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# Status Review Update of Eulachon (*Thaleichthys pacificus*) Listed under the Endangered Species Act: Southern Distinct Population Segment

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25 March 2016

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# Executive Summary

On 18 March 2010, the National Marine Fisheries Service (NMFS) published a final rule in the Federal Register to list the southern distinct population segment (DPS) of eulachon as threatened under the U.S. Endangered Species Act (ESA) (NMFS 2010). This listing encompassed all subpopulations of eulachon within the states of Washington, Oregon, and California and extended from the Skeena River in British Columbia south to the Mad River in Northern California. The ESA requires that NMFS review the status of listed species under its authority at least every five years and determine whether any species should be removed from the list or have its listing status changed. The NMFS West Coast Region is responsible for the 5-year review process and decision-making regarding proposed changes in listing status. This report provides updated information and analyses on the biological status of the southern DPS of eulachon, focusing on: 1) new information relevant to the DPS boundaries; 2) trends and status in abundance, productivity, spatial structure, and diversity; and 3) newly available information on selected threats to the DPS.

In the 2010 status review (Gustafson et al. 2010), the Biological Review Team's (BRT) determination of overall risk to the species used three biological risk categories: at high risk of extinction, at moderate risk of extinction, or not at risk of extinction. See Gustafson et al. (2010, p. 171–176, their table 19) for a description of these qualitative reference levels of extinction risk and a narrative summary of the DPS's viable population elements: abundance, productivity, spatial structure, and diversity. The 2010 BRT determined that the southern DPS of eulachon was at moderate risk of extinction throughout all of its range (Gustafson et al. 2010).

This report summarizes new biological information as to whether the DPS is likely to have moved from "moderate risk of extinction" to either of the other two categories: "high risk of extinction" or "low risk of extinction." The information in this report will be incorporated into the Region's review, and the Region will make final determinations about any proposed changes in listing status, taking into account not only biological information but also ongoing or planned protective efforts.

Adult spawning abundance of the southern DPS of eulachon has clearly increased since the listing occurred in 2010. A number of data sources indicate that eulachon abundance in some subpopulations within the southern DPS were substantially higher from 2011–2015 compared to indications of very low abundance from 2005–2010. The improvement in estimated abundance in the Columbia River, relative to the time of listing, reflects both changes in biological status and improved monitoring. The documentation of eulachon returning to the Naselle, Chehalis, Elwha, and Klamath rivers over the 2011–2015 also likely reflects both changes in biological status and improved monitoring.

Since the 2010 status review (Gustafson et al. 2010), annual monitoring of spawning stock biomass (SSB) has continued in the Fraser River (1995–2015), expanded to the Columbia (2011–2015), Grays (2011–2013, 2015), Cowlitz (2015), Naselle (2015), and Chehalis (2015) rivers. In addition, Washington Department of Fish and Wildlife has retrospectively estimated historical SSB in the Columbia River for 2000–2010 using pre-2011 expansions of eulachon larval densities. These retrospective estimates indicate that total eulachon run biomass in the Columbia River may have been as high as 3,150 mt in 2001 and as low as 35 mt in 2005. Mean SSB over the five-year period (2006–2010) immediately prior to the 2010 BRT's analysis was estimated at 20 mt in the Fraser River and 153 mt in the Columbia River. In contrast, mean SSB over last five years (2011–2015) was estimated at 127 mt in the Fraser River and 4,007 mt in the Columbia River.

The situation in the Klamath River is also more positive than it was at the time of the 2010 status review with adult eulachon presence being documented in the Klamath River in the spawning seasons of 2011–2014, although it has not been possible to calculate estimates of SSB in the Klamath River. However, since Moody's (2008) compilation of information on eulachon abundance, very little additional data on the status of eulachon in coastal rivers north of the Fraser River has become available. Anecdotal observations indicate that the Skeena (2010–2015), Kemano (2015), and Kingcome (2012) rivers have apparently supported substantial runs of spawning eulachon in recent years; however, eulachon in the Kitimat River (2012, 2014) have reportedly remained at low levels.

Although eulachon abundance in monitored populations has generally improved, especially in the 2013–2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years. Therefore, it is too early to tell whether recent improvements in the southern DPS of eulachon will persist or whether a return to the severely depressed abundance years of the mid-late 1990s and late 2000s will reoccur.

# Acknowledgments

This status review update relied on comments and informational reports submitted by the public and by state, tribal, and federal agencies. The authors acknowledge the efforts of all who contributed to this record, especially the Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), Department of Fisheries and Oceans Canada (DFO), and NMFS's West Coast Region (WCR).

