations.

Practice bombs entering the water would be devoid of combustion chemicals found in the warheads of explosive bombs. After sinking to the bottom, the physical structure of bombs would be incorporated into the marine environment by natural encrustation or sedimentation.

Aircraft need to qualify with both explosive and non-explosive ordnance. Air-to-ground bombing using explosive ordnance is mostly conducted at land ranges. However, some live bombs are dropped at sea.

As with underwater detonations, the range within which fish may sustain injury or death from an exploding bomb would depend on environmental parameters: the size, location, and species of the fish; and whether it has a swim bladder (DoN 2005c). Fish without swim bladders are far more resistant to explosions than those with swim bladders (Keevin and Hempen 1997).

Propelled fragments are produced by an exploding bomb. In close proximity to the explosion, fish could be killed outright or sustain injury from propelled fragments (Stuhmiller et al. 1990). However, studies of underwater bomb blasts have shown that fragments are larger than those produced during air blasts and decelerate much more rapidly (O’Keeffe and Young 1984, Swisdak Jr. and Montaro 1992), reducing the risk to marine life.

Explosive bombs will be fused to detonate on contact with the water and it is estimated that 99 percent of them will explode within 5 feet (1.5 meters) of the ocean surface (DoN 2005c). Table 3-3, based on Young’s (1991) model, displays 10-percent mortality (90-percent survival) ranges for the largest explosive bombs that may be deployed during at-sea exercises.

<table>
<thead>
<tr>
<th>Warhead Weight NEW (lb-TNT)</th>
<th>10% Mortality Range by Weight of Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 ounce</td>
</tr>
<tr>
<td>500-lb</td>
<td>1,289 ft (393 m)</td>
</tr>
<tr>
<td>1,000-lb</td>
<td>1,343 ft (409 m)</td>
</tr>
<tr>
<td>2,000-lb</td>
<td>1,900 ft (579 m)</td>
</tr>
</tbody>
</table>

Table 3-3, as expected, reflects the fact that smaller fish are more subject to mortal effects from underwater explosions than larger fish. It also shows the non-linear relationship of the model equations relating explosive weight to range of effect. A four-fold increase in NEW increases the 10 percent mortality range by one and one-half times (doubling the area of effect).

Unlike the nearshore, shallow-water underwater explosive training areas, live bombing exercises would take place in deep water, so fish-effects range models would be appropriate for estimating the impact on fish populations.

Fish would be killed or injured from detonation of explosive bombs in relatively small areas compared to the vast expanse of the NWTRC. Beyond the range of physical effects, the natural reaction of fish would be to leave the area. When the exercise concludes, the area would be repopulated and the fish stock would rebound. The overall impact to water column habitat would be localized and transient. The abundance and diversity of fish within NWTRC is unlikely to be adversely affected as a result of bombing exercises.
Acoustic impacts on fish during live bomb exercises would be similar to those discussed earlier for underwater detonations associated with underwater detonations. Although some fish in the vicinity of the exercises might react negatively to the noise of bomb explosions, the limited number of these events and the relatively small areas affected should minimize the effect on local fish populations. Chemical by-products of bomb detonations would not pose a hazard to marine animals since the chemicals will be diluted prevailing currents and the exercises will be dispersed in time and space.

Noise produced during weapons use may disrupt the behaviors of marine species in the immediate area. Because of the localized nature and short duration of the exercise, there would be no lasting impact on prey availability, as only small portions of the prey population would be affected and populations would rapidly replenish. Due to the shallow detonation depth (<5 feet (1.5 meters) below the surface, bombs dropped in deeper waters would have minimal effects on the seafloor and on the animals that dwell there. The detonation of large bombs in shallow water is very unlikely.

Fragments from detonated bombs would settle to the sea floor where solid metal components would be corroded by seawater at slow rates. Over time, natural encrustation of exposed surfaces would occur, reducing the rate at which subsequent corrosion occurs. Rates of deterioration would vary, depending on the type of material and on environmental conditions. Due to the large area of the NWTRC, expended ordnance would be widely scattered on the ocean floor and would have a minimal impact on the benthic environment.

The proposed bombing exercises likely would result in only minimal or temporary reductions in the quality or quantity of EFH within NWTRC. The disruption to habitat components that support feeding, resting, sheltering, reproduction, to migration of fish would be slight to non-existent.

3.10.2 Naval Gun Fire

Potential effects from the use of naval gun systems have been analyzed in a variety of environmental documents (DoN 2000, 2001a, 2002a, 2004a and b, 2007a). The 5-inch gun has the largest warhead fired during routine gunnery exercises. Most training uses non-explosive 5-inch rounds. The surface area of the ocean impacted by a non-explosive 5-inch round has been estimated to be 20 square inches (129 cm$^2$) (DoN 2007a). So the approximately 3,500 non-explosive 5-inch rounds fired annually in the NWTRC would create a cumulative impact area of 486 ft$^2$ (45 m$^2$). Considering the vast expanse of the NWTRC, few fish would be directly struck by a shell from a 5-inch gun.

Explosive rounds would have the greatest potential for impacts to fish in surface waters. As previously indicated, biological effects of an underwater explosion depend on many factors, including the size, type, and depth of both the animal and the explosive, the depth of the water column, the standoff distance from the charge to the animal, and the sound-propagation properties of the environment. Potential impacts can range from brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997).

Table 3-4 provides an estimation of the potential range of lethal effects on swim bladder fish based on Young’s (1991) model for five-inch explosive projectiles. These rounds have a NEW of TNT of approximately 8 pounds (3.6 kg) and are assumed to detonate at a depth of 5 feet (1.3 meters). Behavioral reactions of fish would extend over a substantially larger area. The overall impacts to water-column habitat would, however, be minor as fish would return following the exercise. The abundance and diversity of fish and the quality and quantity of fish habitat within the range is unlikely to decrease as a result of gun fire training.
Table 3-4: Estimated Fish-Effects Ranges for 5-inch Naval Gunfire Rounds

<table>
<thead>
<tr>
<th>Weight of Fish</th>
<th>10% Mortality Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>feet</td>
</tr>
<tr>
<td>1 oz</td>
<td>405</td>
</tr>
<tr>
<td>1 pound</td>
<td>282</td>
</tr>
<tr>
<td>30 pounds</td>
<td>181</td>
</tr>
</tbody>
</table>

Accurate measurements of the size of the debris field from the underwater explosion of 5-inch shells are not available. However, the shells are typically fused to explode at the sea surface. This, combined with the high downward velocity of the shell at impact, suggests that the debris field from the exploding shell would be restricted in size. As with exploding bombs, the shell fragments rapidly decelerate through contact with the surrounding water. The possibility that the exploding shell fragments and debris would significantly affect EFH and fish populations is considered negligible.

Contaminants released from the detonation of exploding shells would be similar to those discussed previously for bombs. Thus, it is unlikely that the explosive compounds or their combustion products would pose a threat to fish populations or EFH.

Unexploded five-inch shells and non-explosive ordnance practice shells would not be recovered and would sink to the bottom. The explosive material of unexploded ordnance would not be exposed to the marine environment, as it is encased in a non-buoyant cylindrical package. Should the RDX be exposed on the ocean floor, it would break down within a few hours (DoN 2001a). It does not bioaccumulate in fish or in humans. Over time, RDX residue would be covered by ocean sediments or diluted by ocean water.

