Oregon Forage Fish Management Plan

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Executive Summary

The Oregon Forage Fish Management Plan (hereafter 'Plan') is intended to provide active protection for a defined suite of forage fish species in Oregon marine waters. This Plan specifically pertains to commercial species that are not currently managed, regulated, or targeted by Oregon marine fisheries (hereafter 'Forage Fish'). These protections are conveyed by a number of management tools, including prohibition of new directed commercial harvest of these species, and limiting bycatch in other fisheries. Forage Fish provide great benefit to the ecosystem as a whole and to all of Oregon's marine finfish fisheries as an important source of prey for a wide range of species in Oregon waters. Fisheries supported by Forage Fish prey include both state and federal fisheries for groundfish, highly migratory species, coastal pelagic species, and salmon. Ecosystem sustainability also depends on Forage Fish, which provide prey for marine mammals and marine birds and other non-fishery species. In recognition of the importance of Forage Fish to the state and the larger ecosystem, the Plan complements protections provided through joint federal action by the Pacific Fisheries Management Council and the National Marine Fisheries Service, by extending similar protections into state waters. In combination, these state and federal protections promote coordinated management for these species across their distribution within the state and federal waters offshore of Oregon.

As defined in this Plan, the suite of species included in the term 'Forage Fish' are:

- Mesopelagic fishes of the families Myctophidae (lanternfish), Bathylagidae (deep-sea smelts), Paralepididae (barracudina), and Gonostomatidae (bristlemouths)
- Pacific sand lance (*Ammodytes hexapterus*)
- Pacific saury (*Cololabis saira*)
- Silversides (family Atherinopsidae; excluding Grunion)
- Smelts of the family Osmeridae
- Pelagic squids except market squid (*Doryteuthis opalescens* = *Loligo opalescens*) and Humboldt squid (*Dosidicus gigas*) (pelagic squid families: Cranchiidae, Gonatidae, Histioteuthidae, Octopoteuthidae, Ommastrephidae, Onychoteuthidae, and Thysanoteuthidae)

Many of these species are pelagic and have expansive oceanic distributions; many are rarely or never caught in Oregon's existing fisheries. The Plan sets policy for management of these species in state waters (from shore out to 3 nautical miles) to prevent the future development of fisheries targeting these species until the Department has had an adequate opportunity to assess the science relating to any proposed fishery and any potential impacts to our existing fisheries, communities, and ecosystem function.

The management goals for this Plan are to provide protections in state waters that complement the federal action, by prohibiting new directed commercial harvest of Forage Fish and limiting bycatch in other fisheries in order to support 1) existing fisheries and 2) ecosystem function. As defined in this Plan, the management goals are as follows:

- Support existing ecosystem resilience and reliance on Forage Fish
- Allow existing fisheries
- Support sustainability of existing fisheries, relative to the reliance on Forage Fish prey
- Monitor Forage Fish landings.

The Forage Fish protections in this plan include an explicit prohibition of new directed commercial harvest on the defined list of Forage Fish species and species groups, until the Department has had an adequate opportunity to assess the science relating to any proposed fishery and any potential impacts to our existing fisheries, communities and ecosystem function. Additional protections include management tools to implement this prohibition, through the use of: 1) trip-level and annual landing limits (by vessel) for Oregon ports, and 2) annual processing limits by at-sea and shore-based whiting fisheries, and 3) reporting requirements for Forage Fish landings.

Proposed new directed commercial fishing on Forage Fish species that occurs all or in part in federal waters will be evaluated by the Pacific Fisheries Management Council using Council Operating Procedure 24 (COP 24). Proposed new directed commercial fishing that would occur only in state waters (0-3 miles offshore) will be evaluated by the Department by first developing and then implementing guidelines and procedures based on the intent and principles of COP 24.

Introduction

Purpose and Need

Forage fish are important components of the marine ecosystem as a whole, supporting a wide range of higher trophic level species including other finfish, marine mammals, and marine birds. Additionally, Oregon fisheries depend on the availability of forage fish prey, yet our understanding of the vulnerability of the forage fish resource to new harvest pressure is currently limited. We do know that fish populations reliant on forage fish prey support both state and federal fisheries for groundfish, highly migratory species, coastal pelagic species, and salmon. Fish species that can be ecologically classified as 'forage fish' include some managed species targeted by fisheries, in addition to many species that are currently not targeted or specifically managed. Several forage fish species are targeted by fisheries and are actively managed by the Pacific Fisheries Management Council through the Coastal Pelagic Species Fishery Management Plan. However, most forage fish species are not actively targeted for harvest, nor are they managed or monitored. This document is intended to bridge the gap and provide basic management provisions for forage fish that are not yet included in state or federal management plans (hereafter 'Forage Fish').

The purpose of the Oregon Forage Fish Management Plan (hereafter 'Plan') is to collate our current knowledge on Forage Fish, and articulate management measures as a precautionary approach to development of new fisheries that could negatively impact this important resource. The Plan complements protections provided through joint federal action by the Pacific Fisheries Management Council and the National Marine Fisheries Service in 2015, by extending similar protections into state waters. The protections are not intended to disrupt or curtail existing commercial fisheries, or to supersede federal fishery management for Forage Fish. In combination, these state and federal protections promote coordinated management for these species across their distribution off of Oregon.

Goals

The management goals for this Plan are to provide protections in state waters that complement the federal action, by prohibiting new directed commercial harvest of Forage Fish and limiting bycatch in other fisheries in order to support 1) existing fisheries and 2) ecosystem function. Additionally, this Plan (and the federal action) provides opportunity for consideration of new directed commercial harvest of Forage Fish, in the event that interest arises, adequate scientific data on the proposed fishery activity exists, and the potential impacts of the new fishing activity on existing fisheries and ecosystem function can be analyzed. As defined in this Plan, the management goals are as follows:

- Support existing ecosystem resilience and reliance on Forage Fish
- Allow existing fisheries
- Support sustainability of existing fisheries, relative to the reliance on Forage Fish prey
- Monitor Forage Fish landings.

These goals complement federal protections, by extending similar protections into state waters. While there are other conservation measures that would improve our understanding of the Forage Fish resource, they are beyond the scope of this Plan. For example, forage fish spawning habitat is a data gap and research need that is better addressed via the Oregon Nearshore Strategy and the companion Oregon Conservation Strategy. This set of strategies offer recommendations intended to improve our understanding of Oregon's resources and facilitate collaborations to fulfill research needs, such as forage fish spawning habitat protection.

Federal action to protect Forage Fish (2016)

In 2013, the Pacific Fishery Management Council (Council) approved the Fishery Ecosystem Plan (FEP), which laid the foundation for subsequent action to protect forage fish. In March 2015, the Pacific Fishery Management Council (Council) approved Comprehensive Ecosystem-Based Amendment 1 (CEBA 1): Protecting Unfished and Unmanaged Forage Fish Species Draft Environmental Assessment. This Council action provides policy to protect a specific assemblage of forage fish species in federal waters (beyond 3 nautical miles from shore) from new directed commercial fishing. CEBA 1 made changes to all four of the Council's Fishery Management Plans (Coastal Pelagic Species, Groundfish, Highly Migratory Species, and Salmon) to incorporate this new policy. In September 2015, the Council approved draft regulatory language which described the management tools to be applied to provide the protections. As of May 4, 2016, the regulations are federal law under the authority of the National Marine Fisheries Service. Adoption of this state Plan by the Oregon Fish and Wildlife Commission extends similar protections into Oregon state waters. Because this Plan is intended to complement federal management efforts, it relies heavily on the analyses and information found in CEBA 1.

The Oregon Marine Fisheries Management Plan Framework

The Oregon Marine Fisheries Management Plan Framework (hereafter 'Framework') describes the information required to comprehensively evaluate living marine resources and provides direction on developing and articulating harvest management strategies. It is intended to facilitate the development of fishery management plans to achieve the following goals:

1) Provide sustainable access to marine resources for present and future generations
2) Minimize bycatch, incidental catch, and mortality related to fishery interactions with non-target marine organisms
3) Coordinate the management of commercial and recreational fisheries
4) Minimize the complexity of management
5) Consider the socioeconomic needs of local communities, including both consumptive and non-consumptives uses and values
6) Involve the public in the fisheries management processes

Although the Framework was formulated to encompass both harvested and unharvested species, many of the elements identified for inclusion in fishery management plans are most relevant for species that are targeted by – not prohibited for – fisheries. Because forage fish in this Plan are intended to remain as non-targeted species, some components of the Framework are either not applicable or cannot be specified here, due to lack of information. Also, because of the intended prohibition of harvest, we have named this document the 'Oregon Forage Fish Management Plan', intentionally removing 'Fishery' from the title.

Relationship to Other State Policies

There are a number of state policies supporting the use and/or conservation of Oregon's marine resources that are relevant to this Plan. These policies also establish regulations that support the development of the Framework, which is the foundation for the Plan. The policies that support each of these are thoroughly described in the Framework and are listed below:

- Food Fish Management Policy (1975; ORS 506.109)
- Wildlife Policy (1973; ORS 496.012)

- Native Fish Conservation Policy (2003; OAR 635-007-0502 through 635-007-0509).
- Oregon Nearshore Strategy (2015)
- Oregon Territorial Sea Plan (1994)
- Statewide Planning Goals (OAR 660-015)

Public Process Developing this Plan

The initial public process for the principles described in this Plan was conducted through the federal Pacific Fisheries Management Council process, which was lengthy and extensive (for more information, see the description of CEBA-1 on the Council website). The Oregon-specific public process for this Plan occurred in parallel during the finalization of the federal action and adoption of the Plan by the Oregon Fish and Wildlife Commission. The Department convened an advisory group with three representatives: 1) Mike Okoniewski (commercial fishing industry representative), 2) Norm Ritchie (sport fishing representative), and 3) Gilly Lyons (ecosystem representative). The advisory group provided guidance for the Department in developing the Plan content and principles, in planning the public outreach process and content, and in finalizing the Plan through the Commission adoption process. From June 15-July 13, 2016, a public draft of the Plan received over 1,400 letters of support and comment. Comments included significant interest from the public in better understanding the Forage Fish species and their role in the ecosystem including interest in filling research and data gaps particularly about spawning grounds, prioritization of research and monitoring needs and further description about existing fisheries. The Commission considered and adopted this Plan at the September 2, 2016, public meeting.

How this Document is Organized

Following the Framework structure, the Plan is comprised of two main components: the Resource Analysis and the Harvest Management Strategy. The Resource Analysis is a comprehensive description of the current and historical biological and ecological information available for the species of interest, as well as information on fisheries and other factors that may affect these species. The Harvest Management Strategy articulates the management goals for the resource, analyzes management issues and practices, and describes the management tools for Forage Fish protections.

A. Resource Analysis

This section defines the species and species groups included in the Plan, and describes biological and ecological information on each species or species group. In addition, this section addresses harvest impacts, and natural and anthropogenic factors that may affect these species. The amount and type of information available varies widely between species or species group. This section also describes information gaps for this group.

A.1. Description of the species included in the Plan

The California Current Ecosystem (CCE) is home to a diversity of small pelagic fish with expansive oceanic distributions, commonly referred to as "forage fish". Many species that occur in Oregon already have protections in place or are managed under different Fishery Management Plans. This Plan is not intended to duplicate or supersede those efforts, and instead focuses solely on species that do not already have this oversight. For purposes of this Plan, the specific suite of species and species groups that are included (and are referred to hereafter as 'Forage Fish') are:

- Mesopelagic fishes of the families Myctophidae (lanternfish), Bathylagidae (deep-sea smelts), Paralepididae (barracudina), and Gonostomatidae (bristlemouths)
- Pacific sand lance (*Ammodytes hexapterus*)
- Pacific saury (*Cololabis saira*)
- Silversides (family Atherinopsidae; excluding Grunion)
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Excluded from this Plan, but included under federal protections, are species that have geographic ranges outside of Oregon waters. Specifically, the northernmost range of the following species is in Southern California waters, and therefore they are not included in this plan:

- Round herring (*Etrumeus teres*) and thread herring (*Opisthonema libertate* and *O. medirastre*)

As described above, Forage Fish are generally categorized as "low trophic level", and include species that feed either primarily or partially on the lowest trophic level. As a group, they function as the main pathway of energy flow in the CCE from phytoplankton to larger fish and the young life stages of larger predators (Crawford 1987; Cury et al. 2000), and are a critical food web link in the highly productive upwelling-driven CCE (PFMC 2013).

A.1.a. Geographic Scope

In general, species in the unmanaged Forage Fish group occur throughout Oregon's Territorial Sea, which extends from the shore to 3 nautical miles, with the seaward extent equating to a depth of approximately 65 meters on average (minimum = 17 m; maximum = 194 m). Some of these species also use estuarine and shoreline habitat for some life stage. For that reason, protections in this plan also extend to the brackish waters for the species described. Brackish waters extend from the mouth of rivers to the head of tide.

A.2. Biological and ecological information on Forage Fish

In each following element of the Resource Analysis section, information is provided for each species or species group, where possible, and for aggregated groupings otherwise. The format generally follows that laid out in the Framework.

A.2.a. Mesopelagic fishes

Mesopelagic fish are a very abundant, yet lightly exploited, marine resource with worldwide distribution. The global biomass of mesopelagic fish may be nearly 10 billion tons (Irigoien 2014). For comparison, worldwide harvest of all marine capture fisheries was 82.4 million tons in 2011 (FAO 2013). Most mesopelagic fish are small, generally only growing to a few centimeters in length, and thus are considered to be part of the micronekton, which also includes larger-sized crustaceans, such as euphausiids, shrimps, mysids, and small squids, most of which dwell in the mesopelagic zone and undertake diel vertical migration. A notable portion of the fish biomass in the CCE is concentrated in micronektonic fishes, most of which are in the families *Myctophidae*, *Gonostomatidae*, *Bathylagidae*, and juvenile pelagic nekton (Suntsov and Brodeur 2008). Based on the abundance of larvae sampled annually from 1955 through 1960 in the California Current Ecosystem (CCE; Ahlstrom 1969), deep-sea pelagic fishes are predominantly of three kinds, myctophids (41.1%), gonostomatids (40.6%) and bathylagids (18.3%). However, bathylagids appear to be only a small portion of samples from studies of adult mesopelagic fishes in the CCE.

During daylight hours, mesopelagic fish are mostly found in the mesopelagic zone (between 200 m and 1,000 m deep) along the continental slopes and further out into the deep ocean. Many mesopelagic species are diel vertical migrators. They move upward into the shallow waters at night to feed and migrate back to the mesopelagic zone at dawn to avoid predation. In the Northeast Pacific Ocean, vertically migrating mesopelagic fish play an important role in the global carbon cycle and account for 15% to 17% of the carbon exported from the epipelagic zone into the mesopelagic zone (Davidson et al. 2013). Diel vertical migration of micronekton contributes substantially to the rapid vertical transport of organic material from epipelagic down to mesopelagic zones, referred to as the biological pump. Through this biological pump, carbon fixed as living organic matter as well as anthropogenic substances such as insecticides, butyltin, and PCBs are transported to deep-sea ecosystems.