Numerous individual fishery scientists and managers provided information that aided in preparation of this document and deserve special thanks. For information, data, opinions, and advice, we particularly thank Dr. Sean MacConnachie and Bruce McCarter (Pacific Biological Station, DFO); Dr. Jake Schweigert (DFO, Emeritus); Dr. Doug Hay, Nearshore Consulting, Nanaimo, British Columbia (Scientist Emeritus, Pacific Biological Station, DFO); Brad James, Olaf Langness, and Phillip Dionne (WDFW); and Tom Rien and Robert Hannah (ODFW). We also thank members of the Eulachon Recovery Team: Robert Anderson (Team Lead, WCR); Thomas Wainwright, Jeff Hard, and the late Robert Emmett (NWFSC); Steve Munch (SWFSC), and Olaf Langness (WDFW).

The bycatch portion of this document was a joint effort of the Eulachon Bycatch Reporting Team, which included at various times and in various roles, Vanessa Tuttle (NWFSC, A-SHOP), Marlene Bellman, Kayleigh Somers, Yong-Woo Lee (NWFSC, WCGOP), Rick Gustafson, Eric Ward (NWFSC, CBD), Robert Anderson, and Mitch Dennis (NMFS, West Coast Region). We also gratefully acknowledge the hard work and dedication of observers from the West Coast Groundfish Observer Program and the At-Sea Hake Observer Program, as well as contributions from observer program staff. Thank are also due to Jeff Hard and Tom Wainwright for useful comments on the previous versions of this manuscript.

# Introduction

## Background

On 18 March 2010, the National Marine Fisheries Service (NMFS) published a final rule in the Federal Register to list the southern distinct population segment (DPS) of eulachon as threatened under the U.S. Endangered Species Act (ESA) (NMFS 2010). This listing encompassed all subpopulations of eulachon within the states of Washington, Oregon, and California and extended from the Skeena River in British Columbia south to the Mad River in Northern California. The ESA requires that NMFS review the status of listed species under its authority at five year intervals and determine whether a species or DPS should be removed from the list or have its listing status modified. The NMFS West Coast Region is responsible for the 5-year review process and decision-making regarding proposed changes in listing status. The present report summarizes new and additional information that has become available since the 2010 status review (Gustafson et al. 2010) on: 1) delineation of the southern DPS of eulachon; 2) trends in abundance, productivity, spatial structure, and diversity; and 3) selected threats to the DPS. The information in the report will be incorporated into the Region's review, and the Region will make final determinations about any proposed changes in listing status, taking into account not only biological information but also ongoing or planned protective efforts.

Eulachon (*Thaleichthys pacificus*, Osmeridae) is an anadromous smelt that ranges from northern California to the southeastern Bering Sea coast of Alaska (Willson et al. 2006, Moody and Pitcher 2010). The declining abundance of eulachon in the southern portion of its range led the Cowlitz Indian Tribe to petition (Cowlitz Indian Tribe 2007) NMFS to list eulachon in Washington, Oregon, and California as a threatened or endangered species under the ESA. A eulachon Biological Review Team (BRT)—consisting of scientists from the Northwest Fisheries Science Center, Alaska Fisheries Science Center, Southwest Fisheries Science Center, U.S. Fish and Wildlife Service, and U.S. Forest Service—was formed by NMFS, and the team reviewed and evaluated scientific information submitted from state agencies, other interested parties, and compiled by NMFS staff from both published and unpublished literature. The 2010 BRT identified a southern distinct population segment (DPS) of eulachon—that occurs in the California Current and is composed of numerous subpopulations that spawn in rivers from northern California to northern British Columbia. The 2010 BRT concluded that the major threats to the southern DPS of eulachon include climate change impacts on ocean and freshwater habitat, bycatch in offshore shrimp trawl fisheries, changes in downstream flow-timing and intensity due to dams and water diversions, and predation. These threats, together with large declines in abundance, indicated to the 2010 BRT that the southern DPS of eulachon was at moderate risk of extinction throughout all of its range (Gustafson et al. 2010, 2012).

## Eulachon Life History

Adult eulachon typically spawn at age 2–5, when they are 160–250 mm in length (fork length), in the lower portions of rivers that have prominent spring peak flow events or freshets (Hay and McCarter 2000, Willson et al. 2006). Many rivers within the range of eulachon have consistent yearly spawning runs; however, eulachon may appear in other rivers only on an irregular or occasional basis (Hay and McCarter 2000, Willson et al. 2006). The spawning migration typically begins when river temperatures are between 0°C and 10°C, which usually occurs between December and June. Run timing and duration may vary interannually and multiple runs occur in some rivers (Willson et al. 2006). Eulachon in the southern DPS are semelparous, although some individuals in Alaska may spawn more than once (Willson et al. 2006). Fecundity reportedly ranges from 7,000-60,000 eggs, which are approximately 1 mm in diameter. Milt and eggs are released over sand or coarse gravel. Eggs become adhesive after fertilization and hatch in 3 to 8 weeks depending on temperature. Newly hatched larvae are transparent, slender, and about 4 to 8 mm in length (total length). Larvae are transported rapidly by spring freshets to estuaries (Hay and McCarter 2000, Willson et al. 2006) and juveniles disperse onto the continental shelf within the first year of life (Hay and McCarter 2000, Gustafson et al. 2010) and are taken in research trawl surveys beginning at age-1+ over the continental shelf off the U.S. west coast and most often at depths between 50 and 200 m (NWFSC Eulachon Workgroup 2012).