Solid-metal components of unexploded ordnance and non-explosive ordnance would be corroded by seawater at slow rates, which comparable slow release rates. Exposure of fish to chemical constituents from all metallic and non-metallic ordnance components would be further reduced as a result of natural encrustation of external surfaces. Consequently, the release of contaminants from unexploded ordnance and non-explosive ordnance would not adversely affect marine water quality.

Naval gunfire could have acoustic effects from: 1) noise generated by firing the gun (muzzle blast), 2) vibration from the blast propagating through the ship’s hull, 3) sonic-booms generated by the shell flying through the air, and 4) noise from the impact and explosion of the shell.

Firing a deck gun produces a shock wave in air that propagates away from the muzzle in all directions, including toward the air/water surface. Direct measurements of shock wave pressures transferred through the air/water interface from the muzzle blast of a 5-inch gun are well below levels known to be harmful at shallow depths (DoN 2000, Yagla and Stiegler 2003). Noise produced during gunfire may disturb fish in the vicinity of the ship. Because the noise is brief, no adverse effects to managed species or EFH would result.

Gun fire sends energy through the ship structure, into the water, and away from the ship. This effect was also investigated in conjunction with the measurement of 5-inch caliber gun blasts described above (DoN 2000, Yagla and Stiegler 2003). The energy transmitted through the ship to the water for a typical round was found to be about 6 percent of that from the air blast impinging on the water. Therefore, noise transmitted from the gun through the hull into the water would not result in adverse effects to managed species or EFH.

The sound generated by a shell in its flight at supersonic speeds above the water is transmitted into the water in much the same way as a muzzle blast (Pater 1981). The region of underwater noise influence from a single traveling shell is relatively small, diminishes quickly as the shell gains altitude, and is of
short duration. The penetration of sound through the air/water interface is relatively limited (Miller 1991, Yagla and Stiegler 2003). Studies reviewed in DoN 2007a indicate only a small number of submerged species would be exposed to the pressure waves from sonic booms from 5-inch shells fired during routine training exercises.

The potential exists for energy from multiple sonic booms to accumulate over time from multiple, possibly rapid firings of a gun. However, because the area directly below the shells’ path, where the conditions are correct for energy to enter the ocean is small, it is highly unlikely that the energy from more than two or three shells would be additive.

Behavioral effects from the noise of naval gunnery shells exploding would be similar to that already described for other types of underwater explosions. Although fish in the vicinity of the explosion may exhibit avoidance reactions, the noises generated are relatively short-term and localized, and behavioral disruptions would not be expected to have adverse effects on the survival, growth, or reproduction of fish populations.

3.10.3 Small Arms Fire

Small arms rounds and Close-In Weapons System (CIWS) rounds fired directly into the water decelerate to non-lethal velocity within 56 centimeters (22 in) of the water’s surface after impact (DoN 2007a, b). The maximum area of water surface that might be struck by the 20 mm CIWS rounds was estimated by taking the cross-sectional surface area of a 20 mm round multiplied by the total number of rounds fired during a typical year (DoN 2002a). Given the large area of the NWTRC, limited fish mortality and injury would be expected from CIWS and other small arms fire.

Few fish would be directly hit by bullets striking the water during small arms exercises. Bullets rapidly decelerate on contact with water, presenting minimal threat to fish swimming below the surface. The shock waves generated by bullets hitting the water is not expected to be great enough to cause harm to marine animals (DoN 2007a,b). Fish in the area would be startled by the sound, but should return to normal behavior shortly after the exercise.

Fish feeding in the vicinity of the small arms fire exercises could potentially ingest expended shells, shell fragments, or shell casings. The shiny metallic surface of a newly discharged shell casing and its movement through the water may trigger a feeding response. If ingested, the casing could lodge in the digestive system and interfere with food consumption and digestion. However, the probability of such events is low and significant consequences at the level of fish populations would not be likely. Spent shell casings deposited on the sea floor could also be mistaken for food, although, discharged casings will remain shiny for only a short period, reducing the potential for ingestion by fish.

Expended bullets may release small amounts of iron, aluminum, and copper into the sediments and the overlying water column as bullets corrode. Although, elevated levels of these elements can cause toxic reactions in exposed animals, high concentrations in sediments would be restricted to a small zone around the bullet, and releases to the overlying water column would be quickly diluted. The projectiles for 5.56-mm and 7.62-mm gun ammunition have lead cores; however, no significant releases of lead into the water through dissolution are expected because of the neutral pH of ocean waters and sediments (DoN 2005d). Impacts to fish from small arms fire would be minimal and thus have no adverse effects on managed species or EFH.

3.10.4 Torpedo Exercises

Torpedo exercises (TORPEXs) entail aircraft, surface ship, or submarine crews attacking targets with torpedoes (DoN 2004c, 2005b). Submarines practice launching non-explosive training torpedoes against surface ship targets. When a torpedo “hits” its target, or runs out of fuel if it misses its intended target, it drops ballast weights (see previous expended material section) or inflates a gas chamber and floats to the
surface to be recovered by a ship. Torpedoes used in aviation exercises typically employ recoverable exercise torpedoes which do not have fuel or propulsion. Attempts are made to recover all torpedoes.

No ordnance would be detonated during a TORPEX, so the physical force that marine organisms are exposed to would be limited to that produced by torpedo launching and movement. Due to the small area of torpedo traverse, the number of fish strikes by torpedoes would be low.

The primary potential impact to the marine environment would be the release of combustion products into the ocean from torpedo fuel. Torpedo exhaust products, nitrogen oxides, carbon monoxide, carbon dioxide, hydrogen, nitrogen, methane, ammonia, and hydrogen cyanide, would be rapidly dissolved, disassociated, or dispersed in the water column (DoN 2004c). Carbon dioxide, nitrogen, methane and ammonia are naturally-occurring in seawater. Carbon monoxide and hydrogen have low solubility in seawater and would bubble to the surface dissipating into the air. Trace amounts of nitrogen oxides may be present, but are usually below detectable limits.

Hydrogen cyanide (HCN) does not normally occur in seawater, and if present in high-enough concentration, could pose a potential risk to marine biota. The U.S. Environmental Protection Agency national water-quality criterion for HCN in marine waters is 1 part per billion for both acute and chronic effects. In order for the HCN concentration to be below this threshold and be considered non-toxic, marine life would need to be outside an estimated 6.3 meters (21 feet) zone of influence around the torpedo’s path until such time that the HCN is diffused into the water (DoN 2004c). Because HCN has extremely high solubility in seawater, the HCN will rapidly diffuse to levels below one ppb and thus would pose no significant threat to marine organisms. For a substantial quantity of torpedo fuel to be released into the ocean, the torpedo would have to be subjected to stresses beyond its structural design limits and catastrophically fail. Such stress is very unlikely to occur.

The MK-50 torpedo uses lithium metal fuel. Its operation does not result in a routine discharge. A breach of the lithium-fueled boiler systems is extremely rare, but might occur at an estimated rate of once per year worldwide. Based on an analysis of worst-case scenarios, the Navy concluded that a breach of the lithium boiler system at any point in the torpedo run would not adversely affect the marine environment (DoN 2004c).

3.10.5 Missile Exercises

In these exercises, missiles are fired by aircraft, and ships at a variety of airborne and surface targets. Missiles used in most aviation exercises are non-explosive versions and do not explode upon contact with the target or sea surface. Practice missiles do not use rocket motors or their potentially hazardous rocket fuel. The main environmental impact would be the physical structure of the missile itself entering the water.

Intact missiles and aerial targets falling from the sky would impact the ocean surface with great force, producing shock waves that could kill and injure fish. Exploding warheads may be used in air-to-air missile exercises, but to avoid damaging the aerial target, the missile explodes in the air, disintegrates, then, falls into the ocean.