Although occurring from Arctic to Antarctic seas, they are most abundant in tropical and subtropical seas (FAO 1997). California Cooperative Oceanic Fisheries Investigations (CalCOFI) larval fish sampling off Newport, OR and Crescent City, CA found densities (number/1000 m3) of 131.46 for *Myctophidae*, 1.58 for *Bathylagidae*, 0.07 for *Paralepididae* and 0.00 for *Gonostomatidae* (Auth 2009). Each of the four families of mesopelagic fishes that occur off Oregon are described below.

Myctophidae (32 genera)

Myctophids are often the dominant component of micronektonic communities in the North Pacific, with very high abundances and biomass (Beamish et al. 1999; Brodeur and Yamamura 2005). Myctophids represent an important trophic link between phytophagous zooplankton such as copepods and euphausiids and higher trophic level organisms such as salmon, tuna, seabirds, and marine mammals (Brodeur and Yamamura 2005). They dominate the fish biomass in oceanic waters of the Northeast Pacific (Pearcy 1977; Gjøsæter and Kawaguchi 1980; and Beamish et al. 1999), and their transport onto continental shelves represents an important flux of energy into these systems, as represented in food web models of the CCE (Brodeur et al. 1999; Field et al. 2006).

Myctophids are the key members of mesopelagic fish communities and their total resource in the world oceans is estimated at 600 million tons. There are 54 species of Myctophids that occur in the CCE (Love 2011). Worldwide, myctophids comprise at least 50% of all fish larvae taken in open-water plankton tows (Moser and Ahlstrom 1974), and as adults, they comprise some 65% of all mesopelagic fishes (Stiassny 1997). While distribution is worldwide, production appears to be highest in tropical and sub-tropical areas (FAO 1997). Myctophids account for about 75% of global harvested catch of small mesopelagic fishes (Vipin et al. 2011).

Myctophids typically have a maximum size of 7-8 cm (standard length), with individuals in this size range weighing 2-6 g. For example, the Northern lampfish (*Stenobrachius leucopsarus*) matures at about 6 cm and lives to be about 8 years old. Myctophids primarily feed on pelagic crustaceans, copepods, euphausiids and amphipods (Love 2011). A unique characteristic of the myctophids is the presence of non-bacterial bioluminescent organs that give myctophids their common name, lanternfish. Three lanternfish species (*Tarletonbeania crenularis*, S. *leucopsarus*, and *Diaphus theta*) form the bulk of micronekton fishes found in the northern California Current. These three species account for two thirds of all fishes collected in Isaac-Kidd midwater trawl tows in the upper 200 m off Oregon, USA (Pearcy 1977; Suntsov and Brodeur 2008).

The great majority of myctophid species undergo extensive vertical diurnal migrations and while average peak abundance during the day occurs at depths between 300-1200 m, nighttime peaks more usually occur between 10-100 m (at or around the surface mixing zone). Migratory patterns may depend on factors such as recency of last feeding, general condition, and reproductive state (Nafpaktitis et al. 1977). Myctophids are potentially good indicators of deep-sea pollution because they encounter a variety of water masses (of different origin) during their substantial diel vertical migrations (Brodeur and Yamamura 2005). They may also be good indicators of environmental and oceanographic changes (Hsieh et al. 2005).

With large mouths, relatively scarce and serrated gill rakers, well-developed stomach, and short intestine, myctophids consume predominantly actively moving prey (copepods, euphausiids, etc.). Among the micronekton, myctophids are believed to be the most important consumers of crustacean zooplankters, and act as competitors for prey with small pelagic fishes (such as sardine, anchovy, and saury) and the juveniles of various larger-sized oceanic fishes, such as tuna and salmon (Tyler and Pearcy 1975). Suntsov and Brodeur (2008) found that myctophids of the northern California Current primarily prey upon euphausiids, followed by hyperiid amphipods, planktonic tunicates and copepods.

In the sub-Arctic and transitional regions of the Northeast Pacific Ocean, fishes of the families *Myctophidae* and *Microstomatidae* are the most abundant by numbers and biomass, accounting for 80% to 90% of total micronektonic fish catch (Brodeur and Yamamura 2005). Off the U.S. West Coast, myctophids are known as prey for marine mammals, birds, and fish (Gjøsæter and Kawaguchi 1980; Brodeur 1990; and Brodeur and Yamamura 2005). Groundfish consume mesopelagic prey, including myctophids (Pereyra et al. 1969). In the slope region of the Bering Sea, species from the families *Bathylagidae* and *Myctophidae*, along with pollock (*Theragra chalcogramma*), were important forage fish for groundfish predators (Lang and Livingston 1986). In the Kamchatka and North Kuril Islands area, Pacific halibut (*Hippoglossus stenolepis*), Greenland turbot (*Reinchardtius hippoglossoides*) and Kamchatka flounder (*Atherestes evermanni*) all fed on myctophids (Orlov 2007). S*. leucopsarus* were recovered from stomachs of trawl-caught sockeye (*Oncorhynchus nerka*), pink (O*. gorbuscha*) and chum (*O. keta*) salmon and Dolly Varden trout (*Salvelinus malma*) in the Bering Sea (Nagasawa and Nishimura 1997). Among marine mammal species, Dall's porpoise (*Phocoenoides dalli*) have been particularly documented to include myctophids in their diets and consume a large portion of the myctophic biomass (Ohizumi et al. 2003).

Gonostomatidae (20 genera)

Fishes of this family have elongated bodies with adults ranging from 2 to 30 cm. Their common name, bristlemouths, comes from their equally sized bristle-like teeth. The genus *Cyclothone*, with 12 species, is thought to be the most abundant vertebrate genus in the world (Paxton and Eschmeyer 1998). Worldwide, fishes of the families *Myctophidae* and *Gonostomatidae* account for 60% to 90% of the total micronekton catch in both weight and number (Gjøsæter and Kawaguchi 1980). Most of the gonostomatid genus *Cyclothone* and some of the *Gonostoma* genus do not make vertical migrations, remaining in deep water. Maturity varies by species, but the Benttooth bristlemouth (*Cyclothone acclinidens*) grows to 7 cm and lives to be about 3 years old (Love 2011). Bristlemouths have a number of green or red light-producing photophores aligned along the underside of their head and bodies. They feed on zooplankton, such as copepods, chaetognaths, and ostracods (Love 2011).

Paralepididae (five genera)

Paralepidids are small to medium-sized (6 to 56 cm), very elongate and slender aulopiform fishes. The body cross-section is oval or compressed. The eye is medium to large, the snout very long and pointed with terminal mouth, but the lower jaw projects as a fleshy process. They have alternately fixed and depressible fang-like teeth on the lower jaw and roof of mouth. The caudal fin is deeply forked. Their appearance is similar to that of barracuda, and for this reason their common name is barracudina. Barracudinas are found from polar to tropical regions worldwide, but are most common in the tropics. They can be found from the surface to about 800 m. Some species have separate sexes; others are synchronous hermaphrodites. They feed on small fishes.

A 2005 diet study (Allain 2005) of four tuna species from the west and central Pacific found mesopelagic fish to be an important part of the diet of three of the species. The diet of big eye tuna was 36% mesopelagic fish of which *Paralepididae* were 22.3%. The bathypelagic paralepidid, *Magnesudes indica* was 10% of the diet. Yellow fin tuna diet was 5% mesopelagic fish including 3% *paralepididae*. Albacore diet was 47% mesopelagics, 25% of which were paralepidids. Only skipjack tuna, which appears to be a diurnal, epipelagic feeder, did not have mesopelagic fish in its diet.

Bathylagidae (two genera)

Bathylagidae (deep-sea smelts, black smelts) is a family of small (15 cm) open-ocean fish with large eyes, a small mouth, and varying body shape, that probably undertake vertical migrations between different ocean depths. There are about 35 species (Allaby 1999). As stated above in the section on *Gonostomatidae*, Ahlstrom (1969) found that 37.5% of the mesopelagic fish larvae in CalCOFI surveys were bathylagids. Bathylagid larvae exhibited a threefold range in relative abundance between years sampled, with greatest abundance when waters were cooler (Ahlstrom 1969). Whales, along with predatory fishes such as tuna and salmon feed on them (Eschmeyer 1983).

A.2.b. Pacific Sand Lance (*Ammodytes hexapterus*)

Pacific sand lance are an abundant nearshore species ranging from coastal California, northward to Alaska's Beaufort Sea, and westward to the Sea of Okhotsk and the water's off Japan's Hokkaido Island (Kitaguchi 1979; Craig 1984; Hashimoto 1984; Field 1988; and Robards and Piatt 1999).

Pacific sand lance are strongly associated with sand and gravel bottom habitat shoreward of the 50-100 meter depth range (Macy et al. 1978; Field 1988; and Ostrand et al. 2005). Off British Columbia, Pacific sand lance prefer shallow depth habitat (<80 m) featuring coarse sand particles of 0.25-2.0 mm diameter grains and waters with relatively higher current speeds (Robinson et al. 2013). Sand lances, *A. hexapterus* included, are known for a habit of alternating between burying themselves individually in sandy or pebbled substrate and forming pelagic swimming schools (Richards 1965; Meyer et al. 1979; and Ostrand et al. 2005). Sand lance bury themselves both on a nightly basis during their active periods in spring through fall, and for prolonged periods during winter hibernation (Robards and Piatt 1999; Robards et al. 1999a).

Sand lance recruitment success appears to be temperature-related, such that when sea surface temperatures rise or fall beyond their preferred range, recruitment declines (Bertram et al. 2001; Arnott and Ruxton 2002; and Robards et al. 2002). Off the U.S. West Coast, the southern and warmer portion of the species' range, low sand lance recruitment occurs in El Niño years and has been shown to have notable negative effects on seabird nestling survival (Bertram et al. 2001; Hedd et al. 2006).

Pacific sand lance prey upon plankton throughout their lives, focusing on larger-sized zooplankton, particularly copepods, as adults (Field 1988; Allen 2008; and Hipfner and Galbraith 2013). *Ammondytes hexapterus* grows to greater sizes in the northern portions of their range, reaching 27 cm in the Bering Sea, but about 20 cm off California (Robards et al. 1999a). Reaching maturity between their first and second years of life, none of the six *Ammondytes* species worldwide are long-lived. Pacific sand lance have been aged to seven years, although individuals over age-3 are rarely found (Field 1988; Robards and Piatt 1999).

Off the U.S. West Coast, Pacific sand lance are known prey of marine mammals, seabirds, and fish (Hobson 1986; Litzow et al. 2000; Willson et al. 1999; and Daly et al. 2013). Of particular relevance to Oregon, Pacific sand lance have been shown to figure strongly in the diet and survival of juvenile salmon (*Oncorhyncus* spp.) in the northern CCE (Beacham 1986; Daly et al. 2013). Among seabird species, rhinoceros auklet (*Cerorhinca monocerata*), tufted puffin (*Fratercula cirrhata*), and pigeon guillemot (*Cepphus columba)* are known for their heavy sand lance predation (Vermeer 1980; Bertram and Kaiser 1993; Davoren and Burger 1999; Litzow et al. 2000; and Bertram et al. 2001).

A.2.c. Pacific saury (*Cololabis saira*)

Pacific saury are common throughout the epipelagic waters of the northern Pacific Ocean (Hubbs and Wisner 1980). They feed primarily on zooplankton, copepods, euphausiids, and other small crustaceans, and reach a length of 30-33 cm. Major predators include yellowfin (*Thunnus albacares*), bluefin (*Thunnus orientalis*), and albacore tuna (*Thunnus alalunga*), fur seals, sei whales (*Balaenoptera borealis)*, birds and squid (Pinkas et al. 1971; Pearcy 1972; Kato 1992; and Gould et al. 1997b).

Pacific saury are distributed primarily between 20-25° N. lat. and the Gulf of Alaska. There are three distinct stock groups within this broad geographic area: the western Pacific (the largest), the central

Pacific, and the eastern Pacific. Evidence suggests that the western and central stocks mix, while the eastern Pacific population does not (Kato 1992). Within the water column, they are found from the surface down to approximately 230 m.

There has been debate regarding the lifespan of Pacific saury, but more recent research suggests it is two years with maturity reached after one year (Huang et al. 2007). Pacific saury spawn throughout the year in 2-4 month intervals with defined peak spawning periods (Love 2011). Females produce 500-2000 eggs per batch depending on size (Kato 1992). Within the eastern Pacific population, peak spawning first occurs in January off southern California. Saury spawning occurs off the coast of San Francisco in the spring, and then the population migrates northward, with saury eventually spawning off the Washington coast in August through October. Recruitment success is determined by oceanographic conditions and therefore abundance and size composition exhibit large variations from year to year (Huang et al. 2007). Current population estimates for the eastern Pacific stock are unavailable, but past estimates put the entire eastern Pacific stock at 450,000 tons (Kato 1992).

A.2.d. Silversides (family *Atherinopsidae*)

There are two species of silversides off of Oregon: jacksmelt *(Atherinopsis californiensis)* and topsmelt *(Atherinops affinis)*.

Jacksmelt

Jacksmelt is an important member of the coastal and estuarine marine community in California (Allen and DeMartini 1983), as both a consumer and as a prey species; however, they are a relatively poorly studied species. Jacksmelt occur throughout the year in nearshore waters from the tip of Baja California, Mexico, to the northern extent of their range in Yaquina Bay, Oregon. They are schooling fish, often found near kelp and other structures, as well as in most bays and estuaries south of Coos Bay, Oregon. Jacksmelt are rarely seen offshore and are most often found at depths ranging from 5-50 feet. They are a relatively fast growing species and can reach approximately 12.5 cm in their first year and up to 20 cm in their second, with a maximum size of about 42 cm (Clark, 1929; Miller and Lea 1972). Jacksmelt are known to spawn several times from October through April, and to lay their eggs on nearshore algae and eelgrass.

Jacksmelt, like most atherinids, are omnivorous, feeding on algae, crustaceans, and detritus, with their diet varying based on their habitat (Horn 2006). In turn, they are eaten by a variety of nearshore and kelp forest piscivorous fishes such as yellowtail (*Seriola dorsalis)*, kelp bass (*Paralabrax clathratus*), California halibut (*Paralichthys californicus*) and sharks, among others. Jacksmelt are also eaten by some piscivorous birds such as brown pelicans (*Pelecanus occidentalis*), gulls, least terns (*Sterna antillarum*), and common murres (*Uria aalge*) and are likely eaten by other surface feeding birds as well as some marine mammals (Baxter 1960; Feder et al. 1974). Although jacksmelt are likely preyed upon by a variety of predators, little is known about their relative importance as a prey component of the nearshore environment.