## Summary of 2010 BRT Conclusions

### Delineation of the Southern DPS of Eulachon

After consideration of the all available scientific data, the 2010 eulachon BRT determined that the petitioned unit of eulachon that spawn in rivers in Washington, Oregon, and California is not a species under the ESA, as it does not meet all the biological criteria to be considered a DPS as defined by the joint USFWS-NMFS 1996 policy on vertebrate populations (USFWS-NMFS 1996). However, the 2010 BRT did determine that eulachon spawning in Washington, Oregon, and California rivers are part of a DPS that extends beyond the conterminous United States and that the northern boundary of the DPS occurs in northern British Columbia south of the Nass River (most likely) or in southern British Columbia north of the Fraser River (less likely). The 2010 BRT found it difficult to establish a clear northern terrestrial or river boundary for this DPS in light of the fact that the 2010 BRT believed the northern boundary is essentially determined by oceanographic processes. However, it was the majority opinion of the 2010 BRT that the northern boundary of the DPS is south of the Nass River on the north coast of British Columbia. The 2010 BRT proposed that this DPS be termed the southern DPS of eulachon. The 2010 BRT also concluded that eulachon spawning in the Nass River and further north consist of at least one additional (northern) DPS (Gustafson et al. 2010).

### Status of the Southern DPS of Eulachon

The 2010 BRT qualitatively ranked threats to the southern DPS of eulachon subpopulations that spawn in the Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. In each case, the 2010 BRT ranked climate change impacts on ocean conditions as the most serious threat to persistence of eulachon. Climate change impacts on freshwater habitat and eulachon bycatch were scored as moderate to high risk in all subareas of the DPS, and dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers were also ranked within the top four threats in their respective regions (Gustafson et al. 2010).

The 2010 BRT was concerned that although eulachon are a relatively poorly monitored species, the weight of the available information indicated that the southern DPS of eulachon experienced an abrupt decline in abundance throughout its range in the early to mid-1990s. Considering this large decline, in addition to other risk factors, the 2010 BRT determined that the southern DPS of eulachon was at moderate risk of extinction throughout all of its range (Gustafson et al. 2010).

## Brief Review of Eulachon Recovery Plan

NMFS has filed a notice of intent to prepare a recovery plan for the southern DPS of eulachon (NMFS 2013) and has released a Recovery Plan Outline[1]. NMFS has also formed a Eulachon Recovery Team, led by Robert Anderson (Eulachon Recovery Coordinator, NMFS West Coast Regional Office), that consists of five additional members from both the Northwest and Southwest Fisheries Science Centers and Washington Department of Fish and Wildlife. The Eulachon Recovery Team's general function is to assist in the development of a draft recovery plan and, in particular, to develop a set of biological viability criteria—abundance and productivity targets and viability scenarios for each sub-population— and to attempt to develop an oceanographic survival indicator model to determine the significance of plume and ocean conditions that affect eulachon survival. The team has met once in person and has conducted many monthly meetings via conference call since June of 2014.

# New and Additional Information

### Updated Information Related to Delineation of the Southern DPS of Eulachon

An "ESA species" may consist of a taxonomically named species or subspecies, or in the case of vertebrate organisms, a distinct population segment (DPS). A DPS must be "discrete" from the remainder of the species to which it belongs and "significant" to the species as a whole (USFWS-NMFS 1996); however, if multiple DPSs cannot be identified, then the "ESA species" is the taxonomic species or subspecies. A population may be considered discrete if it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors (genetic or morphological differences may provide evidence of this separation). If a population segment is considered discrete, its biological and ecological significance is then evaluated on the basis of: (i) whether it occurs in an

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[1] Available online at: http://www.nwr.noaa.gov/publications/protected_species/other/eulachon/eulachon_recovery_outline_070113.pdf

ecological setting unusual or unique for the species; (ii) whether its loss would result in a significant gap in the species' range; (iii) whether it represents the only surviving indigenous occurrence of the species; or (iv) whether it differs markedly from other populations of the species in its genetic characteristics (USFWS-NMFS 1996).

## 2010 DPS conclusions based on discreteness and significance criteria

In considering the discreteness criteria (USFWS-NMFS 1996), the 2010 BRT concluded that the weight of the available evidence indicated that there are multiple discrete populations of eulachon. In addition to the genetic data, the 2010 BRT considered the strong ecological and environmental break that occurs between the California Current and Alaska Current oceanic domains as contributing evidence for discreteness. The 2010 BRT also considered, but did not weigh heavily, the latitudinal differences in spawn timing, body size, and vertebral counts among samples from different rivers. Overall, the 2010 BRT believed that genetic and ecological data provided strong evidence that eulachon south of the Nass River were discrete from those in the Nass River and northward, but that there was also evidence (from the genetic data) suggesting that Fraser and Columbia River groups may be discrete from more northern groups.