The quantity of fish killed or injured by practice missiles or their debris striking the water would be a very small fraction of the indigenous fish community. As such, missile exercises would not result in adverse effects to fish populations or EFH.

3.10.6 Expeditionary Assault

Expeditionary Assault involves a seaborne force assaulting across a beach in a combination of helicopters, vertical takeoff and landing aircraft, landing craft air cushion, amphibious assault vehicles, and expeditionary fighting vehicle and landing craft. More robust expeditionary assault activities include support by naval surface fire support, close air support, and Marine artillery.
The large vehicles and landing craft crossing shallow water and the beach in an amphibious assault could damage EFH. Before each major amphibious landing exercise is conducted, a hydrographic survey is performed to map out the precise transit routes through sandy bottom areas. During the landing, the crews follow established procedures, such as having a designated lookout watching for other vessels, obstructions to navigation, and significant concentrations of marine animals. Sensitive habitats such as rocky reefs, seagrass beds, and kelp beds would be avoided.

Although amphibious landings are restricted to specific areas of designated beaches, amphibious landings in nearshore sandy subtidal habitat could lead to temporary increases in turbidity. Increases in turbidity could temporarily decrease the foraging efficiency of fish, however, given the dynamic nature of the habitat and the grain size of the material, turbidity is expected to be minimal and localized. Artillery rounds that fall short of land would destroy patches of sandy bottom habitat kill or injure nearby marine life. However, the overall impacts on marine biological resources would be limited because sandy beach habitats support relatively few organisms and are adapted to recover quickly from disturbance.

### 3.10.7 Sinking Exercises

The transportation of naval vessels and craft from the U.S. or from any other location for the purpose of conducting a sinking exercise (SINKEX) involving test and evaluation of conventional ammunition and weapons systems, while not considered ocean dumping, is subject to Environmental Protection Agency (EPA) permit requirements specified in section 229.2 of 40CFR 220-225, 227-229 Ocean Dumping Regulations and Criteria. Each SINKEX operation will be conducted only after approval by the Chief of Naval Operations and after each target vessel has been remediated to standards set by the EPA. During a SINKEX, Navy crews fire live and non-explosive ordnance at a target vessel that has been towed to a location in the NWTRC. A wide variety of assets may be involved, including aircraft, helicopters, surface ships, and submarines (DoN 2006a).

The numbers and types of weapons used in a SINKEX depend on training requirements and the size of the target vessel, but could include air-to-surface missiles and bombs, surface-to-surface missiles, torpedoes, and naval gun fire. The total NEW expended would not exceed 20,000 pound (9,072 kg) per target during the exercise. The NEW of any individual weapon would not exceed 1000 pound (454 kg) (DoN 2006a).

Prior to conducting an exercise, a Notice to Mariners and a Notice to Airmen delineating the exercise area and time would be published. Extensive range clearance activities would be conducted prior to the exercise, ensuring that no shipping is within the range of weapons being fired. In addition, for 90 minutes prior to the commencement of the exercise and between certain series of weapon firings, a 2.5 nautical miles exclusion zone would be surveyed by visual and acoustic means to detect the presence of protected marine mammals and sea turtles. A safety zone would also be established which extends from the exclusion zone at 2.5 nautical miles out another 2 nautical miles. Together, the exclusion and safety zones extend out 4.5 nautical miles from the target.

In the rare event that the deployed ordnance does not sink the target, EOD personnel would scuttle the ship, typically the following day, using charges placed in locations that would breech the hull to sink the unstable ship. Whether guided or unguided, the majority of ordnance would hit the target. Of all the weapons used, only the torpedo is designed to explode in the water column.

The transfer of pressure waves and acoustic energy from detonation of ordnance within the target should have minimal impact on adjacent marine life (DoN 2006a). Effects from gun fire shells, bombs, and missiles that fall short of the target and torpedoes striking the vessel, as discussed previously, could cause mortality or injure pelagic marine life. Although SINKEX can have an adverse effects on managed species, all vessel sinkings are conducted to avoid impacts to sensitive EFH, as described in Chapter 5, Mitigation. Thus, SINKEX activities would not destroy or adversely effect sensitive benthic habitats, but
may alter soft bottom habitats and may provide a beneficial use by providing artificial habitat in the deep water environment.

3.11 Sonar Use

Effects to EFH from sonar use could potentially result from either acoustic impacts or from explosive forces and expended material introduced into the water column and sediments.

Antisubmarine warfare (ASW) and mine warfare (MIW) exercises include training sonar operators to detect, classify, and track underwater objects and targets. There are two basic types of sonar: passive and active. Passive sonars only listen to incoming sounds and, since they do not emit sound energy in the water, lack the potential to acoustically affect the environment. Active sonars emit acoustic energy to obtain information about a distant object from the reflected sound energy. Active sonars are the most effective detection systems against modern, ultra-quiet submarines and sea mines in shallow water.

Modern sonar technology has developed a multitude of sonar sensor and processing systems. In concept, the simplest active sonars emit acoustic pulses (“pings”) and time the arrival of the reflected echoes from the target object to determine range. More sophisticated active sonars emit a ping and then scan the received beam to provide directional as well as range information. Only about half of the Navy's ships are equipped with active sonar and their use is generally limited to training and maintenance activities - 90 percent of sonar activity by the Navy is passive (DON 2007). Active sonars operate at different frequencies, depending on their purpose.

3.11.1 High Frequency Sonar

High frequency sonar (> 10 kHz) is mainly used for establishing water depth, detecting mines, and guiding torpedoes. At higher frequencies, sound energy is greatly attenuated by scattering and absorption as it travels through the water. This results in shorter ranges, typically less than five nautical miles. Mid frequency sonar is the primary tool for identifying and tracking submarines. Mid frequency sonar (1 kHz - 10 kHz) suffers moderate attenuation and has typical ranges of 1-10 nautical miles. Low frequency sonar (< 1 kHz) has the least attenuation, achieving ranges over 100 nautical miles. Low frequency sonars are primarily used for long-range search and surveillance of submarines. Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) is the U.S. Navy's low frequency sonar system (DON 2001d). It employs a vertical array of 18 projectors using the 100-500 Hz frequency range.

Active sonars used in ASW are predominantly in the mid-frequency range (DON 2007), and may be deployed from surface ships, submarines, and rotary and fixed wing aircraft. The surface ships are typically equipped with hull mounted mid frequency active (MFA) sonar but may also tow passive sonar arrays as well. Helicopters are equipped with dipping sonar (lowered into the water). Helicopters and fixed wing aircraft and may also deploy both active and passive sonobuoys to search for and track submarines.

Submarines also use sonars to detect and locate other subs and surface ships. A submarine’s mission revolves around stealth, and therefore submarines use their active sonar very infrequently since the pinging of active sonar gives away their location. Submarines are also equipped with several types of auxiliary sonar systems for mine avoidance, for top and bottom soundings to determine the submarine’s position in the water column, and for acoustic communications. ASW training targets simulating submarines may also emit sonic signals through acoustic projectors.

Sonars employed in MIW training are typically high frequency (greater than 10 kHz). They are used to detect, locate, and characterize mines that are moored, laid on the bottom, or buried. MIW sonars can be deployed from multiple platforms including towed systems or surface ships.