Topsmelt

Similar to jacksmelt, topsmelt range from the Gulf of California, Baja California, Mexico, to the southern end of Vancouver Island, British Columbia; however, they are not common north of Tillamook Bay, Oregon (Emmett et al. 1991). They are usually found near the surface and are common inhabitants of the nearshore coastal environment, typically found around kelp beds and along sandy beaches. Topsmelt are often the most abundant pelagic fishes in estuaries along the Pacific coast (Horn and Allen 1985) and like jacksmelt, are uncommon offshore. Most juvenile and adult topsmelt make seasonal movements between bay and estuarine environments and coastal kelp beds, being typically found in or close to bays in the spring and summer when they move to shallow water to spawn, and found in more coastal areas in the fall and winter (Wang 1986). During their first year of growth, topsmelt grow from 4-10 cm, adding another 5 cm during their second year, at which time most are sexually mature. They are thought to live up to eight years old, with the largest measured topsmelt reaching approximately 37 cm (Miller and Lea, 1972).

Topsmelt are omnivorous, with their prey and feeding habits varying depending on the habitat they are using. When occupying nearshore kelp and beach habitat, they typically feed on zooplankton near the surface, while primarily being herbivorous and feeding along the bottom when in shallow estuarine habitats (Quast 1968; Horn et al. 2006). Topsmelt are the prey of a variety of nearshore piscivorous fish, birds and marine mammals, including kelp and sand bass (*Paralabrax spp.*), California halibut, leopard sharks (*Triakis semifasciata*), cormorants (*Phalacrocorax spp.*), terns, and sea lions (Feder et al. 1974, Kao 2000).

A.2.e. Osmerid smelts

Osmerid smelts found in Oregon estuarine and marine waters include: whitebait smelt (*Allosmerus elongatus*), capelin (*Mallotus villosus*), surf smelt (*Hypomesus pretiosus*), night smelt (*Spirinchus starksi*), and eulachon (*Thaleichthys pacificus*). Eulachon is listed as threatened under the federal Endangered Species Act (ESA) and is managed under that law (hereafter 'Listed'); with a specific focus on the nearshore and freshwater portions of its range. Longfin smelt is currently managed under Oregon state rule (Oregon Administrative Rule - OAR 635-004-0540 or OAR 635-994-0545), and directed harvest of the species in nearshore waters is prohibited. There is a paucity of species-specific information on marine life stages of osmerids, therefore this section focuses on smelts as a species group.

Among anadromous Osmerid smelts of the northeastern Pacific Ocean, many populations tend to be more strongly aggregated as they approach or arrive in their estuarine and freshwater ranges (Martin and Swiderski 2001; Rosenfeld and Baxter 2007; Vandeperre and Methven 2007; Arimitsu et al. 2008; and Therriault et al. 2009). Osmerid smelt species have similar life histories, varying from each other in the northern and southern extents of their ranges, and in how far upriver they travel to spawn. Whitebait smelt, surf smelt, night smelt, longfin smelt, and eulachon are all broadly distributed along the U.S. West Coast, with surf smelt having the most southerly distribution (Hubbs 1925; Eschmeyer et al. 1983; Ilves and Taylor 2008; Gustafson et al. 2010; and Love 2011).

Osmerid smelts are short-lived, several with 2-3 year lifespans, and most living no longer than 8-9 years. Like other anadromous species, some smelt species, such as eulachon, and die after spawning (Macy et al. 1978; Christiansen et al. 2008; and Gustafson et al. 2010). Most Pacific *Osmeridae* with marine life stages, as opposed to those that are almost exclusively freshwater species, spawn in estuarine waters and immediately seaward of the tideline. Of the *Osmeridae* found in the northeast Pacific, eulachon travel the farthest upstream to spawn (Mecklenburg et al. 2002). Smelt eggs adhere to sand particles and both smelt eggs and the spawning adults are heavily preyed upon during the spawning through egg maturation periods.

Osmerid smelts are planktivorous and several studies have shown that adult-stage smelts rely heavily upon crustacean zooplankton like krill (Miller and Brodeur 2007; Wilson 2009; Miller et al. 2010; and Love 2011). Off the U.S. West Coast, osmerid smelts are known prey of marine mammals, seabirds, and fish (Antonelis and Perez 1984; Hunt et al. 1999; London et al. 2002; Roby et al. 2003; Emmett and Krutzikowsky 2008; Roth et al. 2008; Lance and Jeffries 2009; and Strong 2010,). Osmerid smelts are parts of the diets of Chinook salmon (*Oncorhynchus tshawytscha*) (Hunt et al. 1999), Pacific whiting (*Merluccius productus)*, rockfish, and jack mackerel (*Trachurus symmetricus*) (Emmett and Krutzikowsky 2008).

A.2.f. Pelagic Squids

Per the species and species groups covered by this Plan, this section addresses pelagic squids from the families: *Cranchiidae, Gonatidae, Histioteuthidae, Octopoteuthidae, Ommastrephidae* [except Humboldt squid (*Dosidicus gigas*)]*, Onychoteuthidae, and Thysanoteuthidae*, none of which are targeted in any Oregon fisheries; also, this section excludes discussion of the market squid (*Doryteuthis opalescens* = *Loligo opalescens*).

Cranchiid squids

Cranchiid squids are broadly distributed throughout the world ocean, except for within the Arctic Ocean (FAO 2010). A common life history characteristic of cranchiids is that many species tend to occupy sunlit pelagic waters as juveniles, but descend to greater depths as they grow larger and older (Voss 1980). This habit has confused squid taxonomists in their attempts to distinguish among different cranchiid species and habitats (Voss 1980). Predators on cranchiids in the North Pacific include groundfish species, which prey upon the demersal cranchiid life stages, and sharks, tunas, and a wide variety of marine mammals and seabirds, which prey upon cranchiids at various other life stages (Antonelis et al. 1987; Hills and Fiscus 1988; Gould et al. 1997a; Tsuchiya et al. 1998; Buckley et al. 1999; Drazen et al. 2001; Walker et al. 2002; Ohizumi et al. 2003; Pitman et al. 2004; and Kubodera et al. 2007). Clarke (1996) considers *Cranchiidae*, along with *Ommastrephidae*, and *Histioteuthidae* (described below) to be the most prevalent cephalopod families in the diets of whales.

Gonatid squids

Many high seas squid species are distinguishable from each other only by subtle differences in the shapes of their mantles or configurations of their tentacles, some of which are only visible under magnification. Gonatid squids are known as “armhook squids” due to the presence of small hooks, rather than suckers, on some parts of some of their tentacles (FAO 2010). Gonatid squid are temperate and polar species that inhabit near-surface waters as juveniles, but descend to mesopelagic depths as they grow to adulthood. Of the squid families of the northeast Pacific Ocean, *Gonatidae* are the most abundant (Nesis 1997). Although *Gonatidae* are often found as prey within the stomachs of higher order predators, the delicacy of the bodies of most gonatid species makes collecting organisms difficult, complicating potential ecology and life history studies for these species (Jorgensen 2007). Although life history information for *Gonatidae* is minimal, they are thought to live for approximately two years, and to spawn throughout the year, with some periods of concentrated spawning (FAO 2010). Gonatid squid prey heavily upon euphausiids and other crustacean zooplankton as juveniles, then descend in the water column as adults, where they feed broadly on other squids, fishes, and crustaceans. Their North Pacific predators include groundfish species, Chinook salmon, sharks, albacore tuna, and a wide variety of marine mammals and seabirds (Antonelis et al. 1987; Hills and Fiscus 1988; Pearcy et al. 1988; Nesis 1997; Buckley et al. 1999; Drazen et al. 2001; Walker et al. 2002; Pitman et al. 2004; Watanabe et al. 2004b; and Kubodera et al. 2007).

Histioteuthid squids

Histioteuthid squids have several distinct physical characteristics that make them relatively easy to distinguish from squids of other families. One of their common names, "cock-eyed squids" refers to the size differences between their two eyes, with the left eyes of histioteuthids being noticeably larger than their right eyes. Their more complimentary common name, "jewel squids" references the photophores, light-emitting spots that cover their mantles and arms (FAO 2010). In addition to these distinctive characteristics, histioteuthid squids have webbed connective tissue between their arms, giving them a moderate umbrella look. Histioteuthids prey upon fish and crustaceans (Voss et al. 1998) and are preyed upon by groundfish species, sharks, tunas, and a wide variety of marine mammals and seabirds (Antonelis et al. 1987; Hills and Fiscus 1988; Clarke 1996; Gould et al. 1997a; Tsuchiya et al. 1998; Voss et al. 1998; Drazen et al. 2001; Walker et al. 2002; Ohizumi et al. 2003; Pitman et al. 2004; and Kubodera et al. 2007).

Octopoteuthid squids

Octopoteuthid squids inhabit mesopelagic and deeper waters of the world's tropical oceans. Several octopoteuthid species are thought to have wide-ranging habitats throughout the world ocean, although the range of *Octopoteuthis deletron* is thought to be limited to the deep waters of the CCE, (FAO 2010). Like other deep ocean, high seas squids, octopoteuthids are a frequent prey of toothed whales (Clarke 1996), and *Octopoteuthis deletron* serves that role within the CCE (Fiscus et al. 1989), as well as being preyed upon by northern elephant seals and other pinnipeds (Condit and LeBoeuf 1984). Little is known about the life history and reproductive behavior of octopoteuthids, although their complex bioluminescing habits have been recently studied by researchers collecting data via remotely-operated underwater vehicles (ROVs) (Bush et al. 2009; Hoving et al. 2012; and Zylinski and Johnsen 2014). Their known Pacific predators include groundfish species, sharks, tunas, and a wide variety of marine mammals and seabirds (Condit and LeBoeuf 1984; Hills and Fiscus 1988; Fiscus et al. 1989; Clarke 1996; Gould et al. 1997a; Tsuchiya et al. 1998; Drazen et al. 2001; Walker et al. 2002; Ohizumi et al. 2003; Pitman et al. 2004; and Kubodera et al. 2007).

Ommastrephid squids

Ommastrephids are known as "flying squids" for their habit of escaping predators by hurling themselves above the surface and skimming over the water for several meters at a time. According to the FAO, ommastrephids are "the most abundant, widely distributed and ecologically active family of cephalopods" (FAO 2010 at p. 269). As elsewhere in the world, ommastrephids are broadly distributed throughout the North Pacific Ocean. Like all squid species, ommastrephid species are short-lived, usually only living for one year. Ommastrephids, particularly the larger-bodied species like neon flying squid and Humboldt squid, must be voracious predators in order mature quickly and to attain their large sizes. Their high growth rates mean that their survival, abundance, and distribution are all strongly dependent upon prey availability (FAO 2010). Bower and Ichii (2005) demonstrated that neon flying squid abundance is also strongly linked to water temperature and salinity, which may themselves be indicators of prey availability. Due to their rapidly changing body size, the prey favored by the larger-bodied ommastrephids varies considerably throughout their brief lives, ranging from the zooplankton and myctophids they favor as juveniles to the larger fish they consume as adults (Yatsu et al. 1997; Walker et al. 2002; Chen and Chiu 2003; Watanabe et al. 2004a; Bower and Ichii 2005; Xinjun et al. 2008; and FAO 2010). Similarly, ommastrephids are prey for many different species of fish, mammals, and birds.

Onychoteuthid squids

The common name for squids of the family *Onychoteuthidae,* "clubhook", refers to apparatuses at the ends of their tentacles, which include suckers, hooks, and club-shaped tentacle ends. Onychoteuthids tend to inhabit open ocean areas of the temperate and tropical oceans, eschewing northern and southern polar waters. The two clubhook squid species that appear in the U.S. West Coast Exclusive Economic Zone (EEZ, 0-200 nautical miles from shore) as both prey and predators, *Onykia robusta,* and *Onychoteuthis borealijaponicus,* have the one-year life spans of many squid species. Like neon flying squid and Humboldt squid, these Onychoteuthid squids are voracious, rapidly-growing predators that die after spawning. As juveniles, they are prey to a wide range of species and as adults they prey on some of those same species (FAO 2010). Onychoteuthids are considered muscular and fast-swimming, as opposed to some of the more gelatinous squid families like Octopoteuthids. *O. borealijaponicus* migrates to subarctic waters to feed in summer months, but spawns in subtropical waters during the winter. Males mature at about 250 mm mantle length (ML) and females at 300-350 mm ML (Kubodera et al. 1998).

Thysanoteuthid squids

There is only one living Thysanoteuthid squid species, *Thysanoteuthis rhombus*, commonly known as "Diamond" or "rhomboid" squid for its broad diamond-shaped mantles. Diamond squid are widely distributed in a large belt of temperate and tropical waters throughout the world ocean. This species exclusively uses tropical waters for spawning and is one of the few squid species with egg masses known to float at the surface (Nigmatullin et al. 1995, Miyahara et al. 2006). Off the U.S. West Coast, diamond squid is not common in the cooler waters off Oregon and Washington. Although capable of migrations to 650-800 meters in depth, diamond squid often drift fairly passively in upper ocean layers. Like other squid species, they feed on myctophids, small fishes and small squids (Bower and Miyahara 2005). Their varied vertical distribution makes them prey for a range of predators, from highly migratory tunas feeding near the surface, to sperm whales feeding at lower depths (FAO 2010). Like the other squid discussed in this section, diamond squid are highly fecund and have a one-year life cycle.

A.3. Predator-prey relationships: Federally-managed FMP species and Forage Fish

This section describes the reliance of fishery species (species managed and targeted in existing harvest activity) and ecosystem component species (species that are not targeted) on the forage fish assemblage. This analysis provides some of the context for evaluating any future proposals for targeting species covered in this Plan.

A.3.a. Coastal Pelagic Species

Coastal pelagic species (CPS) are federally managed via the Council's CPS Fishery Management Plan (FMP), which addresses five species: Pacific sardine *(Sardinops sagax*), Pacific or "chub" mackerel

(*Scomber japonicas*), northern anchovy (*Engraulis mordax*), market squid (*Doryteuthis opalescens* = *Loligo opalescens*), jack mackerel (*Trachurus symmetricus*), and one species group: krill, or euphausiids. The FMP also lists two "ecosystem component species": Pacific herring (*Clupea pallasii*), and jacksmelt (*Atherinopsis californiensis*). All of these species also occur in state waters. While some of these species are often referred to as forage fish because they are important prey for many higher trophic species, for purposes of this Plan, we use the collective term "CPS" for these 8 species (or species groups) to include both the managed and ecosystem species in the CPS FMP; in contrast, we use "Forage Fish" for the species covered by this Plan, as described above.