In evaluating the significance criteria (USFWS-NMFS 1996), the 2010 BRT focused primarily on criteria 1 (ecological setting), criteria 2 (evidence that loss would result in a significant gap in the range of the species), and criteria 4 (markedly differs in genetic characteristics). The 2010 BRT concluded that there was evidence supporting the significance criteria under the scenario of there being one DPS south of the Nass River/Dixon Entrance or an alternate scenario of there being one DPS inclusive of eulachon in the Fraser River to California. In particular, there is evidence under either scenario for a significant break in ecological setting, and loss of a putative DPS defined by either boundary would without question result in a significant gap (or reduction) in the range of the overall species. The 2010 BRT also considered whether the available genetic data provided any evidence for "markedly different" populations, but concluded that although the genetic data provides evidence for discreteness (lack of gene flow) there was little evidence to support the existence of deep intraspecific phylogenetic breaks that the 2010 BRT believed were necessary to be considered "marked." Support for a discrete and significant eulachon population south of the Nass River/Dixon Entrance was provided by evidence that eulachon in this southern area are "markedly separated on the basis of ecological and physiological features" from eulachon to the north. In summary, the 2010 BRT believed the evidence most strongly supported one DPS south of the Nass River/Dixon Entrance (Gustafson et al. 2010).

Information of all types, from published and unpublished sources, was reviewed in order to assess whether sufficient data existed to justify a reconsideration of the boundary of the southern DPS of eulachon.

## Genetic population structure

The 2010 status review (Gustafson et al. 2010) reviewed four published genetic studies of genetic population structure in eulachon. One of these studies (McLean et al. 1999) used restriction fragment length polymorphism (RFLP) analysis to examine variation in mitochondrial DNA. The other studies (McLean and Taylor 2001, Kaukinen et al. 2004, Beacham et al. 2005) analyzed microsatellite DNA loci. The most extensive study of eulachon, in terms of sample size and number of loci examined, was that of Beacham et al. (2005). Beacham et al. (2005) examined microsatellite DNA variation in eulachon collected at 9 sites ranging from the Columbia River to Cook Inlet, Alaska, using the 14 loci developed by Kaukinen et al. (2004). A cluster analysis of genetic distances showed genetic affinities among the populations in the Fraser, Columbia, and Cowlitz rivers and also among the Kemano, Klinaklini, and Bella Coola rivers along the central British Columbia coast. In particular, there was evidence of a genetic discontinuity north of the Fraser River, with Fraser and Columbia/Cowlitz samples being approximately 3–6 times more divergent from samples further to the north than they were to each other (Beacham et al. 2005). However, the 2010 BRT noted that there was some uncertainty about the genetic population structure due to the small number of temporally replicated samples in all of the above studies. Beacham et al. (2005) found genetic differences among sampling years within three separate populations (Nass, Kemano, and Bella Coola rivers) in British Columbia that were similar to levels of genetic differentiation among these three geographically separated populations, indicating a lack of temporal stability in the pattern of population structure.

**New genetic evidence**—Two genetic studies have been published since the 2010 status review (Gustafson et al. 2010) was released, one utilizing microsatellite DNA differentiation to study population structure among samples of eulachon in Alaska (Flannery et al. 2009, 2013) and another utilizing newly developed single nucleotide-polymorphisms (SNPs) (Candy et al. 2015).

Flannery et al. (2009, 2013) examined eulachon population structure among 26 rivers in Alaska by analyzing variation at the same 14 microsatellite DNA loci used by Beacham et al. (2005) to analyze population structure in British Columbia and the Columbia River. All collections occurred in either 2003 or 2004, and there was no temporal sampling at any of the 26 locations (Flannery et al. 2013). Eulachon in Alaska exhibited a low degree of genetic divergence, with a broad scale regional level of population structure. Samples from the northern region (Yakutat Forelands, Cook Inlet, and Prince William Sound) were significantly different from samples obtained from the southern region (Behm and Lynn canals, Stikine Strait, and Berners Bay) (Flannery et al. 2013); however, there was little inter-regional differentiation. According to Flannery et al. (2013, p. 1040), "The level of genetic divergence between regions was four times as great as that within regions." The fine scale genetic population structure that Beacham et al. (2005) described, based on samples of eulachon from British Columbia and the Columbia River, was absent in Alaskan eulachon (Flannery et al. 2013).

Candy et al. (2015) examined eulachon population structure among 12 sampling locations ranging from Washington (Columbia and Cowlitz rivers) to south-central Alaska (Twenty-mile and Kenai rivers in Cook Inlet) by analyzing genetic variation among a panel of 3,911 putatively neutral SNPs and a panel of 193 putatively adaptive SNPs. There was no temporal sampling at any of the 12 locations included in the Candy et al. (2015) study.