Torpedoes use high-frequency, low-power, active sonar. Their guidance systems can be autonomous or electronically controlled from the launching platform through an attached wire. The autonomous guidance systems are acoustically based. They operate either passively, exploiting the emitted sound energy by the
target, or actively, ensonifying the target and using the received echoes for tracking and targeting. Military sonars for establishing depth and most commercial depth sounders and fish finders operate at high frequencies, typically between 24 and 200 kHz.

Although most fish cannot hear sound frequencies over 10 kHz, some shad and herring species can detect sounds in the ultrasonic range, i.e., over 20 kHz. (Mann 2001, Higgs et al. 2004). Ross et al. (1995, 1996) reviewed the use of high frequency sound to deter alewives from entering power station inlets. The alewife, a member of the shad family (Alosinae) which can her sounds at ultrasonic frequencies (Mann et al., 2001), uses high frequency hearing to detect and avoid predation by cetaceans. Wilson and Dill (2002) demonstrated that exposure to broadband sonar-type sounds with high frequencies cause behavioral modification in Pacific herring.

Since high-frequency sound attenuates quickly in water, high levels of sound from mine hunting sonars would be restricted to within a few meters of the source. Even for fish able to hear sound at high frequencies, only short-term exposure would occur, thus high frequency military sonars are not expected to have significant effects on resident fish populations.

Because a torpedo emits sonar pulses intermittently and is traveling through the water at a high speed, individual fish would be exposed to sonar from a torpedo for a brief period. At most, an individual animal would hear one or two pings from a torpedo and would be unlikely to hear pings from multiple torpedoes over an exercise period. Most fish hear best in the low- to mid-frequency range and therefore are unlikely to be disturbed by torpedo pings.

Dipping sonar is also only active for short periods. Sonobuoys operate at relatively high frequencies, well beyond the hearing range of most fish. The area within which fish could hear the high frequency signals from active sonobuoys would be limited by the low signal strengths emitted.

The effects of high frequency sonar, on fish behavior, for species that can hear high frequency sonar, would be transitory and of little biological consequence. Most species would probably not hear these sounds and would therefore experience no disturbance.

3.11.2 Low Frequency Sonar

Low frequency sound travels efficiently in the deep ocean and is used by whales for long-distance communication (Richardson et al. 1995; NRC 2003, 2005). Concern about the potential for low frequency sonar (< 1 kHz) to interfere with cetacean behavior and communication has prompted extensive debate and research (DON 2001d, 2005a, 2007; NRC 2000, 2003).

Some studies have shown that low frequency noise will alter the behavior of fish. For example, research on low frequency devices used to deter fish away from turbine inlets of hydroelectric power plants showed stronger avoidance responses from sounds in the infrasound range (5-10 Hz) than from 50 and 150 Hz sounds (Knudsen et al. 1992, 1994). In test pools, wild salmon exhibit an apparent avoidance response by swimming to a deeper section of the pool when exposed to low frequency sound (Knudsen et al. 1997).

Turnpenny et al. (1994) reviewed the risks to marine life, including fish, of high intensity, low frequency sonar. Their review focused on the effects of pure tones (sine waves) at frequencies between 50-1000 Hz. Johnson (2001) evaluated the potential for environmental impacts of employing the SURTASS LFA sonar system. While concentrating on the potential effects on whales, the analysis did consider the potential effects on fish, including bony fish and sharks. It appears that the swimbladders of most fish are too small to resonate at low frequencies and that only large pelagic species such as tunas have swimbladders big enough to resonate in the low frequency range. However, investigations by Sand and Hawkins (1973), and Sand and Karlsen (1986) revealed resonance frequencies of cod swim bladders from 2 kHz down to 100 Hz.
Hastings et al. (1996) studied the effects of low frequency underwater sound on fish hearing. More recently, Popper et al. (2005, 2007) investigated the impact of Navy SURTASS LFA sonar on hearing and on non-auditory tissues of several fish species. In this study, three species of fish in Plexiglas cages suspended in a freshwater lake were exposed to high intensity LFA sonar pulses for periods of time considerably longer than likely LFA exposure. Results showed no mortality and no damage to body tissues either at the gross or histological level. Some individuals exhibited temporary hearing loss but recovered within several days of exposure. The study suggests that SURTASS LFA sonar does not kill or damage fish even in a worst case scenario.

Although some behavioral modification might occur, adverse effects from low frequency sonar on fish are not expected.

### 3.11.3 Mid-Frequency Sonar

ASW training operations use mid-frequency sound sources (1-10 kHz). Most fish only detect sound within the 0.05-3 kHz range, with few fish hearing sounds above 4kHz (Popper 2003, Hastings and Popper 2005). Thus, it is expected that most fish species would be able to detect the ASW mid frequency sonar at the lower end of its frequency range.

Some investigations have been conducted on the effect on fish of acoustic devices designed to deter marine mammals from gillnets (Gearin et al. 2000, Culik et al. 2001). These devices generally have a mid frequency range, similar to the sonar devices that would be used in ASW exercises. Adult sockeye salmon exhibited an initial startle response to the placement of inactive acoustic alarms designed to deter harbor porpoise. The fish resumed their normal swimming pattern within 10 to 15 seconds. After 30 seconds, the fish approached the inactive alarm to within 30 cm (1 feet). The same experiment was conducted with the alarm active. The fish exhibited the same initial startle response from the insertion of the alarm into the tank; however, within 30 seconds, the fish were swimming within 30 cm (1 feet) of the active alarm. After five minutes of observation, the fish did not show any reaction or behavior change except for the initial startle response. This demonstrated that the alarms were either inaudible to the fish, or the fish were not disturbed by the mid frequency sound.

Jørgensen et al. (2005) carried out experiments examining the effects of mid frequency (1 to 6.5 kHz) sound on survival, development, and behavior of fish larvae and juveniles. Experiments were conducted on the larvae and juveniles of Atlantic herring, Atlantic cod, saithe *Pollachius virens*, and spotted wolffish *Anarhichas minor*. Swimbladder resonance experiments were attempted on juvenile Atlantic herring, saithe, and Atlantic cod. Sound exposure simulated naval sonar signals. These experiments did not cause any significant direct mortality among the exposed fish larvae or juveniles, except in two (of a total of 42) experiments on juvenile herring where significant mortality (20-30 percent) was observed. Among fish kept in tanks one to four weeks after sound exposure, no significant differences in mortality or growth related parameters (length, weight and condition) between exposed groups and control groups were observed. Some incidents of behavioral reactions were observed during or after the sound exposure - 'panic' swimming or confused and irregular swimming behavior. Histological studies of organs, tissues, or neuromasts from selected Atlantic herring experiments did not reveal obvious differences between control and exposed groups.

The work of Jørgensen et al. (2005) was used in a study by Kvadsheim and Sevaldsen (2005) to examine the possible ‘worse case’ scenario of sonar use over a spawning ground. They conjectured that normal sonar operations would affect less than 0.06 percent of the total stock of a juvenile fish of a species, which would constitute less than 1 percent of natural daily mortality. However, these authors did find that the use of continuous-wave transmissions within the frequency band corresponding to swim bladder resonance will escalate this impact by an order of magnitude. The authors therefore suggested that modest restrictions on the use of continuous-wave transmissions at specific frequencies in areas and at time periods when there are high densities of Atlantic herring present would be appropriate.
The results of several studies have indicated that acoustic communication and orientation of fish, in particular of hearing specialists, may be limited by noise regimes in their environment (Wysocki and Ladich 2004). Most marine fish are hearing generalists, though a few have been shown to detect sounds in the mid-frequency and ultrasonic range. While these species can detect mid-frequency sounds, their best hearing sensitivities are not in the mid-frequency range. If a sound is at the edge of a fish’s hearing range, the sound must be louder in order for it to be detected than if in the more sensitive range.