Most of the finfish in the CPS FMP have a similar ecology to Forage Fish in that they prey upon similar species, and are consumed by similar predators. For example, adult Pacific mackerel are known to prey upon copepods and other crustacean zooplankton, and on unidentified finfish (Collette and Nauen 1983). In contrast, jack mackerel is a voracious mid-trophic predator that preys upon several Forage Fish species. While euphausiids are jack mackerel's dominant prey, Brodeur et al. (1987) found fishes (including northern anchovy) in jack mackerel stomachs. Grinols and Gill (1968) found Pacific saury and myctophids in diets of jack mackerel sampled off Oregon. Emmett and Krutzikowsky (2008) analyzed the stomach contents of night-feeding jack mackerel collected over a seven year period and found their prey to include a wide variety of crustaceans, molluscs, and Forage Fish, including osmerids, myctophids, and sand lance. Brodeur et al. (2014) characterized jack mackerel, along with Pacific whiting, spiny dogfish, and albacore as one of the CCE predators with the greatest predation influence on the abundance of Forage Fish populations in the CCE. Therefore, the CPS FMP species jack mackerel may be considered a predator of the following Forage Fish species or species groups: mesopelagic fishes, Pacific sand lance, Pacific saury, osmerid smelts, and, possibly, pelagic squids.

A.3.b. Groundfish

Groundfish are federally managed by the Pacific Fishery Management Council and the National Marine Fisheries Service, with additional state management of Oregon's commercial nearshore and recreational fisheries. There are over 90 species in the Council's Groundfish FMP, including: 60+ rockfish species, 12 flatfish species, 6 roundfish species, 6 sharks and rays, plus spotted ratfish (*Hydrolagus colliei*), finescale codling (*Antimora microlepis*), and Pacific grenadier (*Coryphaenoides acrolepis*). General descriptions of the life histories of Groundfish FMP species may be found in Appendix B, Part 2, to the Groundfish FMP (PFMC 2005b). Many groundfish species occupy the mid-trophic levels that may prey upon Forage Fish species and, as a group, are described with other mid- to high trophic level fishes and invertebrates in the Council's FEP (PFMC 2013). Species in the Groundfish FMP tend to occupy those parts of the water column close to or at the ocean floor; therefore, their prey from the Forage Fish species group tend to be those species that are also found at or near the ocean floor. Groundfish FMP species diet data varies widely from species to species, with some species being particularly well-studied and others not studied at all. The following section separates Groundfish FMP species roughly by type, addressing whether Forage Fish are eaten by some members of the groups: roundfish, rockfish, flatfish, and minor Groundfish FMP species (sharks, skates, ratfish, morids, and grenadiers). More detailed diet descriptions for some groundfish species are available in Chapter 6 of *Groundfish Essential Fish Habitat Synthesis: A Report to the Pacific Fishery Management Council* (NMFS 2013b; and Appendix at NMFS 2013c). Groundfish species for which diet analyses were not available are not discussed herein.

Roundfish

Laidig et al. (1997) examined the contents of 1,868 sablefish (*Anoplopoma fimbria*) stomachs, found sablefish to be strongly piscivorous, and found their prey to include Forage Fish from the mesopelagic fish and pelagic squid groups. Brodeur et al. (2014) confirmed sablefish predation on myctophids, based on stomachs collected in 2005 and 2008. Buckley et al. (1999) analyzed the diets of Pacific whiting (1,334 stomachs) and sablefish (731 stomachs), among other groundfish species. Both species eat a wide variety of prey, and their prey includes the Forage Fish species myctophids, gonostomatids, Pacific saury, osmerid smelts, and gonatid squids (Buckley et al. 1999). Brodeur et al. (1987) also included sablefish and Pacific whiting in a larger study of the diets of finfish species and found sablefish and whiting stomach contents to include the Forage Fish or species groups of myctophids, Pacific sand lance, Pacific saury, and osmerid smelts. Emmett and Krutzikowsky (2008) examined Pacific whiting stomach contents from samples taken off Oregon, and found whiting diet to include osmerid smelt and Pacific sand lance. Brodeur et al. (2014) characterize Pacific whiting as one of the most important predators in the EEZ for the effects their predation has on Forage Fish population abundance, including osmerids. Tinus (2012) found a wide variety of fishes, including Pacific sand lance, and invertebrates in the stomachs of lingcod (*Ophiodon elongatus*) taken off Oregon. Beaudreau and Essington (2009) also found sand lance in the stomachs of lingcod taken off the San Juan Islands of Washington state, as well as other Forage Fish including mesopelagic fishes, and osmerids. Therefore, Groundfish FMP roundfish species may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific sand lance, Pacific saury, osmerid smelts, and pelagic squids.

Rockfish

Brodeur and Pearcy (1984) examined the contents of 480 stomachs of a mix of five shelf rockfish species: yellowtail rockfish (*Sebastes flavidus*), canary rockfish (*S. pinniger*), Pacific ocean perch (*S. alutus*), splitnose rockfish (*S. diploproa*), and darkblotched rockfish (*S. crameri*). This study found that these shelf rockfish, taken off the coast of Oregon, fed predominantly on euphausiids, but also that their prey included myctophids, osmerid smelts, Pacific sand lance, and gonatid squids (Brodeur and Pearcy 1984). Brodeur et al. (1987) examined over 1,600 stomach of 20 finfish species taken off Oregon, including black rockfish (*S. melanops*) and yellowtail rockfish. Both black and yellowtail rockfish diets in the Brodeur et al. (1987) study had eaten a wide variety of smaller-sized crustaceans, but also included Pacific sand lance and osmerid smelts. A more recent study of black rockfish taken off Oregon also showed osmerid smelts in black rockfish stomachs (Gladics et al. 2014). Adams (1987) examined the contents of 381 widow rockfish stomachs and found that, although widow rockfish feed heavily on salps (*Thaliacea* spp.), their Forage Fish prey include myctophids. Buckley et al. (1999) collected stomach samples from commercially important groundfish species taken off the U.S. West Coast, including shortspine and longspine thornyhead, and found the two thornyhead species diets to include bathylagids, myctophids, Pacific saury, and gonatid squid. Therefore, Groundfish FMP rockfish species may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific sand lance, Pacific saury, osmerid smelts, and pelagic squids.

Flatfish

Dover sole (*Microstomus pacificus*), one of the most common West Coast flatfish species, predominantly preys upon benthic worms and smaller benthic crustaceans (Pearcy and Hancock 1978, Gabriel and Pearcy 1981, Buckley et al. 1999), rather than on Forage Fish. Pearcy and Hancock (1978) confirmed this trend for other, smaller flatfish species, finding that rex sole (*Glyptocephalus zachirus*) has a diet similar to Dover sole, feeding on polychaetes and amphipods, while Pacific sanddab (*Citharichthys sordidus*) and slender sole (*Lyopsetta exilis*, not an FMP species) tend to prey on pelagic crustaceans. Ketchen and Forrester (1966) found that petrale sole (*Eopsetta jordani*) preyed upon Pacific sand lance in addition to its primary prey of euphausiids and Pacific herring (*Clupea pallasii*). Buckley et al. (1999) also looked at the stomach contents of arrowtooth flounder (*Atheresthes stomias*), a larger-bodied flatfish, and found that arrowtooth prey largely upon a wide variety of crustaceans and other invertebrates, but that their vertebrate prey includes osmerid smelts and mesopelagic fishes. Yang and Nelson (2000) studied the diets of a variety of groundfish taken off Alaska, and found that arrowtooth flounder taken off Alaska also prey primarily upon crustaceans, with some osmerids, Pacific sand lance, and myctophids in their diets. Therefore, Groundfish FMP flatfish species may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific sand lance, and osmerid smelts.

Minor Groundfish FMP species (sharks, skates, ratfish, finescale codling, and Pacific grenadier)

Jones and Geen (1977) studied the stomach contents of spiny dogfish (*Squalus acanthias*) taken off British Columbia and found both eulachon and Pacific sand lance in dogfish stomachs. Brodeur et al. (1987) found gonatid squid beaks in the stomachs of soupfin sharks (*Galeorhinus zyopterus*) and Brodeur et al (2014) found osmerid smelts in the stomachs of spiny dogfish. Although CCE dogfish is not as abundant as Pacific whiting, Brodeur et al (2014) characterized spiny dogfish as one of the EEZ predators that most strongly influences Forage Fish biomass. Grinols and Gill (1968) observed blue sharks (*Prionace glauca*, a HMS species), and soupfin sharks feeding on Pacific saury and myctophids off the coast of Oregon. Robinson et al. (2007) collected longnose skates (*Raja rhina*) off the coast of California and identified gonatid squids, histioteuthid squids, and myctophids within the wide variety of prey species in their stomachs. Leopard sharks sampled from California's Elkhorn Slough had eaten a variety of invertebrates as well as several fish species, including Pacific topsmelt (Kao 2000). Diets for big skate (*Raja binoculata*) taken off the U.S. West Coast have not been identified to the species or family level; however, Ebert et al. (2008) found Pacific sand lance within the varied diet of big skates sampled from the Gulf of Alaska. There are few food habits studies on ratfish, although those studies that do address ratfish diet characterize ratfish as preying primarily upon smaller invertebrates like shrimp, molluscs, and echinoderms (Johnson and Horton 1972; Quinn et al. 1980), and thus are less likely to prey upon Forage Fish species. There is little available information on the diets of CCE finescale codling. Like its Atlantic analog, blue antimora (*Antimora rostrata*), finescale codling occupies bathypelagic waters and tends to regurgitate upon being raised to the surface, making stomach content sampling difficult (Sedberry and Musick 1978); therefore, finescale codling diets were not considered in this Plan. A Drazen et al. (2001) study on the diets of Pacific grenadier and giant grenadier (*Albatrossia pectoralis*, not an FMP species) identified shared ecosystem component pelagic squids (cranchiidae, gonatidae, histioteuthidae, octopoteuthidae) among the Pacific grenadier stomach contents. Buckley et al. (1999) also identified gonatid and cranchiid squid as Pacific grenadier prey, as well as myctophids. Therefore, minor Groundfish FMP species (sharks, skates, ratfish, finescale codling, and Pacific grenadier) may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific sand lance, Pacific saury, silversides, osmerid smelts, and pelagic squid.

A.3.c. Highly Migratory Species

Although far less common in state waters than in federal waters, some Highly Migratory Species (HMS) occasionally spend a portion of their life cycle within Oregon waters. These species are managed by the Council HMS FMP and include: North Pacific albacore, yellowfin tuna, bigeye tuna, skipjack tuna, northern bluefin tuna, common thresher shark, shortfin mako or bonito shark, blue shark, striped marlin, swordfish, and dorado or dolphinfish. General descriptions of the life histories of HMS FMP species may be found in Appendix F of the HMS FMP (PFMC 2003). HMS FMP species are among the highest order cold-blooded predators of the CCE and, as a group, are described with other mid- to high trophic level fishes and invertebrates in the Council FEP (PFMC 2013). Species of the HMS FMP tend to occupy waters farther offshore than many other Council-managed species; therefore, their Forage Fish prey tend to be those species that are also found farther offshore.

As their name implies, the HMS FMP species that spend some part of their life cycle within the U.S. West Coast EEZ also migrate to and throughout the larger Pacific Ocean. Diet studies for the HMS FMP species that migrate between the U.S. EEZ, the EEZs of other nations, and the high seas are developed by scientists from the member nations of the multi-national HMS management entities of the Pacific Ocean, described in the Council FEP (PFMC 2013). While the HMS FMP species' diet studies discussion below includes studies from individual fish taken in waters off Washington, Oregon, and California, it also includes scientific work on fish taken from the high seas, or from waters off other northern and eastern Pacific nations. The Council FEP separates species roughly by type, addressing whether Forage Fish are eaten by tuna species (albacore, yellowfin, bigeye, skipjack, and bluefin), shark species (common thresher, shortfin mako, and blue), billfish species (striped marlin and swordfish), or dorado.

Albacore, yellowfin tuna, bigeye tuna, skipjack tuna, and bluefin tuna

As discussed above, yellowfin tuna, bigeye tuna, and albacore are all predators of mesopelagic fishes (Tyler and Pearcy 1975; Moteki et al. 2001; Allain 2005; and Brodeur and Yamamura 2005). Pacific saury has also been documented as the prey of albacore, yellowfin, and bluefin tuna (Pinkas et al. 1971; Pearcy 1972; and Kato 1992). Glaser (2009) found albacore prey to include myctophids, Pacific saury, and gonatid, octopoteuthid, and onychoteuthid squids. Pinkas et al. (1971) found a wide array of prey species in the diets of albacore, bluefin tuna, and bonito, including jacksmelt in the diet of bluefin tuna, and onychoteuthid squid in the diet of albacore. Tsuchiya et al. (1998) found a variety of pelagic squid species in the stomachs of albacore, bigeye tuna, and swordfish taken in the tropical East Pacific. Brodeur et al. (2014) characterized albacore as one of the CCE's most voracious predators of Forage Fish, with albacore populations strongly influencing Forage Fish population abundance. Shimose et al. (2013) found round herring in the stomachs of bluefin tuna. Therefore, HMS FMP tuna species may be considered predators of the following Forage Fish: round and thread herring, mesopelagic fishes, Pacific saury, silversides, and pelagic squids.

Common thresher shark, shortfin mako shark, blue shark

Preti et al. (2012) compared the CCE diets of the three FMP shark species and found that mako sharks feed heavily on jumbo squid and Pacific saury, the most important prey for blue sharks are jumbo and gonatid squids, and thresher sharks prey heavily on CPS FMP species like anchovy and sardine. This same study found that the diets of these three shark species included the following Forage Fish: *paralepipdidae*, Pacific saury, topsmelt, and gonatid, histioteuthid, octopoteuthid, and onychoteuthid squids (Preti et al. 2012). In a 2001 common thresher shark diet study, Preti et al. found a variety of FMP-managed species (e.g. anchovy, Pacific whiting, Pacific mackerel, and sardine) in thresher shark stomachs, as well as California grunion and gonatid squids (Preti et al. 2001). Kubodera et al. (2007) examined stomachs of blue and salmon sharks (*Lamna ditropis*), and found that blue shark (an FMP species) preyed upon a wide variety of cephalopods, including cranchiid, gonatid, histioteuthid, octopoteuthid, and onychoteuthid squids, as well as several different myctophid species. Markaida and Sosa-Nishizaki (2010) reviewed both blue shark diet literature and the stomach contents of almost 900 blue sharks taken in Pacific waters off Mexico, and found the following Forage Fish in blue shark stomachs: cranchiid, gonatid, histioteuthid, octopoteuthid, ommastrephid, and onychoteuthid squids, and Pacific saury. Therefore, HMS FMP shark species may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific saury, silversides, and pelagic squids.