According to Candy et al. (2015), the neutral and adaptive eulachon SNP panels showed a regional population structure that was similar to that observed by Beacham et al. (2005) using microsatellite DNA markers. Candy et al. (2015) interpreted their results as indicating that:

> … there is a three-population southern Columbia-Fraser group (Cowlitz, Columbia, and Fraser rivers), a seven-population British Columbia (BC) – SE Alaska group (Stikine, Nass, Skeena, Klinaklini, Kingcome, Kemano and Bella Coola rivers) and a two-population northern Gulf of Alaska (GOA) group (Twenty Mile and Kenai rivers)

Surprisingly, pairwise $F_{ST}$ comparisons for the neutral SNPs showed that Columbia River eulachon were not significantly differentiated from any other population (all pairwise $F_{ST} \leq 0.0000$) (Candy et al. 2015, their table 2). However, the adaptive SNPs displayed statistically significant pairwise $F_{ST}$ values for the Columbia River sample compared to all other rivers, with the exception of the Cowlitz River. The Columbia River sample consisted of larval eulachon collected downstream of the Cowlitz River, so these larvae may have originated from the Cowlitz River (Candy et al. 2015).

Small et al. (2015) described preliminary results of a study using microsatellite DNA variation to examine potential temporal differences in genetic population structure of eulachon in the Columbia River Basin. An early winter run of eulachon typically enter the Columbia and eventually the Cowlitz River, often in late November, December, or early January. This early winter run has been given the popular label of “scout” or “pilot” run (Stockley and Ellis 1970), as these fish enter several weeks prior to the main eulachon run. In addition, the 2010 BRT (Gustafson et al. 2010, p. 47) stated that “Comparison of average dates of initial landings in the commercial fishery in the Cowlitz River (January 25) and in the Sandy River (March 21) confirm that a nearly two month period separates the average run timing in these two tributaries.” In light of these temporal differences in spawn timing in the Columbia River Basin, Small et al. (2015) proposed to examine genetic population structure among: 1) 95 larval samples from the early winter, or “pilot,” run in the Cowlitz River; 2) a mainstem Columbia River collection of 95 larval eulachon near the end of the larval outmigration period; and 3) 95 tissue samples from Sandy River eulachon. Additional eulachon samples were also analyzed from samples collected near Ucluelet and Pachena Bay, offshore of the west coast of Vancouver Island (WCVI) (Small et al. 2015). The early winter run larval samples from the Cowlitz River proved not to be eulachon, and the mainstem larval Columbia River samples and Sandy River sample were genetically indistinguishable. The early winter run samples were most likely longfin smelt (*Spirinchus thaleichthys*), another closely related anadromous osmerid, and not eulachon. Small et al. (2015) also stated that samples collected off WCVI showed no detectable genetic differences with Columbia River eulachon. Earlier studies (Schweigert et al. 2012) had determined that about 56% of eulachon collected off WCVI could be genetically assigned as originating in the Columbia River. More recent estimates indicate that about two-thirds of the eulachon collected off WCVI could be genetically assigned back to the Columbia River[2].

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[2] Sean MacConnachie, Fisheries and Oceans Canada, Nanaimo, BC, Canada. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., 21 August 2015.

## Impact on DPS Boundary Delineation

The 2010 BRT considered whether the available genetic data (McLean et al. 1999, McLean and Taylor 2001, Beacham et al. 2005) provided any evidence for “markedly different” populations, but concluded that although the genetic data provides evidence for discreteness (lack of gene flow) there was little evidence to support the existence of deep intraspecific phylogenetic breaks that the 2010 BRT believed were necessary to be considered “marked.” However, support for both a discrete and a significant eulachon population south of the Nass River/Dixon Entrance was provided by evidence that eulachon in this southern area are “markedly separated on the basis of ecological and physiological features” from eulachon to the north (Gustafson et al. 2010).

Candy et al. (2015, p. 11) invoked both meristic (vertebral counts) and genetic (SNP and microsatellite DNA data) information to bring into question the 2010 BRT’s majority opinion that the northern boundary of the southern DPS of eulachon extends to the Skeena River. Candy et al. (2015) stated that “the data suggested that the southern distinct population segment (DPS) extends only as far north as the Fraser River, instead of possibly the Nass River as proposed by Gustafson et al. (2012).” Firstly, meristic data in the form of differences in average vertebral counts of eulachon among river systems were considered largely uninformative, for purposes of determining discreteness and significance, by the 2010 BRT. As Levesque and Therriault (2011, p. 5) stated, “… meristic series vary as a function of temperature and that variation in vertebral number can be environmentally induced.” At best, these meristic data indicate that eulachon from southern rivers experienced warmer temperatures during development than eulachon developing in more northern rivers, and that complete mixing of northern and southern groups does not occur, as this would overwhelm the differences in the mean vertebral counts. As most vertebrate poikilotherms exhibit similar latitudinal clines in these meristic characters, their similar occurrence in eulachon offers, at best, weak evidence that eulachon in the southern and northern portion of their range are “markedly separated” from one another. Secondly, the pattern and level of genetic differentiation of eulachon displayed in Candy et al. (2015) were similar to that reviewed by the 2010 BRT based on the Beacham et al. (2005) study. The 2010 BRT did not believe that the then available genetic data provided evidence that eulachon in the Fraser and Columbia rivers were “markedly separated” from other populations, as required by the DPS policy. It should be emphasized that the discreteness and significance criteria (USFWS-NMFS 1996) define a DPS, which is likely to be composed of many stocks or subpopulations, and these criteria incorporate evidence of discreteness and significance for many factors, not just genetic differentiation.