Experiments on fish classified as hearing specialists (but not those classified as hearing generalists) have shown that exposure to loud sound can result in temporary hearing loss, but it is not evident that this may lead to long-term behavioral disruptions in fish that are biologically significant (Amoser and Ladich 2003, Smith et al. 2004 a,b). There is no information available that suggests that exposure to non-impulsive acoustic sources results in fish mortality.

In summary, some marine fish may be able to detect mid frequency sounds, most marine fish are hearing generalists and have their best hearing sensitivity below mid frequency sonar. If they occur, behavioral responses would be brief, reversible, and not biologically significant. Sustained auditory damage is not expected. Sensitive life stages (juvenile fish, larvae and eggs) very close to the sonar source may experience injury or mortality, but area-wide effects would likely be minor. The use of Navy mid frequency sonar would not compromise the productivity of fish or adversely affect their habitat.

3.11.4 Conclusion – Sonar Use

While the impact of anthropogenic noise on marine mammals has been extensively studied, the effects of noise on fish are largely unknown (Popper 2003, Hastings and Popper 2005, Popper 2008). There is a dearth of empirical information on the effects of exposure to sound, let alone sonar, for the vast majority of fish. The few studies on sonar effects have focused on behavior of individuals of a few species and it is unlikely their responses are representative of the wide diversity of other marine fish species (ICES 2005, Jorgensen et al. 2005). The literature on vulnerability to injury from exposure to loud sounds is similarly limited, relevant to particular species, and, because of the great diversity of fish, not easily extrapolated. More well-controlled studies are needed on the hearing thresholds for fish species and on temporary and permanent hearing loss associated with exposure to sounds. The effects of sound may not only be species specific, but also depend on the mass of the fish (especially where any injuries are being considered) and life history phase (eggs and larvae may be more or less vulnerable to exposure than adult fish). The use of sounds during spawning by some fish, and their potential vulnerability to masking by anthropogenic sound sources, also requires further investigation. No studies have established effects of cumulative exposure of fish to any type of sound or have determined whether subtle and long-term effects on behavior or physiology could have an impact upon survival of fish populations. The use of sounds during spawning by some fish and their potential vulnerability to masking by anthropogenic sound sources requires closer investigation.

With these caveats and qualifications in mind, the limited information currently available suggests that populations of fish are unlikely to be affected by the projected rates and areas of use of military sonar. Thus, sonar use in NWTRC training is not anticipated to result in adverse effects to fish populations or EFH.

3.12 Mitigation Measures

As part of the Navy’s commitment to sustainable use of resources and environmental stewardship, the Navy incorporates measures that are protective of the environment into all of its activities. These include employment of best management practice, standard operating procedures (SOPs), adoption of conservation recommendations, and other measures that mitigate the impacts of Navy activities on the environment. Some of these measures are generally applicable and others are designed to apply to certain geographic areas during certain times of year, for specific types of Navy training. Mitigation measures covering habitats and species occurring in the Northwest Training Range Complex (NWTRC) have been
developed through various environmental analyses conducted by the Navy for land and sea ranges and adjacent coastal waters. In addition, the Navy also has a Protective Measures Assessment Protocol (PMAP) initiative in place which is intended to ensure the latest protected species/habitats mitigation data and guidance are available to the operators conducting training exercises in the open ocean. For major training exercises, these mitigation measures are promulgated through the use of Navy messages issued to all units and commands participating in the exercise as well as to non-Navy participants (e.g., Department of Defense agencies).

The alternatives proposed could affect individual fish and have localized affects on their habitats, but would not affect communities or populations of species or their use of the NWTRC. Table 3-5 presents a summary of effects on fish for the No Action, Alternative 1, and Alternative 2. Mitigation measures for activities involving underwater detonations, implemented for marine mammals and sea turtles, also offer protections to habitats associated with fish communities. No additional mitigation measures are proposed or warranted because no substantial effects on fish or fish habitat were identified.

**Table 3-5: Summary of Environmental Effects on Fish and Essential Fish Habitat in the NWTRC**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>On-Land and U.S. Territorial Waters</th>
<th>Non-U.S. Territorial Waters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Action Alternative</strong></td>
<td>• Aircraft overflight, weapons firing disturbance, and expended materials associated with the No Action Alternative would result in minimal effects to fish and no adverse effects to EFH.</td>
<td>• Aircraft overflight, weapons firing disturbance, and expended materials associated with the No Action Alternative would result in minimal harm to fish or no adverse effects to EFH.</td>
</tr>
<tr>
<td></td>
<td>• Because only a few species of fish may be able to hear the relatively higher frequencies of mid-frequency sonar, effects of sonar used in Navy exercises on fish are minimal and no adverse effects to EFH.</td>
<td>• Because only a few species of fish may be able to hear the relatively higher frequencies of mid-frequency sonar, sonar used in Navy exercises would result in minimal harm to fish or no adverse effects to EFH.</td>
</tr>
<tr>
<td></td>
<td>• Effects of non-explosive ordnance use on fish populations would be minimal or no adverse effects to EFH.</td>
<td>• Non-explosive ordnance use would result in minimal harm to fish populations or no adverse effects to EFH.</td>
</tr>
<tr>
<td></td>
<td>• Explosive ordnance use may result in injury or mortality to individual fish but would not result in impacts to fish populations. Baseline environmental conditions of critical habitat would remain the same.</td>
<td>• Explosive ordnance use may result in injury or mortality to individual fish but would not result in impacts to fish populations. Baseline environmental conditions of critical habitat would remain the same.</td>
</tr>
<tr>
<td></td>
<td>• Underwater explosions may result in disturbance, injury, or mortality to ESA-listed salmonid species.</td>
<td>• No impacts to threatened and endangered species or critical habitat</td>
</tr>
<tr>
<td><strong>Alternative 1</strong></td>
<td>• Impacts generally the same as described in the No Action Alternative. Environmental conditions of critical habitat would be improved compared to current baseline conditions.</td>
<td>• Impacts generally the same as described in the No Action Alternative. Environmental conditions of critical habitat would be improved compared to current baseline conditions.</td>
</tr>
<tr>
<td><strong>Alternative 2 (Preferred Alternative)</strong></td>
<td>• Impacts generally the same as described in the No Action Alternative. Environmental conditions of critical habitat would be improved compared to current baseline conditions.</td>
<td>• Impacts generally the same as described in the No Action Alternative. Environmental conditions of critical habitat would be improved compared to current baseline conditions.</td>
</tr>
</tbody>
</table>
3.13 **Cumulative Impacts**

The approach taken to analysis of cumulative impacts (or cumulative effects)\(^1\) follows the objectives of the National Environmental Policy Act (NEPA) of 1969, Council on Environmental Quality (CEQ) regulations and CEQ guidance. CEQ regulations (40 Code of Federal Regulations [CFR] §§ 1500-1508) provide the implementing procedures for NEPA. The regulations define “cumulative effects” as:

> “. . . the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.” (40 CFR 1508.7).