A.3.d. Salmon

Salmon are anadromous fish native to the rivers and oceans of the northern hemisphere. Seven salmon species are native to the Pacific Ocean and five of those species spawn in the rivers of the western U.S.: Chinook, chum, coho (*O. kistuch*), pink, and sockeye. Steelhead, an anadromous form of rainbow trout (*O. mykiss*), occupies similar habitats and a similar ecological niche to the Pacific salmon species. There is little in information on oceanic steelhead interactions with forage fish. In cases where salmon is mentioned in this Plan, it is likely that there would be a similar interaction with oceanic steelhead. Salmon and steelhead are collectively referred to as 'salmon' in this document.

The Salmon FMP manages U.S. West Coast fisheries for Chinook, coho, and pink salmon. The following section discusses salmon species broadly and looks at whether Forage Fish are eaten by Chinook, coho, and pink salmon. This Plan focuses on the marine (not freshwater) diets of predator species. Salmon occupy mid- and higher trophic levels that may prey upon Forage Fish (PFMC 2013).

Chinook salmon

Groot et al. (1995) reviewed Chinook stomach contents and identified Chinook salmon marine prey as including fish (particularly Pacific herring and sand lance), euphausiids and other crustacean zooplankton, squid, and amphipods. Dufault et al. (2009) identified Chinook diet within the CCE as including: megazoobenthos (crabs), cephalopods, viperfish (*Chauliodus macouni*), small deepwater rockfish, small planktivores (anchovy, sardine, Pacific herring), and large zooplankton (euphausiids, chaetognaths, pelagic shrimps, pelagic polychaetes, pasiphaeids). Osmerid smelts, which also include anadromous species, have been found in Chinook stomachs (Hunt et al. 1999), as have myctophids (Brodeur et al. 1987), and gonatid squids (Pearcy et al. 1988). Hunt et al. (1999) found, among other prey, sand lance, Pacific saury, and jacksmelt within stomachs of Chinook salmon. Therefore, Chinook salmon may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific sand lance, Pacific saury, silversides, osmerid smelts, and pelagic squids.

Coho salmon

Coho salmon are nearly as piscivorous as Chinook salmon and have some diet similarities to Chinook. Groot et al. (1995) reviewed coho stomach contents and found the following marine prey: amphipods, euphausiids, and fish (including, among others, osmerids and Pacific sand lance). While crustacean zooplankton dominate coho stomach content in several studies, coho diets also include osmerids, myctophids, paralepidids, cephalopods (particularly gonatid squid) and sand lance (Pearcy et al. 1988; Schabetsberger et al. 2003; Aydin et al. 2005; Pool et al. 2008; and Daly et al. 2009). Therefore, coho salmon may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific sand lance, osmerid smelts, and pelagic squids.

Pink salmon

The U.S. West Coast EEZ is at the southern end of the range of pink salmon within the eastern North Pacific, so there tends to be less diet data available for West Coast pink salmon than for other salmon species. Pink salmon are more planktivorous and less piscivorous than Chinook and coho. According to Groot et al. (1995), pink salmon diets are dominated by hyperiid amphipods, although the Forage Fish they consume include myctophids and squids. North Pacific studies confirm the presence of gonatid squid in the diets of pink salmon (Kaeriyama et al. 2004; Aydin et al. 2005). There is some evidence that adult pink salmon of the western North Pacific also prey upon sand lance and capelin (Brodeur 1990). Therefore, pink salmon may be considered predators of the following Forage Fish: mesopelagic fishes, Pacific sand lance, osmerid smelts, and pelagic squids.

A.4. Predator-prey relationships: Seabirds and Forage Fish

A variety of seabird species prey upon Forage Fish, including the three West Coast seabirds listed under the ESA: short-tailed albatross (*Phoebastria albatrus*, USFWS 2008a) and California least tern (*Sterna antillarum browni*, UWFWS 1985), endangered; and marbled murrelet (*Brachyramphus marmoratus*), threatened (USFWS 1997). In addition its work under the ESA, the USFWS assesses U.S. migratory, nongame bird populations under the Fish and Wildlife Conservation Act for whether they are likely to become designated as threatened or endangered under the ESA, and designates those species likely to become ESA-listed without directed conservation measures as Birds of Conservation Concern (BCC, USFWS 2008b). The Migratory Bird Treaty Act (MBTA) protects birds that migrate between the U.S. and other nations from unlicensed or unlawful directed harvest, including seabirds. This action does not address the take of seabirds in fisheries or elsewhere; however, many Forage Fish are prey of CCE seabirds. This section examines the predator-prey interactions, if known, between Forage Fish and seabirds. Seabirds occupy the higher trophic levels that may prey upon Forage Fish and, as a group are described with other high trophic level non-fish species in the Council FEP (PFMC 2013). This section discusses only those seabird species or species groups that are known to spend at least some portion of their lives within the U.S. West Coast EEZ. Shorebirds that primarily prey upon intertidal invertebrates are not discussed herein.

CCE seabirds likely to prey upon Forage Fish may be roughly divided by taxonomic order and family. Seabird species of the order Procelliformes include albatrosses, petrels, shearwaters, and storm-petrels. Procellliformes species tend to be highly migratory and may breed outside of the U.S. West Coast EEZ, yet migrate through and feed within the EEZ. Seabird species of the order Pelecaniformes include two families of seabird species that occur off the U.S. West Coast, Pelecanidae (pelicans) and Phalacrocoracidae (cormorants). Pelecaniformes are more nearshore species than Procelliformes and those that are residents of the U.S. West Coast EEZ may spend all or most of their lives within the EEZ. Species of the order Charadriiformes include the suborder Lari (gulls, terns, noddies, and skimmers) and Alcae (murres, auklets, guillemots, and puffins). Charadriiformes are also nearshore species, often known for their large coastal colonies at breeding sites. Further information on Oregon seabird dependence on forage fish can be found in Audubon Society of Portland (2014).

A.5 Predator-prey relationships: Marine Mammals and Forage Fish

The U.S. West Coast EEZ supports a large and diverse marine mammal community that plays an important role in the ecosystem as top-level predators. Because most marine mammals make annual migrations between feeding and breeding sites, the specific species and the number of marine mammals found in the U.S. West Coast EEZ will vary both seasonally and inter-annually. However, some models estimate that cetaceans may consume around 2 million tons of prey (primarily krill, but also small fishes and squids and other prey) annually in the in U.S. West Coast EEZ (Barlow et al. 2008). Although some marine mammals prefer specific types of prey, most are opportunistic feeders. Most Forage Fish species are preyed upon to some degree by at least one species of marine mammal. The following section separates U.S. West Coast EEZ marine mammals into three species groups to discuss whether any members of those groups are known to prey upon shared ecosystem component species: odontocetes (toothed cetaceans, including sperm whales, orcas, beaked whales, and dolphins); mysticetes (baleen whales); and pinnipeds (seals and sea lions).

A.5.a. Odontocetes

Odontocetes of the U.S. West Coast EEZ include a variety of dolphins, porpoises, beaked whales, sperm whales, and killer whales (*Orcinus orca*). The most important shared ecosystem component species to toothed whale diets are likely the pelagic squids, followed by the mesopelagic fishes. Approximately 80 percent of all *odontocete* species worldwide regularly consume squids, with squids being a main food item in 28 different species (Clarke 1996). U.S. West Coast EEZ *odontocete* predators of various squid species include the sperm and beaked whales, as well various dolphins and porpoises (Kawakami 1980; Fiscus et al. 1989; Nesis 1997; and Walker et al. 2002). Mesopelagic fishes also often appear in marine mammal diet studies and are commonly consumed by the smaller *odontocetes*, such as dolphins and porpoises (Fitch and Brownell 1968).

Ohizumi et al. (2003) examined the stomach contents of 386 Dall's porpoises, finding their diets to include a wide array of pelagic squid species, mesopelagic fish species, and Pacific saury. The Dall's porpoises in that study had been taken incidentally in salmon gillnet fisheries across the North Pacific Ocean and the authors estimated that Dall's porpoise are the primary myctophid consumers in the North Pacific (Ohizumi et al. 2003). Walker et al. (1998) examined the stomach contents of beached Dall's porpoises and harbor porpoises (*Phocoena phocoena*) from the beaches of Washington and British Columbia, finding their diets to include eulachon, Pacific sand lance, and gonatid and onychoteuthid squids.

In a study of the ecology and feeding behavior of bottlenose dolphins (*Tursiops truncatus*) in the Southern California Bight, Hanson and DeFran (1993) found the diet of this highly-piscivorous species to include jacksmelt and topsmelt (atherinopsids). Fitch and Brownell (1968) found that, in addition to mesopelagic fishes and anchovies, Pacific saury were among the stomach contents of short-beaked common dolphins (*Delphinus delphis*) off Southern California. Walker et al. (1986) examined the stomach contents of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) that had stranded on the beaches of Southern California and the west coast of Baja California and found their diets to include, among other organisms, mesopelagic fishes and pelagic squid. Morton (2000), studying Pacific white-sided dolphins off British Columbia, observed them feeding on schools of capelin and eulachon as well as Pacific herring (not a Shared ecosystem component species). Stroud et al. (1981) found the diets of Pacific white-sided dolphins and Dall's porpoises taken off California and Washington to include, among other organisms, Pacific saury, osmerid smelts, mesopelagic fishes, and pelagic squid.

Killer whale diets vary by population type, whether "residents" of nearshore waters that largely feed on fish, or "transients" passing through nearshore waters that feed primarily on mammals and birds. For the most part, piscivorous killer whales eschew shared ecosystem component species for larger and higher trophic order fish species; however, beached killer whale stomach contents have been documented to include pelagic squid (Ford et al. 1998). Fiscus et al. (1989) documented a wide variety of cephalopods in the stomachs of sperm whales, including *cranchiidae*, *gonatidae*, *histioteuthidae*, *octopoteuthidae*, *ommastrephidae*, and *onychoteuthidae*. Flinn et al. (2002) examined the preserved stomachs of sperm whales taken from commercial whaling stations of British Columbia in the 1960s, finding a strong presence of pelagic squid in sperm whale stomachs. Therefore, *odontocetes* may be considered predators of the following shared ecosystem component species or species groups: mesopelagic fishes, Pacific sand lance, Pacific saury, silversides, osmerid smelts and pelagic squid.

A.5.b. Mysticetes

There are 7 species of baleen whales (Suborder Mysticeti) that can be found off of the U.S. West Coast EEZ. Mysticetes or baleen whales primarily feed on euphausiids and copepods and other zooplankton and do not notably rely on the shared ecosystem component species. Blue whales (*Balaenoptera musculus)*, for example, prey almost exclusively on euphausiids, even showing preferences for particular euphausiid species. Off the U.S. West Coast, euphausiids are sufficiently abundant that blue whales do not need to seek out other prey (Fiedler et al. 1998, Reeves et al. 1998). Gray whales (*Eschrichtius robustus*) also tend to prey primarily on crustacean zooplankton, including mysids and crab larvae (Dunham and Duffus 2002, Newell and Cowles 2006, Moore et al. 2007). The North Pacific right whale (*Eubalaena japonica*) is extremely rare, making diet studies, fecal sampling, and stomach sampling from beached whales also rare. However, based on the diets of other right whale species worldwide and on observations of North Pacific right whales during feeding, they are also thought to prey almost exclusively on euphausiids and other crustacean zooplankton (NMFS 2013d). The existing U.S. West Coast EEZ prohibition on euphausiid (krill) harvest already preserves the prey base for mysticetes, particularly those that feed more exclusively on euphausiids.

Although mysticetes strongly prefer euphausiid prey, some mysticetes will also regularly feed on small schooling fishes such as herrings and anchovies. Specifically, fin (*Balaenoptera physalus*), minke (*Balaenoptera acutorostrata*), sei (*Balaenoptera borealis)* and humpback whales (*Megaptera novaeangliae*) will all commonly or opportunistically feed on fishes (Gaskin 1982; Kasamatsu and Tanaka 1991; and Witteveen et al. 2008). Of the shared ecosystem component species fishes, sei whales are known to consume saury (Kato 1992), and humpback whales feed on Pacific sand lance, myctophids and certain osmerid smelts, such as capelin, while feeding in waters off of Alaska (Frost and Lowry 1981; Neilson and Gabriele 2008; Witteveen et al. 2008). Flinn et al. (2002) examined the preserved stomachs of fin and sei whales taken from commercial whaling stations of British Columbia in the 1960s, and found that both species primarily preyed upon euphausiids and copepods, although their other prey species included Pacific saury and myctophids, (shared ecosystem component species), as well as rockfish and ragfish (*Icosteus aenigmaticus*), among the otherwise unspeciated fish and squid stomach contents. Witteveen et al. (2008) tracked humpback whales on foraging dives off Alaska and found them preying upon schools of capelin, eulachon, and pollock (not a shared ecosystem component species). Minke whales feed primarily on euphausiids, but will feed opportunistically on schooling fish. Although we could not find minke whale diet studies for the eastern North Pacific, western North Pacific populations have been noted for preying upon Pacific herring and anchovy and, among other species, Pacific saury and sand lance (Tamura and Fujise 2002; Song and Zhang 2014). Therefore, mysticetes may be considered predators of the following shared ecosystem component species or species groups: mesopelagic fishes, Pacific saury, osmerid smelts, and Pacific sand lance.

A.5.c. Pinnipeds

Pinniped species of the U.S. West Coast EEZ include: California sea lion (*Zalophus californianus californianus)*, harbor seal (*Phoca vitulina richardsi*), northern elephant seal (*Mirounga angustirostris*), Guadalupe fur seal (*Arctocephalus townsendi*), northern fur seal (*Callorhinus ursinus*), and Steller sea lion (*Eumetopias jubatus*). Since seals and sea lions spend some portion of their lives on land, more detailed diet information is typically available for them through scat samples than for other marine mammals (Lowry 2011). Estimates suggest that pinnipeds in the U.S. West Coast EEZ may consume as much as a million tons of fish and squid prey annually (Hunt et al. 2000). California sea lions are known to prey on shared ecosystem component species within every group except for the herrings (Lowry 2011; Feder et al. 1974; and Weise and Harvey 2008). Harbor seals, typically feeding nearshore, are known predators of both sand lance and osmerids (Brown and Mate 1983; London et al. 2002; Orr et al. 2004; and Lance and Jefferies 2009). Antonelis et al. (1987) sampled the stomach contents of 59 live elephant seals and found their diet to include a variety of squid species, including cranchiids, gonatids, histioteuthids. Guadalupe fur seals are listed as threatened under the ESA and their population is small enough that diet data collection is more difficult

A.6 Predator-prey relationships: Listed species and Forage Fish

The Endangered Species Act (ESA; 16 USC 1531-1544) is one of the primary laws used to protect fish, wildlife and flora within the United States. Additionally, Oregon has a state endangered species act that compliments the federal ESA (Oregon Revised Statute 496.171-192). Because these lists identify species that are at risk of extinction, there is additional concern about and responsibility to protect the primary prey of listed species, to support these vulnerable stocks and increase likelihood of recovery. This section describes information on the reliance of state and federal listed species on Forage Fish as prey.