The 2010 BRT was concerned that Beacham et al. (2005) compared microsatellite DNA variation of samples between the Fraser and Columbia rivers taken in only a single year, and thus the temporal stability of genetic variation observed between these two rivers could not be adequately assessed. Nevertheless, after review of the Beacham et al. (2005) study, the 2010 status review (Gustafson et al. 2010, p. 64) stated that “there appears to be little doubt that there is some genetic structure within eulachon and that the most obvious genetic break appears to occur in southern British Columbia north of the Fraser River.” The study of Candy et al. (2015) verifies this result with a new class of genetic markers; however, this additional genetic analysis, with essentially parallel results and similar lack of temporal genetic sampling as in Beacham et al. (2005), would not be expected to change the consensus opinion of the BRT as to the northern boundary of the southern DPS of eulachon. Finally, the 2010 BRT found it difficult to identify a clear northern terrestrial or river boundary for this southern DPS as the majority of the 2010 BRT believed this boundary is largely associated with oceanographic, not terrestrial, processes and is largely defined by the extent of the Northern California Current (Gustafson et al. 2010).

# Updated Status of the Southern DPS of Eulachon

## IUCN Species-Wide Assessment of Eulachon

The IUCN (International Union for Conservation of Nature) published a range-wide (from Monterey Bay, California, to Nushagak River and Pribilof Islands, Bering Sea, Alaska) assessment of eulachon for potential inclusion on its Red List of threatened species in March of 2013[3]. IUCN concluded that, based on the IUCN criteria, eulachon would qualify to be:

> Listed as Least Concern in view of the large extent of occurrence, large number of subpopulations, and large population size. Trend over the past 10 years or three generations is uncertain; species may be declining but probably not fast enough to qualify for any of the threatened categories under Criterion A (reduction in population size).

## Additional Information on Status in Canada

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reviewed the status of eulachon in British Columbia in April 2011 and grouped eulachon populations into three “Designatable Units” (DU) based on their criteria for discreteness and evolutionary significance: 1) Fraser River DU, 2) Central Pacific Coast DU (including all rivers between the Fraser and Skeena rivers), and 3) Nass/Skeena DU (including the Nass and Skeena rivers). The Fraser and Central Pacific Coast DUs were both assessed as endangered and the Nass/Skeena DU was originally assessed as threatened in May 2011 (COSEWIC 2011). COSEWIC re-assessed the status of the Nass/Skeena DU as “Special Concern” in May 2013 (COSEWIC 2013). The Fraser River eulachon DU and the Central Pacific Coast eulachon DU remain under consideration for listing as endangered under Canada’s Species at Risk Act (SARA). According to the DFO (Department of Fisheries and Oceans Canada) website[4]:

> Due to conservation concerns DFO has undertaken several specific activities since 1995 to protect Eulachon including:
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> - closure of the commercial Eulachon fishery on the Fraser;
> - suspension of dredging on the Fraser River during Eulachon spawning season;
> - closure of the shrimp fishery in Queen Charlotte Sound;

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[3] Available online at: http://www.iucnredlist.org/details/full/202415/0.

[4] See information online at: http://www.dfo-mpo.gc.ca/species-especes/profiles-profils/eulachon-eulakane-eng.html

- implementation of bycatch reduction measures in the commercial shrimp trawl fishery including bycatch reduction devices and potential closures when cumulative Eulachon bycatch level is reached;
- full closure of recreational harvesting for Eulachon in all tidal waters and freshwater systems; and
- an annual egg/larval survey to monitor stock on the Fraser in conjunction with First Nations.

In 2012, DFO published a final version of a Recovery Potential Assessment (RPA) for eulachon in Canada (Levesque and Therriault 2011, Schweigert et al. 2012). Schweigert et al. (2012, p. vi) stated that:

> A lack of consistent long term indices of population abundance made it extremely difficult to determine the recovery potential for these DUs. Indices of in-river abundance were summarized for each DU and examined in relation to time series of putative threats in freshwater and marine environments, at both coastwide and localized scales. No single threat could be identified as most probable for the observed decline in abundances among DUs or in limiting recovery. However, mortality associated with coastwide changes in climate, fishing (direct and bycatch) and marine predation were considered to be greater threats at the DU level, than changes in habitat or predation within spawning rivers.