CEQ provides guidance on cumulative impacts analysis in *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ 1997). This guidance further identifies cumulative effects as those environmental effects resulting “from spatial and temporal crowding of environmental perturbations. The effects of human activities will accumulate when a second perturbation occurs at a site before the ecosystem can fully rebound from the effects of the first perturbation.” Noting that environmental impacts result from a diversity of sources and processes, this CEQ guidance observes that “no universally accepted framework for cumulative effects analysis exists,” while noting that certain general principles have gained acceptance. One such principal provides that “cumulative effects analysis should be conducted within the context of resource, ecosystem, and community thresholds—levels of stress beyond which the desired condition degrades.” Thus, “each resource, ecosystem, and human community must be analyzed in terms of its ability to accommodate additional effects, based on its own time and space parameters.” Therefore, cumulative effects analysis normally will encompass geographic boundaries beyond the immediate area of the Proposed Action, and a time frame including past actions and foreseeable future actions, in order to capture these additional effects. Bounding the cumulative effects analysis is a complex undertaking, appropriately limited by practical considerations. Thus, CEQ guidelines observe, “[i]t is not practical to analyze cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful.”

Geographic boundaries for analyses of cumulative impacts in this Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) vary for different resources and environmental media. Table 3-6 identifies the geographic scope of this cumulative impacts analysis, by resource area.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Area for Impacts Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous Materials and</td>
<td>Offshore Operating Areas (OPAREAs), Seaplane Base/Survival Area, Seaplane Base EOD Training Range, Crescent Harbor and Floral Point Underwater EOD Training Ranges, OLF Coupeville, Indian Island and Bangor EOD Training Ranges, Darrington, Okanogan, and Roosevelt Inland OPAREAs</td>
</tr>
<tr>
<td>Hazardous Wastes</td>
<td></td>
</tr>
<tr>
<td>Water Resources</td>
<td>Offshore OPAREAs, Crescent Harbor and Floral Point Underwater EOD Training Ranges, OLF Coupeville, Indian Island and Bangor EOD Training Ranges</td>
</tr>
<tr>
<td>Marine Plants and Invertebrates</td>
<td>Offshore OPAREAs, Crescent Harbor and Floral Point Underwater EOD Training Ranges, Indian Island and Bangor EOD Training Ranges</td>
</tr>
<tr>
<td>Fish</td>
<td>Offshore OPAREAs, Crescent Harbor and Floral Point Underwater EOD Training Ranges, Indian Island and Bangor EOD Training Ranges</td>
</tr>
</tbody>
</table>

\(^1\) CEQ Regulations provide that the terms “cumulative impacts” and “cumulative effects” are synonymous (40 CFR § 1508.8(b)).
3.13.1 Environment Potentially Affected By Cumulative Impacts

3.13.1.1 Ocean Currents of Pacific Northwest
The North Pacific Gyre has a clockwise circular pattern and comprises four prevailing ocean currents: the North Pacific Current (NPC) to the north, the California Current to the east, the North Equatorial Current to the south, and the Kuroshio Current to the west. The NPC approaches the U.S. coast and splits north and south; the north becoming the Alaska Current and the south becoming the California Current.

3.13.1.2 Oceanography
Water current regimes in the NPC are complex and variable on seasonal and longer time scales. The California Current is a Pacific Ocean current that moves south along the western coast of North America, beginning off southern British Columbia, and ending off southern Baja California. It is part of the North Pacific Gyre, a large swirling current that occupies the northern basin of the Pacific. The movement of northern waters southward makes the coastal waters cooler than coastal areas of comparable latitude on the east coast of the United States. Additionally, extensive upwelling of colder sub-surface waters occurs, caused by the prevailing northwesterly winds acting through the Ekman Effect (Ocean Motion 2008). The winds drive surface water offshore with wind flow, which draws water up from below to replace it. The upwelling further cools the already cool California Current. This is the mechanism which produces coastal California's characteristic fog. The cold water is highly productive due to the upwelling, which brings to the surface nutrient-rich sediments, supporting large populations of whales, seabirds and important fisheries. A narrower, weaker counter current, the Davidson Current, occasionally moves somewhat warmer water northwards during the winter months (Miller, McWilliams, et al. 1999).

Closer to the shore along the continental shelf, prevailing onshore winds reverse this flow, resulting in a net along-shore surface flow toward the southeast (Lentz and Winant 1979). There is also a very-nearshore circulation pattern caused by surf along the beaches (Jones, 1971). Below about 500 feet (ft), there is a northwardly current flow inshore of the California Current. This water is of equatorial Pacific origin and has higher temperature, salinity, and phosphate concentrations and a lower oxygen concentration than the deep water in the California Current located at the same depth but farther offshore (Jones 1971). Surface waters in the California Current maintain an annual temperature range of 13° to 20°C. Temperature drops with increasing water depth to about 4°C in the deeper basins. Dissolved oxygen concentration also tends to decrease with depth.

3.13.1.3 El Nino
Many environmental changes in the Pacific Northwest (PACNW) waters are connected with long-term, low-frequency, inter-annual oceanographic patterns. Displacement of cool surface waters—and their inhabitants—by clear, nutrient-poor warm water is correlated with periodic warm-water events off the coast of Peru and in the tropical Pacific. These are the El Niño events, which occur several times per decade (e.g., 1976, 1979, 1982-84, 1986-87, 1991-92, 1993, 1994, 1997-98, 2002-03, 2006-07 (NOAA 2007)) and are characterized by warm water, a deeper surface-mixed layer, elevated sea levels, increased abundance of southern planktonic and pelagic organisms, alterations of benthic community structure, and degeneration of coastal kelp beds (Jackson, 1986). During El Niño events, the California Current is disrupted, leading to declines in phytoplankton, resulting in cascading effects up the food chain, such as declines in fisheries, seabird breeding failures and marine mammal mortality. In 2005 a failure in the otherwise predictable upwelling events, unassociated with El Niño, caused a collapse in krill in the current, leading to similar effects (Miller, McWilliams, et al. 1999).

3.13.1.4 Habitats and Other Natural Resources
Natural habitats and resources characteristic of the PACNW coast include abundant deep water close to shore, commercially or recreationally valuable fish and shellfish stocks, wildlife breeding and
overwintering areas, kelp beds, beach and water recreation areas, and a temperate climate. These habitats and resources are described in detail in Chapter 3, and are briefly summarized here.

As a result of the local oceanographic regime, the California Current is an enclave of communities of marine life specific to the area (although diminished during El Niño years). Numerous types of marine mammals are present, including both regional and migratory populations. Four species of sea turtles may be present, at least periodically. Numerous sea birds are present in the bight, and Channel Islands provide breeding habitat for some species of sea birds. Commercially exploitable stocks of fish spawn and grow primarily in the bight. Deeper waters of the bight host a diversity of mesopelagic fishes that spend parts of their life cycles in surface waters. The benthic fauna of the continental shelf, especially polychaetes and crustaceans, are diverse and constitute an important food source for many fish species. Rocky intertidal and subtidal areas, which cover large areas of the shoreline of the bight, host diverse epifauna (snails, mussels, crabs, etc.) and attached seaweeds.

Beds of the giant kelp _Macrocystis pyrifera_, which attach to the bottom and can grow to over 164 ft in length extend into the Strait of Juan de Fuca to Crescent Rock, and some of the largest beds in the State are in the strait (Foster and Schiel 1985). About 45 percent of the shoreline of the strait consists of kelp habitat, compared to only 11 percent of the shoreline of the other four Puget Sound basins (Shaffer 1998).

The size and distribution of kelp beds varies spatially and temporally in response to changes in natural and anthropogenic conditions. Natural changes in surface water temperature and nutrient concentrations associated with El Niño events, and possibly with longer-term ocean warming trends, have resulted in declining kelp beds in some areas, and winter storms can devastate large kelp beds. These storms probably are the most important factor influencing the condition and extent of kelp beds, but human activities—such as kelp harvests, boat traffic, and possibly wastewater discharges—have also affected local giant kelp beds.