The federal ESA-listed species (T = threatened, E = endangered) that occur within Oregon waters, include marine mammals, seabirds, sea turtles, two species of abalone, green sturgeon (*Acipenser medirostris*), eulachon, and several populations of salmonids. ESA listed fish species (or ESA-listed distinct population segments or runs, within the species) that have biological ranges within state waters include green sturgeon (T), eulachon (T), Chinook salmon (9 ESUs listed, T and E), chum salmon (2 ESUs listed, T), coho salmon (4 ESUs listed, T and E), sockeye salmon (1 ESUs listed, T and E), steelhead (11 DPSs listed, T and E) (ODFW 2014, NOAA 2014). Among these species, Chinook salmon (2 ESUs, T) and coho salmon (1 ESU, T) are also listed under the Oregon ESA.

Bird species that occur within state waters that are also on the state or federal endangered species list include Brown Pelican (E), California Least Tern (E), Marbled Murrelet (T), Short-tailed Albatross (E) (USFWS 2014). Western Snowy Plover (T, federal listing of coastal population only) occurs in the state land and waters. The Xantus's murrelet is a candidate for federal listing, the tufted puffin has been petitioned for listing, and the black oystercatcher has been identified as a species of concern by the U.S. Fish and Wildlife Service and is included as a strategy species in the Oregon Nearshore Strategy.

Of the many marine mammal species that occur in Oregon waters, one species is listed as threatened (sea otter), and seven species are listed as endangered under the federal ESA, including: the southern resident killer whale, sperm whale, gray whale, humpback whale, blue whale, fin whale, sei whale, and Northern Pacific right whale. The Oregon ESA lists the blue whale, sei whale, fin whale, humpback whale, north Pacific right whale, gray whale, and sperm whale as endangered.

A.7. Fishery-independent and fishery-dependent data

A.7.a Mesopelagic fishes

Mesopelagic fishes are not targeted in Oregon fisheries. In Oregon, the only recorded harvests of mesopelagic fish are small amounts (0.2 tons) of barracudina (family *Paralepididae*) as incidental catch in the midwater trawl fishery between 2008 and 2012 (ODFW 2015). There is no logbook, discard data, or fishery-dependent biological data available for this species complex.

Worldwide, there are very few examples of fisheries targeting mesopelagic fishes. These include three historical fisheries that pursued this complex. A Soviet fishery for the myctophids *D. coeruleus* and *Gymnoscopelus nicholski* (species considered edible) in the Southwest Indian Ocean and Southern Atlantic began in 1977, and catches by the former Soviet Union reached 51,680 tons in 1992, after which the fishery ceased (Kock 2000). While no fisheries are currently active, the Commission for Conservation of Antarctic Marine Living Resources still permits a total allowable catch for this fishery of 200,000 tons in its convention area. An industrial purse seine fishery for the *myctophid Lampanyctodes hectoris* in South African waters closed in the mid-1980s due to processing difficulties caused by the high oil content of the fish (FAO 1997). In the late 1970s and early 1980s, researchers investigated the feasibility of developing a commercial fishery for mesopelagic fishes in the northern Arabian Sea. These studies indicated that such a fishery might be commercially feasible, especially for *Benthosema pterotum* in the Gulf of Oman region (FAO 1997). After decades of studies and planning, with recommendations based on extensive research as to the best fishing seasons, areas and depths, trial catch rates were too low (<30 tons daily per boat) to support a commercially viable fishery (Valinassab et al. 2007).

Data from fishery independent surveys are also limited. CalCOFI sampled larval fish in the transitional zone off Newport, OR and Crescent City, CA and found densities (number/1000 m3) of 131.46 for *Myctophidae*, 1.58 for *Bathylagidae*, 0.07 for *Paralepididae* and 0.00 for *Gonostomatidae* (Auth 2009). Additionally, a deep-sea survey in the CCE occurred annually from 1955-1960, estimating proportional abundances of mesopelagic fishes in catch (Ahlstrom 1969).

Because mesopelagic fishes are not a component of Oregon fisheries, and are not a component of fishery independent surveys, data are not collected with the geographic and temporal regularity needed to estimate population abundances.

A.7.b. Pacific sand lance

Pacific sand lance are not targeted in Oregon fisheries. No fishery-dependent data are available for either the commercial or sport fisheries and there are no logbook, discard data, or fishery-dependent biological data available for this group. Sand lance are targeted in fisheries in other parts of the world, particularly in the North Sea off of Europe.

In the U.S., existing sand lance research tends to focus on populations in particular bays and estuaries, such as Puget Sound (West 1997; Quinn 1999; and Penttila 2007), and the bays and islands of British Columbia (Bertram and Kaiser 1993; Hedd et al. 2006; and Haynes et al. 2007) and Alaska (Robards et al. 1999b; Bertram et al. 2001; and Ostrand et al). In areas where sand lance fisheries occur, sand lance recruitment success appears to be inversely related to fisheries harvest levels (Furness 2002; Frederiksen et al. 2004; and Greenstreet et al. 2006). Interestingly, seabird predation has similar effects on sand lance recruitment in areas where sand lance fisheries do not occur (Bertram and Kaiser 1993; Hedd et al. 2006).

Because sand lance are not a component of Oregon fisheries, and are not a component of fishery independent surveys, data are not collected with the geographic and temporal regularity needed to estimate population abundances.

A.7.c. Pacific saury

No eastern Pacific saury fishery currently exists in U.S. waters. In Oregon, there has been one nominal catch (1 pound) of Pacific saury as commercial bycatch, since 1981. Because Pacific saury are not specifically targeting in fisheries, no logbook, discard data or fishery-dependent biological data currently exist for this species group.

Historically, targeting Pacific saury was considered as a viable option by Japan. In the 1960s, the western Pacific saury stock reached record lows, which led to research by Japan into a potential fishery off the U.S. West Coast. However, with catches not considered high enough for economical fishing and the rebound of the western Pacific population, fishing efforts off the coast of the U.S. were abandoned in the 1970s (Kato 1992).The western Pacific saury stock is the largest and is fished heavily by Japan for food and fish meal. Additionally, it is a preferred baitfish in the Japanese longline fishery for tuna. The average annual catch in Japan is 258,000 mt (Huang et al. 2007).

Because Pacific saury are not a component of Oregon fisheries, and are not a component of fishery independent surveys, data are not collected with the geographic and temporal regularity needed to estimate population abundances.

A.7.d. Silversides

As a commercial species along the U.S. West Coast, jacksmelt is a small component of landings, showing up intermittently as incidental catch in some fisheries in California. Because jacksmelt are not specifically targeting in Oregon fisheries, no logbook, discard data or fishery-dependent biological data currently exits for this species group.

Most West Coast commercial catch of jacksmelt over the years has been incidental to roundhaul/encircling net fisheries; however, some minor directed catch of jacksmelt, typically by gillnets in harbors and bays, has occurred historically with the fish marketed in fresh fish markets. Jacksmelt commercial landings have varied over the last 70 years with landings reaching a high in 1945 of approximately 1,000 mt (likely a result of the high sardine catches at the time). Since the mid-1990s, annual landings have varied between a high of approximately 18 mt to a low of less than a ton (CDFG 2001; CDFW 2013). From 2000 through 2009, average incidental catch in the coastal purse seine fisheries was 5.79 mt, with most of the catch being landed in the Los Angeles area as incidental catch to the Coastal Pelagic Species (CPS) fisheries (PFMC 2011a). In California, jacksmelt are also commonly caught from piers and along the shoreline (Love 2011) and make up a notable portion of recreational landings in the state.

As it relates to fishery exploitation, topsmelt are far less common as incidental catch compared to jacksmelt in commercial fisheries, possibly due to their smaller size and lower affinity for schooling. Topsmelt are not specifically targeted in Oregon fisheries, although a small amount (10,000 fish) were caught as bycatch in the recreational fishery between 1980-1989 and 1993-2002 (Marine Recreational Fishery Statistical Survey 2015). Furthermore, like jacksmelt, topsmelt make up a notable portion of the recreational pier and shore catch throughout California, and small amount of the recreational catch in Oregon (ODFW 2015; CDFG 2001; CDFW 2013).

No commercial data are available for topsmelt or jacksmelt. Overall, data are not collected with the geographic and temporal regularity needed to estimate population abundances.

A.7.e. Osmerid smelts

No targeted commercial fishing is authorized for these species in ocean waters off the Oregon coast. However, smelts are taken as bycatch in the Oregon pink shrimp (*Pandalus jordani*) fishery (Hannah and Jones 2007) and are discarded at sea. Smelts are also taken as bycatch in groundfish fisheries (Al-Humaidhi et al. 2012). Eulachon are very commonly encountered in Oregon shrimp trawls and can be a large component of the bycatch that remains after bycatch reduction devices have excluded the majority of incidentally caught fishes (in some years). Recent developments in bycatch avoidance strategies in the Oregon pink shrimp fishery such as the use of LED lights along the groundline have led to significant reductions in the bycatch of eulachon. Whitebait smelt are commonly encountered when shrimpers trawl inside of about 65 fathoms. In recreational fisheries, trace amounts of unspecified smelts have been harvested in estuary waters since 2000.

Although there is some fishery-dependent catch data available for some osmerid species, such as eulachon and whitebait smelt, data are not collected with the geographic and temporal regularity needed to estimate ocean population abundances. Furthermore, no logbook or discard data exists for this species group. However, because of growing concern about eulachon sustainability and the recent federal ESA listing (Threatened), data sets are developing to inform some aspects of the life history of this one species; for example, we now have good estimates of the spawning population returning to the Columbia River.

A.7.f. Pelagic squids

Per the species and species groups covered by this Plan, this section addresses pelagic squids from the families: *Cranchiidae, Gonatidae, Histioteuthidae, Octopoteuthidae, Ommastrephidae* [except Humboldt squid (*Dosidicus gigas*)]*, Onychoteuthidae, and Thysanoteuthidae*, none of which are targeted in any Oregon fisheries; also, this section excludes discussion of the market squid (*Doryteuthis opalescens* = *Loligo opalescens*).

The muscularity required for their flying habits make many ommastrephid species appealing for human consumption and they are important commercial fishery targets throughout the world (FAO 2010), although they are not known to be targeted in Oregon. Humboldt squid and neon flying squid (*Ommastrephes bartramii*) dominate commercial catches of North Pacific ommastrephids (FAO 2010). Neon flying squid were the subject of large high seas driftnet fisheries in the 1970s and 1980s, and have been studied by various scientists of North Pacific nations (Yatsu et al. 1997; Bower and Ichii 2005; and FAO 2010). Diamond squid (family: Thysanoteuthidae) are not common off of Oregon, and tend not to aggregate in large numbers in much of their world habitat, making them more difficult to target in commercial fisheries. However, they do aggregate somewhat within the coastal waters of Japan, and are caught in relatively large numbers there (Miyahara et al. 2005; FAO 2010). Except for one of the more demersal of the *Gonatidae, Berryteuthis magister,* gonatid squids are not the subject of target fisheries, but they can be taken incidentally in temperate and near-polar fisheries (Jorgensen 2007). *Berryteuthis magister* has been directly targeted in commercial fisheries off Russia and Japan since the 1960s, but is primarily taken as bycatch in demersal fisheries off northern North America (Nesis 1997).

Histioteuthid squid and octopoteuthid squids are generally deep water species (Watanabe et al. 2006), making them challenging research subjects and less appealing as fishery targets. Some families, such as cranchiid and many onychoteuthid squids are unappealing for human consumption due to their gelatinous bodies or to their ammonia-filled mantles (FAO 2010).

Because there are no directed fisheries for pelagic squids in Oregon, there are no logbook or fishery-dependent biological data collected for this group. Furthermore, pelagic squid data are not collected with the geographic and temporal regularity needed to estimate population abundances.

A.8. Threats from climate change and oceanographic factors

Climate change is expected to lead to substantial, and relatively unpredictable, changes to the physical oceanography of the CCE, and to related complex impacts to the biological system, including marine populations, fisheries, and ecosystem services (Scavia et al. 2002, Harley et al. 2006, Doney et al. 2012). Section 4.5 of the Council FEP identifies three major aspects of future climate change that will have direct effects on the CCE: ocean temperature, pH (acidity versus alkalinity) of ocean surface waters, and deep-water oxygen (or lack thereof, hypoxia). Although the effects of warming ocean temperatures have been identified as being negative for eulachon (NMFS 2013a), the effects of climate change on other Forage Fish and their ability to adapt to those changes are unknown.

Global average ocean temperature is rising and is expected to rise by at least 1°C by 2050 (by the most conservative estimates, IPCC 2007). Concurrently, ocean chemistry is leading to more acidic conditions (‘ocean acidification’) in the upper 500 m at a rate of approximately -0.0017 pH per year (Byrne et al. 2010). On a more regional basis, within the CCE deep-water oxygen levels have shown a steady and relatively rapid decrease since the mid 1980’s (Bograd et al. 2008, McClatchie et al. 2010).

These three factors are linked: ocean temperature affects ocean pH (and circulation patterns), ocean temperature and deep water oxygen levels can be controlled by large scale circulation patterns, and primary production can be affected by both oxygen and pH (Gilly et al. 2013). All three factors show long-term trends and decadal-scale variance similar to changes in the Pacific Decadal Oscillation (PDO; Mantua et al. 1997) and North Pacific Gyre Oscillation (NPGO; DiLorenzo et al. 2008) climate signals. In addition to these three large-scale aspects of climate change, some more immediate and localized aspects of climate change observed in coastal marine ecosystem include: intensification of upwelling (Bakun, 1990, Schwing and Mendelssohn, 1997), changes in phenology (Bograd et al. 2009), and changes in the frequency and intensity of existing temporal climate patterns (Yeh et al. 2009, NMFS 2012, and references therein).