Boldt et al. (2015) summarized status and trends for eulachon in Canada through 2014, prior to the release of the 2015 Fraser River spawning stock biomass (SSB) data. At that time it was noted that eulachon were at low levels of abundance in rivers in southern and central British Columbia. Following a period of declining abundance from 1994–2010, Fraser River eulachon SSB increased slightly in 2011 and 2012, although biomass was again reduced in 2013 and 2014 (Boldt et al. 2015). A subsequent survey in 2015 found Fraser River eulachon SSB to have risen to an estimated 317 mt, the first time since 2003 that the Fraser River biomass had been above the eulachon action level of 150 mt[5].

## DFO Offshore Juvenile Abundance Indices

The Department of Fisheries and Oceans Canada no longer produces the eulachon biomass indices as described below (DFO 2013b). These indices were based on bycatch of eulachon in the fishery-independent bottom trawl surveys using small-mesh nets that target shrimp off West Coast Vancouver Island (WCVI) (Perry et al. 2015) and in Queen Charlotte Sound. The 2010 status review summarized trends in these offshore indices through 2009; this section updates this information to 2012. These biomass indices were last produced for the 2012 survey year, and had provided an index of offshore eulachon abundance from 1973–2012 for WCVI and from 1998–2012 for Queen Charlotte Sound (Figs. 1 and 2) (DFO 2012a, b). These DFO shrimp surveys use a randomized design to assign sampling stations in a number of offshore Shrimp Management Areas (SMAs) in British Columbia. Eulachon are often taken as

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[5] Available online at: http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/river1-eng.html.

bycatch in these surveys. Both the WCVI and Queen Charlotte Sound indices provided information on pre-spawning juvenile eulachon biomass derived from 2 to 4 broodyears at sea. As stated in Schweigert et al. (2012):

> The multispecies small mesh surveys have been conducted consistently with DFO research vessels using a small mesh otter trawl net towed along the bottom with a target duration of 30 min at a depth range of 50–200 m. The surveys are conducted in April to May within the west coast of Vancouver Island (WCVI) region and Central Coast region and in September in the North Coast region (restricted to Chatham Sound). … The surveys capture eulachon of all age groups although very few young-of-the-year are captured during the spring survey. Usually two distinct size modes are present … These surveys began in 1973 in the WCVI region, but did not begin until 1998 and 1999 in the North Coast and Central Coast regions, respectively.

Analysis of eulachon data from these multispecies small mesh bottom trawl surveys showed that the spatial distribution and density of eulachon can vary on an annual basis off the west coast of Vancouver Island (Hay et al. 1997). Levesque and Therriault (2011) stated that:

> The WCVI and QCSD [Queen Charlotte Sound] multispecies small mesh bottom trawl surveys provide an index of abundance for eulachon for these specific locations, but eulachon can be found outside of these areas … and it is therefore unknown what proportion of the total offshore eulachon population these surveys capture. … It also is unclear what proportion of each age class (1+, 2+ and maybe some 3+ year olds) make up the pooled biomass index for each area. The biomass proportions that comprise each age class are difficult to estimate accurately based on length frequency data alone. Small fish may not be measured in their represented proportions due to selectivity and physical damage. Also, growth is highly variable between areas and years and there is uncertainty in the ages of larger fish.

A detailed description of these biomass indices can be found in Gustafson et al. (2010, p. 91–92). DFO (2012a, p. 5) stated that the WCVI:

> …eulachon biomass indices for 2012 increased in all SMA's surveyed... Eulachon biomass index for SMA 23OFF+21OFF increased to 1322.2 t in 2012 from 1054.6 t in 2011. The eulachon biomass index for SMA 124OFF increased significantly to 2146.6 t in 2012 from 510.4 t in 2011 and also increased significantly for SMA 125OFF to 1375.1 t in 2012 from 128.8 t in 2011. [see Fig. 1].

In reference to this index, DFO (2013a, p. 7) also stated that "It is important to note that this is a biomass index and not a biomass estimate and that eulachon caught in this survey include stocks from the Fraser River, the Columbia River, and possibly other areas." These indices were derived from multispecies small mesh bottom fisheries-independent trawl surveys that were conducted in specific locations, and it is possible that eulachon may have been anomalously abundant in these specific locations and may also have occurred outside of these surveyed areas.  In addition, this index tracked at least 2 year classes of eulachon at sea and was usually conducted in April and May.  Significant mortality could occur between when this juvenile biomass index took place and when adults returned to rivers to spawn; 9–11 months and 18–22 months for the older and younger cohorts, respectively.