Sargassum (Sargassum muticum) is a non-indigenous brown algae from Asia that has been established in the Pacific Northwest for decades (DoN 2006) (Figure 3.6-2). Sargassum colonizes cobble and rocky substrates in lower and shallow subtidal habitats and occurs along approximately 18 percent of the Washington shoreline. Sargassum is common along the shorelines of the Hood Canal, San Juan Archipelago, and Strait of Georgia. It is least common along the outer coast. Little is known about its interaction with local species.

Seagrasses are submerged aquatic vegetation that form extensive underwater meadows or beds in shallow water (Thayer et al. 1984; DoN 2006). In the Pacific Northwest, eelgrass (Zostera marina) and surfgrass (Phyllospadix spp.) are the dominant native seagrasses (den Hartog 1970). Eelgrass grows in shallow, subtidal, or intertidal unconsolidated sediments and surfgrass grows on wave-beaten rocky shores. Eelgrass is the primary vegetation in the intertidal areas of the Strait of Juan de Fuca, covering more than 40 percent of the intertidal area (Bailey et al. 1998).

PACNW ocean waters contain undersea oil deposits. Oil and tar continuously ooze from undersea seeps, periodically creating large marine oil slicks. Over time, these slicks breakup and wash up on local beaches and bays.

### 3.13.1.5 Anthropogenic Activities

#### 3.13.1.5.1 Fishing

Commercial and recreational fishing constitutes a significant non-military use of the ocean areas of the NWTRC. As discussed in Section 3.7, the Pacific Fisheries Information Network (PacFIN) maintains commercial catch block data for ocean areas off the coasts of Washington, Oregon, California, Alaska, and British Columbia (PacFIN 2008). The annual catch of fish and invertebrates within Washington waters for 2007 amounted to approximately 180,221,946 pounds (see Table 3.14-1). Within the NWTRC OPAREA, groundfish species encompass the majority of the commercial catch. Groundfish species are
categorized in the following groups: flatfish, rockfish, thornyheads, scorpionfish, roundfish, skates, sharks, and chimaeras. Pelagic species are managed under the Coastal Pelagic Species Fisheries Management Plan (FMP) and include several species within six families (anchovies, jacks, herrings, mackerels, squids, and krill). Salmonid species with known or potential occurrence within the NWTRC include five species of Pacific salmon: the chinook, chum, coho, pink, and sockeye; and three species of trout: the cutthroat, steelhead, and bull. For the 2007 annual catch, groundfish accounted for 65.7 percent, pelagic species accounted for approximately 18.7 percent, and Salmon accounted for 14.98 percent (Refer to Table 3.14-1 for detailed list). Other commercial fishing targets include crustaceans (Dungeness crab and shrimp), geoduck, squid, urchins, and other invertebrates.

Fishing can adversely affect fish habitat and managed species. Potential impacts of commercial fishing include over-fishing of targeted species and by-catch, both of which negatively affect fish stocks. Mobile fishing gears such as bottom trawls disturb the seafloor and reduce structural complexity. Indirect effects of trawls include increased turbidity, alteration of surface sediment, removal of prey (leading to declines in predator abundance), removal of predators, ghost fishing (i.e., lost fishing gear continuing to ensnare fish and other marine animals), and generation of marine debris. Lost gill nets, purse seines, and long-lines may foul and disrupt bottom habitats. Recreational fishing also has the potential to affect fish habitats because of the large number of participants and the intense, the concentrated use of specific habitats.

Removal of fish by fishing can have a profound influence on individual populations. In a recent study of retrospective data, Jackson et al. (2001) analyzed paleoecological records of marine sediments from 125,000 years ago to present, archaeological records from 10,000 years before the present, historical documents, and ecological records from scientific literature sources over the past century. Examining this longer term data and information, they concluded that ecological extinction caused by overfishing precedes all other pervasive human disturbance to coastal ecosystems including pollution and anthropogenic climatic change.

Natural stresses include storms and climate-based environmental shifts, such as algal blooms and hypoxia. Disturbance from ship traffic and exposure to biotoxins and anthropogenic contaminants may stress animals, weakening their immune systems, and making them vulnerable to parasites and diseases that would not normally compromise natural activities or be fatal.

### 3.13.1.5.2 Ocean Pollution

Environmental contaminants in the form of waste materials, sewage, and toxins are present in, and continue to be released into, the oceans off the PACNW. Polluted runoff, or non-point source pollution, is considered the major cause of impairment of ocean waters. Stormwater runoff from coastal urban areas and beaches carries waste such as plastics and Styrofoam into coastal waters. Sewer outfalls also are a source of ocean pollution in the PACNW. Sewage can be treated to eliminate potentially harmful releases of contaminants; however, releases of untreated sewage occur due to infrastructure malfunctions, resulting in releases of bacteria usually associated with feces, such as *Escherichia coli* and *enterococci*. Bacteria levels are used routinely to determine the quality of water at recreational beaches, and as indicators of the possible presence of other harmful microorganisms.

As recent as 2006, toxic chemicals have been released into sewer systems in the PACNW; a fine of $180,000 was levied against a Redmond fish-food and aquaculture company for dumping toxic chemicals into the sewer drain, failing to separate potentially explosive chemicals and hazardous materials (Seattle 2008a). While such dumping has long been forbidden by law, the practice has left ocean outflow sites contaminated. Superfund cleanup sites have been identified in the Puget Sound and dredge spoils are slated to be dumped within the bay (Seattle 2007). These sites of accumulation are being rectified by Superfund cleanups in the Sound.
Sewage treatment facilities generally do not treat or remove persistent organic pollutants. Plastic and Styrofoam waste in the ocean chemically attracts hydrocarbon pollutants such as Polychlorinated Biphenyls (PCBs) and Dichloro-Diphenyl-Trichloroethane (DDT), which accumulate up to 1 million times more in plastic than in ocean water. Fish, other marine animals, and birds consume these wastes containing elevated levels of toxins. DDT mimics estrogen in its effects on some animals, possibly causing the development of female characteristics in male hornyhead turbots and English sole, according to a study by the Southern California Coastal Water Research Project.

Regulatory activities have made progress in reducing both non-point source pollution such as runoff, and point source pollution such as that which may emanate from sewer outfall sites. In 1998, Washington and Oregon received conditional Federal approval of its Coastal Nonpoint Source Pollution Control Program from the U.S. Environmental Protection Agency and the National Oceanic and Atmospheric Administration (the agencies that administer the Clean Water Act and Coastal Zone Management Act, respectively). The program includes the coordinated participation of the Coastal Commission, the State Water Resources Control Board, and the Regional Water Quality Control Boards. The current plan covers the years 2003 to 2008.

Pollution from vessels is a source of ocean contamination. Sewage, sludge, blackwater, graywater, bilge water, plastics and other trash components and waste materials are routinely discharged from vessels into coastal and ocean waters in the PACNW. Most recently, an international shipping company was fined $7.25 million for dumping oil sludge at sea, the largest penalty for dumping ever assessed in the Pacific Northwest (Seattle 2008b).