These changes in upwelling and major climate patterns result in changes to the phenology of physical and biological events within the CCE. Recent trends over the past five years indicate an earlier timing to the start of upwelling in the south, and a later start to upwelling in the north (NMFS 2012), with an earlier start of upwelling likely leading to higher integrated productivity. In any case, changes in the timing of upwelling may result in match-mismatch between predators and their prey, if those timings are somewhat uncoupled (e.g. salmon entering the ocean may have a different timing set by terrestrial forcing, as opposed to the timing of upwelling initiation). Changes in the timing of upwelling will also likely have impacts all the way up the food chain to the top level predators and consumers, since it is the timing and strength of upwelling that primarily controls primary productivity of the CCE, and thereby overall productivity. However, the exact nature of how upwelling phenology may change is not clear, as it is affected by many factors, such as wind patterns, sea surface temperature (SST), mixing, stratification, circulation etc., and may vary by region. These physical factors, SST, mixing, wind etc., are in turn controlled by interrelated large-scale patterns – which are undergoing both long-term changes, and changes in their strength and variability as described above – therefore further complicating prediction of ecosystem response. An important secondary effect of changes in upwelling strength and phenology are potential changes in upper ocean pH. Upwelled water may act to further decrease the surface ocean pH, which means that changes in upwelling phenology are also likely to change seasonal and long-term patterns of ocean pH.

While information is not available for oceanographic interactions on all Forage Fish, many exhibit variations in distribution, reproduction, and recruitment based on oceanographic patterns. For example, Pacific saury distribution is strongly influenced by SST (Tseng et al. 2013), with a preference for waters between 15-18° C. As a result, Pacific saury make extensive migrations from the subtropical spawning regions to subarctic regions as temperatures change seasonally. This link between distribution and SST may also make Pacific saury susceptible to interannual and interdecadal environmental change (Tseng et al. 2013). For this reason, Pacific saury may be a useful indicator of changing oceanographic conditions (Brodeur et al. 2005). Among the mesopelagic fishes, myctophids may be potentially good indicators of environmental and oceanographic changes because they encounter a variety of water masses (of different origin) during their substantial diel vertical migrations (Hsieh et al. 2005; Brodeur and Yamamura 2005).

A.9. Threats from non-fishery sources

Forage Fish species are similar to each other in their place in the food web and in having relatively brief lives and high fecundity. However, they have different habitat preferences from each other, which means that they may be affected to greater and lesser degrees by a wide variety of human activities. Nearshore and anadromous forage fish include osmerid smelts and silversides, as well as Pacific sand lance. Forage Fish distributed primarily farther offshore include mesopelagic fish species, Pacific saury, and pelagic squids. The nearshore and anadromous Forage Fish are more likely to be affected by non-fishing human activities, simply because they live in proximity to greater concentrations of humans. Non-fishing human activities identified under the ESA, Magnuson-Stevens Act (MSA), and National Environmental Protection Act (NEPA) as having effects on species similar to Forage Fish include:

- Climate change, ocean, and freshwater effects
- Water quality, including: dredge material disposal, wastewater discharge with pharmaceutical, fertilizer, pesticide, and other chemicals, and discharges of oil, fire retardants, and other hazardous substances
- Coastal development, shoreline modification, and nearshore habitat alteration, including dredging and other channel disturbances
- Dams or other water diversions, and
- Water intake structures

In addition to these effects categories, Oregon would also need to consider impact on Forage Fish from changes in:

- Offshore renewable energy development
- Watershed health, including erosion (sediment load), logging activity, river hydrology

Non-fishing activities that introduce chemical pollutants, sewage, changes in water temperature, salinity, dissolved oxygen, and suspended sediment into the marine environment pose a risk to all Forage Fish. Pacific sand lance and atherinopsids that spawn in nearshore gravel and sand may be particularly affected by human activities that alter the quantity or quality of nearshore habitat. The negative effects of oil contamination of nearshore sand habitat on Pacific sand lance have been noted in scientific literature and were thoroughly studied in the wake of the 1989 Prince William Sound oil spill (Pinto et al. 1984; Robards et al. 2002).

The effects of shoreline modification and shoreline armoring have been particularly well-studied in Puget Sound, and documented as having negative effects on the productivity of osmerid smelts, Pacific sand lance, and other Forage Fish (Rice 2006; Pentilla 2007). Dams, other water diversions, and reduced freshwater flow may impede anadromous osmerid smelt life cycles in the same way that they impede salmon life cycles. The 1996 Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes particularly identified reduced freshwater flow, water diversions, and water intake structures as affecting the abundance of delta and longfin smelt, both osmerids (USFWS 1996). The 2013 Federal Recovery Outline for Pacific Eulachon also identified reduced freshwater flow, dams and water diversions, and climate impacts on ocean conditions as threats to eulachon abundance (NMFS 2013a).

Forage Fish may be affected by water pollution, whether introduced by point or non-point sources from land, by ships, or energy installations at sea, or by nearshore aquatic human activities like port operations and aquaculture. Actions under the jurisdiction of the Federal Energy Regulatory Commission (FERC) include permits for energy generating projects located in or immediately adjacent to the coastal waters of the U.S. West Coast. Most of the West Coast offshore energy projects are in the testing or planning phase for using wave or tidal energy, but analyses of the potential effects (both of individual projects and of cumulative effects) of these projects must take into account the effects of those projects on the biological environment.

In addition to non-fishing actions that may introduce habitat modification or pollutants into the marine environment, there are non-fishing conservation projects or regulations that may positively affect Forage Fish, their predators, and other aspects of the biological environment. In 2012, the United States Coast Guard (USCG) established a standard for the allowable concentration of living organisms in ships' ballast water discharged in waters of the United States, with the intent of preventing and controlling invasions of aquatic nuisance species transported in ships' ballast water from elsewhere in the world (77 FR 17254, March 23, 1012). Invasive species often compete with native species for prey and habitat, making USCG efforts to limit their spread to U.S. waters beneficial to all native species, including Forage Fish. In 2013, the U.S. Environmental Protection Agency (EPA) built on the USCG ballast water regulations and standards with general vessel permits for vessel discharges, limiting ballast water and pollutant discharge in U.S. waters.

A.10. Sustainable harvest levels

Given the role that Forage Fish play in the CCE and the paucity of available scientific information on them collectively, it is recommended that Oregon complement the existing federal action, and prohibit new directed commercial harvest of Forage Fish in state waters until we have adequate scientific data on the proposed fishery activity and we are able to analyze the potential impacts of the new fishing activity on existing fisheries and ecosystem function. This is a precautionary approach, based on the fact that we have critical information gaps (see below), which create barriers to understanding the population dynamics of Forage Fish either for ecosystem support or as a fishery resource. As such, it is a tremendous challenge to understand what sustainable levels of harvest might be, above and beyond ecosystem needs, and how management errors at the forage fish level might be amplified up into higher trophic levels.

A.11. Information gaps and research needs

There is little information available for many Forage Fish other than limited life history information. The intent of this section is to identify and prioritize informational needs for improving the quality of future analyses. Table 1 summarizes the forage fish species' known data gaps and research needs for each species or group. This summary is not intended to be a comprehensive data gap analysis, but is instead intended to highlight key research needs to better inform management strategies.

Table 1. Known data gaps and research needs for Forage Fish described in the Plan.

Species or Species Group	Life-History	Ecology and Habitat Associations	Population Abundance and Stock Status
Mesopelagic fishes	Natural mortality unknown. Age, growth, maturity, known for most groups except *Bathylagidae.*	Migratory and movement patterns of *Bathylagidae*.	Abundance and stock status not known.
Pacific Sand Lance	Natural mortality and migratory patterns are unknown. Little information on older (> age 3) individuals. Little information on spawning areas in Oregon nearshore.	Research tends to focus on geographically localized populations in bays and estuaries.	Abundance and stock status not known.
Pacific Saury	Natural mortality unknown. No scientific consensus over lifespan and maturity.	Distribution influenced by sea surface temperature—populations may be susceptible to changing ocean conditions.	Population estimates for the eastern Pacific stock are not current.
Silversides	Natural mortality unknown. Little information on spawning areas in Oregon nearshore.	Little known about jacksmelt importance as prey component of nearshore environment.	Abundance and stock status not known.
Smelts	Species-specific marine life stage information. Natural mortality unknown. Little information on spawning areas in Oregon nearshore.	Marine life stage information.	Ocean abundance and stock status not yet well-known, but is developing.
Pelagic Squids	Natural mortality unknown. Little life history information for *Gonatidae*, Octopoteuthid and Onychoteuthid squids. Reproductive information on Octopoteuthids.	Species-habitat and depth associations among Cranchiid and Octopoteuthid squids.	Abundance and stock status not known for any of the pelagic squid species groups.

B. Harvest Management Strategy

Harvest management strategies articulate the goals for Forage Fish both in terms of the resource and the people utilizing it. This section examines the issues and practices involved with management of the Forage Fish resource.

B.1. Management goals

The management goals of this Plan are to provide protections in state waters that complement the federal action, by prohibiting new directed commercial harvest of Forage Fish and limiting bycatch in other fisheries in order to support existing fisheries and ecosystem function. Additionally, this Plan (and the federal action) provides opportunity for consideration of new directed commercial harvest of Forage Fish, in the event that interest arises, and when the Department has had an adequate opportunity to assess the science relating to any proposed fishery and any potential impacts to our existing fisheries, communities, and ecosystem function.

As defined in this Plan, the management goals are as follows:

- Support existing ecosystem resilience and reliance on Forage Fish
- Allow existing fisheries
- Support sustainability of existing fisheries, relative to the reliance on Forage Fish prey
- Monitor Forage Fish landings.

B.1.a. Biological/Ecological

The biological and ecological goals of this Plan are to support existing ecosystem reliance on Forage Fish. Forage fish are important components of many higher trophic level marine species such as finfish, marine mammals, and marine birds. In recognition of the importance of Forage Fish to the larger ecosystem, this Plan provides protections for these ecologically important species.

B.1.b. Socioeconomic

The socioeconomic goals of this Plan are to avoid constraining existing fisheries. While Forage Fish are not currently targeted in Oregon commercial fisheries, some species are taken as bycatch, or caught recreationally. The intent of this Plan is to minimize disruption to the fleet, and the protections in this Plan are not intended to disrupt or curtail existing commercial fisheries.

B.1.c. Goals related to other fisheries management

This Plan is intended to support other fisheries in Oregon, which target species that depend on Forage Fish as prey. Fish populations reliant on Forage Fish prey support both state and federal fisheries for groundfish, highly migratory species, coastal pelagic species, and salmon.

B.1.d. Metrics and Monitoring

This Plan prohibits directed fishing on the defined list of Forage Fish species and species groups, until we have adequate scientific data on the proposed fishery activity and we are able to analyze the potential impacts of the new fishing activity on existing fisheries and ecosystem function. Enforcement action on directed fishing will be gauged by measuring the landing amounts of those same species and species. The metrics being used both in federal rule and in this Plan are vessel landings by trip and vessel landings accumulated over a year, based on aggregate weight landed for this group of species. Enforcement of vessel landings amounts for Forage Fish require more accurate and precise data on Forage Fish landings than had previously been collected, and through this Plan implement new sorting and reporting requirements:

1. New sorting and reporting requirements for the Humboldt squid (*Dosidicus gigas*). Species-specific sorting of Humboldt squid allow it to be distinguished from the existing aggregate species group "Other Squid". "Other Squid" includes Forage Fish species groups covered in this Plan as well as some that are not – including Humboldt squid. Humboldt squids are large schooling squid that are landed in large amounts during some years. With a species-specific sorting requirement, high volume landings of Humboldt squid will be easily identified and will not be mistaken for a spike in Forage Fish landings.
2. New reporting requirement for all landed catch. Sorting Forage Fish to species or species group is an unreasonable and unnecessary burden to meet the goals of this Plan. However, full accounting of all landed catch on fish tickets provides a maximum estimate of possible Forage Fish landings, for use in landings trends analysis. While this reporting change does not provide an exact metric for Forage Fish nor does it provide an enforceable landings amount for all Forage Fish species and species groups, it does provide valuable information for monitoring changes in fishery activity.

B.2. Current issues related to the resource

Primary concerns about the sustainability of the Forage Fish resource include current and future changes in ocean conditions (climate change, El Nino events, etc.) and harvest related to fishmeal production (or other reduction products). Although Forage Fish are not targeted for harvest in Oregon, some are taken in the fisheries of other nations. Taking into account global landings of all lower trophic level species (including those covered by this Plan), this forage group is generally converted into various commodities through value-added production processes (Herrick et al. 2009). Based on FAO fisheries commodities, production, and trade data from 1976-2009, most of the reported forage species commodities production was in the fishmeal and fish oil category. During that period, commodities in the fishmeal and fish oil category increased to well over 50% of total annual lower trophic level species commodities production. The growing importance forage species to global fishery landings may reflect their increasing use in the production of fishmeal and fish oils.

Demand for these species in the production of fishmeal has mainly been driven by the dramatic growth of global aquaculture, which is expected to continue into the foreseeable future (Tacon and Metian 2008; Shamshak and Anderson 2008; and Herrick et al. 2009). The production of many aquaculture species depends on forage species to supply the raw ingredients in today's aquafeeds. In response to the recent boom in capture-based aquaculture, demand has increased for whole live/fresh/frozen forage species for pen fattening aquaculture operations (Zertuche-Gonzales et al. 2008). The interest in wild-caught forage species will likely continue to increase and will be an ongoing concern for the sustainability of Forage Fish covered by this Plan, as well as other species. It will also be an ongoing business concern for the aquaculture industry, because there are limited effective protein substitutes (in comparison to protein substitutes' success in livestock production). Given the limited potential for increasing fishmeal production from forage species collectively it is likely that prices for fishmeal and fish oil will continue to rise and that interest in developing fisheries on forage species, including Forage Fish in this Plan, all that more likely. This Plan is therefore useful to establish a precautionary approach to consider future fishery activity.

B.3. Analysis of Forage Fish landings

Although Forage Fish are not currently targeted in Oregon commercial fisheries, some species are taken as commercial bycatch, or caught recreationally. Of the Forage Fish species in this Plan, ODFW commercial fishery species landing codes currently identify only barracudina, Pacific sandlance, Pacific saury, topsmelt, whitebait smelt, surf smelt and eulachon. Other smelt are coded as “smelt species”. Additionally, there is an ODFW commercial fishery code for unspecified squid, although the majority of landings are likely Humboldt squid (which are not included as Forage Fish in this plan).

Current Oregon commercial fisheries may land small amounts of forage species as bycatch, with no commercial value (Table 2). With the exception of eulachon from the Columbia River and unspecified squid species, which are likely Humboldt squid, the annual ex-vessel revenue from Oregon landings of all these species has been zero for the past decade. During the mid-1980s, landings of unspecified smelt species peaked at 33 mt (Figure 1) with an ex-vessel value of $21,000. Landings of unspecified smelt species declined to less than 1 mt in most years after 1989.

Table 2. Oregon marine commercial landings (metric tons) of Forage Fish between 2004 and 2016[2]. This does not include Columbia River landings. Data source: ODFW commercial fish ticket system. Blank cells indicate no commercial landings reported via fish ticket data.