Increases in impervious surfaces increase the amount of chemicals, oils and other residues which end up in the human food chain. Impervious surfaces are mainly constructed surfaces - rooftops, sidewalks, roads, and parking lots - covered by impenetrable materials such as asphalt, concrete, brick, and stone. These materials seal surfaces, repel water and prevent precipitation and meltwater from infiltrating soils. Soils compacted by urban development are also highly impervious. They can also lead to impaired freshwater quality that is cleaned up at considerable taxpayer expense. Many of these chemicals attach themselves to the stream bottom (sediment) and to the fatty tissue of fish and other animals. In the case of persistent organic pollutants, or POPs, the chemicals build up with each successive eater in the food chain. In most cases, we are seeing contamination which lasts for over 30 years even if the chemical has stopped being used. Flame retardants (polybrominated diphenyl ethers) and PCBs, are examples.

Increases in impervious surfaces also increase the delivery of bacteria and pathogens - associated with the fecal waste of wild, domestic and human animals. Some of these can cause illness in humans from swimming or contact with contaminated waters or beaches or from eating contaminated shellfish. Potential illnesses and afflictions that can result include general intestinal distress, giardia, hepatitis and a range of other ailments.

### 3.13.2 Cumulative Impact Analysis

#### 3.13.2.1 Hazardous Materials and Wastes

The primary impact of cumulative hazardous materials use in the NWTRC would be to increase the amounts of hazardous constituents that are released to the environment. Hazardous materials settling out of the water column would contribute to contamination of ocean bottom sediments. Relevant activities would include releases of hazardous constituents from fishing vessels, other ocean vessels, wastewater treatment plant outfalls, and non-point source pollution from terrestrial sources. The effects of these activities in the NWTRC are known only in a very general sense.

Commercial ocean industries, such as fishing and ocean transport, are dispersed over broad areas of the ocean. Discharges of hazardous constituents from non-point source runoff and treatment plant outfalls mostly affect the waters within 3 nm of the coast, whereas most of the Navy activities occur beyond the 12 nm limit of Federal waters. The quantities of contaminants released, however, would be cumulatively...
insignificant relative to the volume of the water and the area of bottom sediments affected. The use of hazardous materials by the Navy under the Proposed Action, when added to that of other projects, would not significantly impact resources in the NWTRC.

3.13.2.2 Water Resources

Superfund sites at Naval Undersea Warfare Center (NUWC) Keyport were identified as threats to water quality. NUWC Keyport was listed on the EPA's National Priorities List in October 1989. As a result of the initial assessment study, six areas of contamination were recommended for further investigation: Area 1 (Keyport Landfill), Area 2 (Van Meter Road Spill/Drum Storage Area), Area 3 (Otto Fuel Leak Area), Area 5 (Sludge Disposal Area), Area 8 (Plating Shop Waste/Oil Spill Area), and Area 9 (Liberty Bay shorelines). NUWC Keyport was organized into two operable units (OUs). OU 1 includes the Keyport Landfill (Area 1) and OU 2 contains the other five areas (Areas 2, 3, 5, 8, and 9). Subase Bangor also has Superfund sites.

Potential threats to water quality in Port Townsend Bay include agriculture, logging, development, failing septic systems and untreated storm water (DoN 2000c). The Boat Haven and marina and the Port Townsend Paper Mill present other potential threats to water quality (Norris and Hutley 1997).

Cumulative impacts on ocean water quality would consist of the effects of the Proposed Action in concert with other marine projects, actions, and processes that contributed to water pollutants. Such activities would include recreational and commercial fishing, offshore oil and gas development, and other ocean industries. The effects of these activities on the NWTRC are known only in a very general sense.

Commercial ocean industries, such as fishing and ocean transport, are dispersed over broad areas of the ocean, as are the effects of the Proposed Action. Most of the Navy training takes place in remote areas of the open ocean. No major offshore oil and gas facilities are located in the NWTRC, and no permit applications for such facilities are under consideration by State or Federal agencies. In summary, cumulative effects on marine water quality in the NWTRC are expected to be less than significant.

Cumulative impacts on terrestrial Whidbey Island water quality would consist of the effects of the Proposed Action in conjunction with other Navy on-island actions that contributed contaminants to surface soils. On-island maintenance activities would involve the use of potential water pollutants, but facilities and procedures in compliance with Federal and State regulations would limit the release of such contaminants to de minimis amounts. New construction similarly would require the use and application of potential water pollutants, but construction procedures in compliance with Federal and State regulations would limit any releases of contaminants. Overall, the cumulative effects would be similar to the effects anticipated for the Proposed Action, and would be less than significant.

3.13.2.3 Marine Plants and Invertebrates

Potential cumulative impacts on marine plants and invertebrates in the NWTRC include releases of chemicals into the ocean, introduction of debris into the water column and onto the seafloor, and mortality and injury of marine organisms near the detonation or impact point of ordnance or explosives.

Materials expended during training include sonobuoys; parachutes and nylon cord; towed, stationary, and remote-controlled targets; inert ordnance; unexploded ordnance, and fragments from exploded ordnance, including missiles, bombs, and shells. Materials include a variety of plastics, metals, and batteries. Unless otherwise noted in the discussion or the table, targets are not recovered.

Most of these materials are inert and dense, and will settle to the bottom where they will eventually be covered with sediment or encrusted by physical or biological processes. However, some of the metals and other materials such as lead, lithium, and batteries, are hazardous. Section 3.4 on Water Resources discusses any detrimental effects from such material dispersal. The presence of persistent organic compounds such as DDT and PCBs are of particular concern. In light of these concerns, Navy activities would have small or negligible potential impacts.
Detonated ordnance used in mine countermeasure training produce negligible amounts of solid materials because the bulk of the explosive is consumed in the explosion. Other material effects from commercial and recreational fishing, point-source pollution accumulation, and other non-point source pollution sources would contribute to a much greater extent to the material wastes found in the Puget Sound and northwest areas.

The Proposed Action was evaluated for long-term effects on marine communities that would result from explosions, based on their force, location, and proximity to the bottom. Short-term effects, including increases in local turbidity and the creation of shallow depressions in bottom sediments, were not considered because they disappear relatively quickly under the influence of ocean and tidal currents and the natural sediment transport processes that operate continuously in the ocean and the sound.

There would be no long-term changes to species abundance or diversity, no loss or degradation of sensitive habitats, and no effects to threatened and endangered species. None of the potential impacts would affect the sustainability of resources, the regional ecosystem, or the human community.

### 3.13.2.4 Fish

The overall effect on fish stocks from certain activities such as vessel movement, aircraft overflight, sonar, non-explosive ordnance use, weapons firing disturbance, expended materials, would be negligible additions to impacts of fish stocks in the NWTRC. The NWRTC Study Area includes critical habitat areas designated for the Puget Sound chinook salmon, Hood Canal summer-run chum salmon, and Coastal-Puget Sound bull trout. Threatened species potentially affected include the Puget Sound chinook salmon ESU, Hood Canal summer-run chum salmon ESU, Coastal-Puget Sound bull trout DPS, or Puget Sound steelhead trout DPS.

There will be minimal impacts to these protected species from aircraft, missile and target overflights; weapons firing; non-explosive ordnance; sonar activities; or expended materials. Effects from underwater detonations and explosive ordnance would have the potential to affect juvenile populations of salmon and bull trout. This depends on the size of the charge and the distance from the shoreline that the explosions occur. When adults are in the general vicinity of the training areas, they too could be injured or killed as a result. However, the distances over which adult Chinook or chum salmon could be injured or killed are considerably smaller than the injury distances for juveniles.

There would be no long-term changes in species abundance or diversity, no loss or degradation of sensitive habitats, and only potential effects to threatened and endangered species. None of the potential impacts would affect Essential Fish Habitat, sustainability of resources, the regional ecosystem, or the human community.
4 References

4.1 References Cited


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4.2 WEBSITES ACCESSED
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