Species	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016[2]**
Barracudinas					< 0.01		0.05	0.01	0.09		< 0.01	0.03	0.02
Pacific Sandlance													
Pacific Saury									< 0.01			< 0.01	
Silversides													
Topsmelt													
Jacksmelt													
Osmerid Smelts													
Eulachon (marine)							< 0.01			0.08			
Surf Smelt													
Whitebait Smelt													
Unsp. Smelt	<0.01					0.01				0.09	0.13		0.26
Pelagic Squids (Unsp.)[1]				103.15	351.08	63.01	68.92	15.81	20.24	16.43	21.41	30.39	11.84

1/ Pelagic squid landings are likely comprised of Humboldt squid landings.
2/ Landings data for partial year; extracted from ODFW commercial fish ticket system on August 17, 2016.

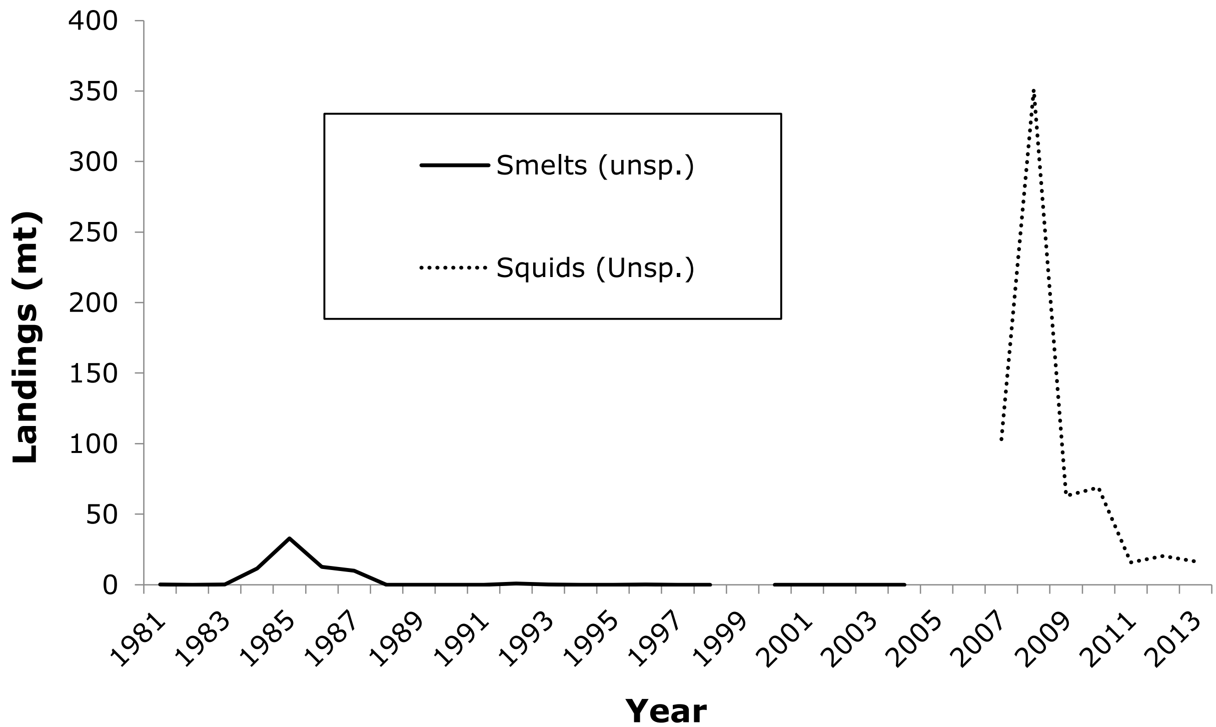

Figure 1. Oregon landings (metric tons; mt) of unspecified smelts and unspecified squids (likely Humboldt squids) between 1981 and 2013.

In recent years, bycatch of these species, excluding unspecified squid species and eulachon, have been taken primarily in the whiting fishery, pink shrimp fishery, and groundfish trawl fishery. For example, recent annual landings of barracudina, a mesopelagic fish, are very small (<0.1 metric ton) and occur as bycatch in the whiting fishery. In the pink shrimp fishery, some Forage Fish are commonly taken but discarded at sea. Myctophids are a common bycatch in shrimp trawls at depths greater than about 90 fathoms; whitebait smelt are common in trawls inside of about 65 fathoms; and Pacific sand lance are rarely encountered (R. Hannah, pers. comm., ODFW, Research biologist, January 16, 2014). Eulachon are commonly taken in shrimp trawls and can be a large component of the bycatch that remains after bycatch reduction devices have excluded the majority of incidentally-caught fishes.

For recreational fisheries, fishing for all Forage Fish is allowed, although recreational fishing for eulachon is limited to particular areas. Recreational targeting in marine waters is rare, but does occasionally occur for surf smelt near or from shore. Occasionally, Pacific sand lance may be incidentally taken while fishing for herring. Between 1980-1989 and 1993-2002 surfsmelt (2,202 total fish), topsmelt (10,000 total fish) and night smelt (1,000 total fish) were landed in the state (Marine Recreational Fishery Statistical Survey).

B.4. Social and cultural uses

Little is known about cultural uses of these species. Various smelt species have been part of the diets of Native Americans for centuries (see Gustafson et al. 2010 for eulachon in human cultural history).

B.5. Biological reference points

For many Forage Fish, scarce information limits or may even preclude the establishment of allowable harvest levels and biological reference points. Development of methods for examining stock status trends or indicators for “data-poor” or “data-limited” fisheries is an active area of research.

B.6. Evaluation of management tools

The management tools in this Plan are the same as those being implemented by federal action. These tools include: 1) trip-level and annual landing limits on vessels landing Forage Fish to Oregon ports, and 2) annual processing limits of Forage Fish by at-sea and shore-based whiting fisheries. These tools are intended to prohibit development of new directed commercial harvest of Forage Fish, until such time that we have fishing industry interest to harvest, we have adequate scientific data on the proposed fishery activity and we are able to analyze the potential impacts of the new fishing activity on existing fisheries and ecosystem function. The following section describes the federal management tools more fully and describes the impacts to Oregon’s fisheries and regulatory framework, by state adoption of these tools.

B.6.a Federal regulations on Forage Fish

In September 2015, the Council approved draft federal regulations providing for management of Forage Fish species. These regulations prohibit new directed commercial harvest of Forage Fish in federal waters but specify that this prohibition does not apply to fishing occurring entirely within state waters. Under the draft federal regulations, a “directed fishery” on Forage Fish is defined as a vessel landing solely Forage Fish species without landing any other species, or landing Forage Fish species in amounts more than: 1) 10 metric tons combined weight of all Forage Fish species from any fishing trip, or 2) 30 metric tons combined weight of all Forage Fish species in any calendar year. Processing at sea is prohibited, except as allowed while processing groundfish, and the following annual limits are set for processing Forage Fish species in whiting fisheries: 1) 1 mt of Forage Fish species other than Forage Fish squid or 2) 40 mt of any Forage Fish squid species. Figure 2 shows exact regulatory language as published in the Federal Register (final federal regulation), on May 4, 2016.

B.6.b. Osmerid smelts

Prior to adoption of this Plan, commercial fishing for Forage Fish was allowed in marine waters off Oregon, with the exception of osmerid smelts. Directed commercial fishing for osmerid smelts is prohibited and bycatch may not exceed 1% of the landing by weight (OAR 635-004-0545), a bycatch definition that is more conservative than the draft federal regulations on Forage Fish. Under this Forage Fish Management Plan, the 1% landing limit would still apply for osmerid smelts; osmerid smelts in combination with the other species covered by this plan (in aggregate) would be used to determine whether the trip or annual landings were in compliance with the definition of directed fishing. While commercial fishing for eulachon may occur in the Columbia River if allowed under rule (OAR 635-042-0130), but this fishing activity is outside the scope of this Plan.

For the reasons set out in the preamble, 50 CFR part 660 is amended as follows:

PART 660—FISHERIES OFF WEST COAST STATES

■□1. The authority citation for part 660 continues to read as follows:
Authority: 16 U.S.C. 1801 *et seq.*, 16 U.S.C. 773 *et seq.*, and 16 U.S.C. 7001 *et seq.*

■□2. In § 660.1 revise paragraph (a) to read as follows:

§ 660.1 Purpose and scope.

(a) The regulations in this part govern fishing activity by vessels of the United States that fish or support fishing inside the outer boundary of the EEZ off the states of Washington, Oregon, and California.
* * * * *

■□3. Add subpart B to read as follows:

Subpart B—All West Coast EEZ Fisheries

Sec.
660.5 Shared Ecosystem Component Species.
660.6 Prohibitions.

§ 660.5 Shared Ecosystem Component Species.

(a) *General.* The FMPs implemented in this part 660 each contain ecosystem component species specific to each FMP, as well as a group of ecosystem component species shared between all of the FMPs. Ecosystem component species shared between all of the Pacific Fishery Management Council's FMPs, and known collectively as ''Shared EC Species,'' are:
(1) Round herring (*Etrumeus teres*) and thread herring (*Ophisthonema libertate* and *O. medirastre*).
(2) Mesopelagic fishes of the families *Myctophidae, Bathylagidae, Paralepididae,* and *Gonostomatidae*.
(3) Pacific sand lance (*Ammodytes hexapterus*).
(4) Pacific saury (*Cololabis saira*).
(5) Silversides (family *Atherinopsidae*).
(6) Smelts of the family *Osmeridae*.
(7) Pelagic squids (families: *Cranchiidae, Gonatidae, Histioteuthidae, Octopoteuthidae, Ommastrephidae* except Humboldt squid [*Dosidicus gigas,*] *Onychoteuthidae,* and *Thysanoteuthidae*).
(b) *Directed commercial fishing for Shared EC Species.* For the purposes of this section, ''directed commercial fishing'' means that a fishing vessel lands Shared EC Species without landing any species other than Shared EC Species, or lands Shared EC Species with other species and in amounts more than:
(1) 10 mt combined weight of all Shared EC Species from any fishing trip; or
(2) 30 mt combined weight of all Shared EC Species in any calendar year.

§ 660.6 Prohibitions.

In addition to the general prohibitions specified in § 600.725 of this chapter, and the other prohibitions specified in this part, it is unlawful for any person to:
(a) *Directed commercial fishing.* Engage in directed commercial fishing for Shared EC Species from a vessel engaged in commercial fishing within the EEZ off Washington, Oregon, or California. This prohibition does not apply to:
(1) Fishing authorized by the Hoh, Makah, or Quileute Indian Tribes, or by the Quinault Indian Nation, or
(2) Fishing trips conducted entirely within state marine waters.
(b) *At-sea processing.* At-sea processing of Shared EC Species is prohibited within the EEZ, except while processing groundfish in accordance with subpart D of this part.

■□4. In § 660.112, add paragraphs (d)(16) and (e)(10) to read as follows:

§ 660.112 Trawl fishery—prohibitions.

* * * * *
(d) * * *
(16) Retain and process more than 1 mt of Shared EC Species other than squid species in any calendar year; or, retain and process more than 40 mt of any Shared EC squid species in any calendar year.
(e) * * *
(10) Retain and process more than 1 mt of Shared EC Species other than squid species in any calendar year; or, retain and process more than 40 mt of any Shared EC squid species in any calendar year.

Figure 2. Final published federal regulations: http://www.westcoast.fisheries.noaa.gov/publications/frn/2016/81fr19054.pdf

B.6.c. Regulatory conformance

For federally-managed species, the Oregon Fish and Wildlife Commission incorporates relevant federal regulations into state rule by reference (OAR, Division 003 and Division 004). Further, the regulations are extended shoreward to include Oregon's Territorial Sea (0-3 nautical miles) for management of all federally-managed species except salmon, for which federal regulations refer to the fishery management area, therefore extension into state waters is not needed. Commercial fishing activity must conform to the specified regulations, including the federal list of authorized fisheries and gears (CFR Title 50, Part 600.725(v)). Most of the federal Forage Fish regulations are found in a section of federal regulations (CFR Title 50, Part 660, Subpart B) which are now incorporated by reference in state regulations. State Forage Fish regulations extend into estuaries upstream to the head of tide.

B.6.d. Monitoring

Because none of the Forage Fish considered in this Plan are targeted by Oregon marine commercial fisheries, and these fisheries only occasionally take small amounts of these species, prohibition of fishery targeting will likely have only minor impacts on current Oregon fisheries. However, the new sorting and reporting requirements described in B.1.d above inform both state and federal monitoring programs. Primarily, the sorting and reporting requirements provide metrics for estimating the maximum possible landings of Forage Fish and will be used to inform the annual NMFS State of the California Current Ecosystem Report to the PFMC.

B.6.e. Allowance for new directed commercial harvest

The Plan is designed to support the decisions and the benefits of the federal action in protecting Forage Fish while still allowing consideration for future fishery development. The federal action allows development of new directed commercial fisheries on Forage Fish, upon consideration of adequate scientific information on the proposed directed fishery and its potential impacts to existing fisheries, fishing communities, and the greater marine ecosystem. The federal action provides a mechanism and criteria, via an exempted fishery permit, to obtain information, upon approval, about a potential new fishery and its impacts. Proposed new directed commercial fishing on Forage Fish species that occurs all or in part in federal waters will be evaluated by the Pacific Fisheries Management Council using Council Operating Procedure 24 (COP 24). Proposed new directed commercial fishing that would occur only in state waters (0-3 miles offshore) will be evaluated by the Department by first developing and then implementing guidelines and procedures based on the intent and principles of COP 24.

The Department has mechanisms for allowing new fishing activity including issuance of an "Experimental Fishing Gear Permit" – to allow testing of fishing gears that may be used to target Forage Fish. Under state rule (OAR 635-006-0020), an experimental fishing gear permit may be issued for the taking of food fish provided the use of such fishing gear is not otherwise prohibited by commercial fishing laws. In addition, the Oregon Fish and Wildlife Commission may adopt rules to allow new directed fishing.

The goal of the Plan is to provide protection for Forage Fish in Oregon state waters adequate to support existing ecosystem resilience and reliance on these species, and to ensure precautionary and sustainable approaches to potential directed harvest or bycatch of Forage Fish. The Plan complements federal regulations developed to protect those Forage Fish species and species groups addressed in the federal forage fish actions. The state management tools described in this Plan are metrics of vessel landings by trip and vessel landings accumulated over a year, as a measure of directed fishing on this group of species. Evaluation of fishery performance over time, as well as enforcement of landings amounts, require more accurate and precise sorting and reporting requirements than were previously in place. With adoption of this Plan, metrics are now in place to track ecosystem-relevant changes in Forage Fish landings to inform future management decision-making.

C. Literature cited and general reference material

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