DFO (2012b, p. 3) stated that the Queen Charlotte Sound eulachon biomass index indicated that "Eulachon biomass on the shrimp grounds increased in 2012 to 2600.8 t from 2161.5 t in 2011" (see Fig. 2).  Estimated ocean shrimp (aka smooth pink shrimp) biomass in the Queen Charlotte Sound SMA "decreased to 6380.6 t in 2012 from 7014.3 t in 2011…" (DFO 2012b, p. 1).

The biomass indices of juvenile eulachon in the above offshore surveys (Figs. 1–2) were one to two orders of magnitude greater than known or suspected freshwater eulachon spawning stock biomass in the DPS (Gustafson et al. 2010, COSEWIC 2011, Schweigert et al. 2012).  The reasons for this apparent discrepancy were not fully understood; however, the apparent discrepancy led both the status report of eulachon in Canada (COSEWIC 2011) and the Recovery Potential Assessment for eulachon in Canada (Schweigert et al. 2012) to regard the WCVI and Queen Charlotte Sound marine biomass indices as unreliable, based on the belief that the marine trends were misleading.  According to DFO (2013b), a "eulachon biomass index is no longer required for setting Eulachon Action Levels so eulachon biomass indices for SMA23IN, 23OFF+21OFF, 124OFF, and 125OFF" are no longer being calculated.

### West Coast Vancouver Island Small Mesh Trawl Survey

Although the above biomass indices of juvenile eulachon are no longer being calculated from the WCVI multispecies small mesh survey, this DFO fishery-independent survey is still being conducted each May as described above, and catch per unit effort (CPUE) data for eulachon from this survey were recently obtained[6].  Eulachon CPUE data are available for Shrimp Management Areas (SMAs) 125OFF (1987, 1988, 1990, 1992–2004, 2006–2015), 124OFF (1987, 1988, 1990–2004, 2006–2015), 123OFF (1994, 1996–2004, 2006–2015), 121OFF (1994, 1996–2004, 2006–2015), and 123IN (2012–2015) (see map inset in Fig. 1). These regions are also known as Nootka Grounds (Area 125), Tofino Grounds (Area 124), and Barkley Sound Grounds (Areas 121 – 123) (Perry et al. 2015).  All CPUE values were standardized to kilograms of eulachon captured per hour of tow effort (kg/h) (Figs. 3–7).  The patterns of fluctuation in mean CPUE over time are similar across all aggregated SMAs (Fig. 3) and in each of the four SMAs (125OFF, 124OFF, 123OFF, and 124OFF) where long-term data are available (Figs. 4–7).  In general, high mean CPUE ( > 100 kg eulachon per hour) occurred during 2001–2003 and again from 2013–2015 in all of the SMAs (Figs. 3–7).  The highest mean CPUE for eulachon in these surveys across all WCVI SMAs surveyed has occurred during the past three years with overall mean CPUE for 2013, 2014, and 2015 reaching 254, 199, and 235 kg of eulachon per hour of tow, respectively (Fig. 3).

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[6] Sean MacConnachie, Fisheries and Oceans Canada, Nanaimo, BC, Canada, e-mail to Rick Gustafson, NMFS. Pers. commun., 3 September  2015.

## West Coast Vancouver Island Pelagic Ecosystem Night Trawl Survey

Flostrand et al. (2015, p. 93) reported on recent results of a night-time pelagic trawl survey "used to monitor trends in distribution and relative abundance of pelagic fish species" that has been conducted from August 5 to 15 off the west coast of Vancouver Island since 2006 (no survey occurred in 2007). Results of the survey for eulachon are reported as mean (±SE) CPUE (kg/$m^3$ or mt /$km^3$), and as the proportion of positive tows containing eulachon. Flostrand et al. (2015) stated that "Eulachon mean CPUE and proportion of positive tows was slightly higher in 2014 than other years." Interpretation of graphical data in Flostrand et al. (2015; their fig. 20–4C) indicates that mean eulachon CPUE (mt /$km^3$) and percent positive tows increased from about 0.5 mt /$km^3$ and 20% in 2013 to about 2.0 mt /$km^3$ and over 40% in 2014, respectively. As Flostrand et al. (2015, p. 97) emphasize, "Eulachon … exhibit both demersal and pelagic behaviour and may not be well sampled by the surface trawl; therefore survey observations for [eulachon] … may be less indicative of actual population dynamics."

## West Coast Bottom Trawl Survey (WCBTS)

Starting in 2003, the Fishery Resource Analysis and Monitoring (FRAM) Division of the NWFSC began combined slope and shelf surveys for groundfish off the U.S. west coast between the U.S.-Canada border at Cape Flattery, Washington to the U.S.-Mexico border (Keller et al. 2012, Bradburn et al. 2011). Bottom trawls are fished during the daytime at a nominal tow duration of 15 min on the bottom at 4.0 km/h, mainly from late May to late July (early cruise) and again from late August to late October (late cruise). The NWFSC shelf/slope survey is based on a random-grid design; covering the coastal waters from a depth of 55 m to 1,280 m. This design uses four industry chartered vessels per year, assigned to a roughly equal number of randomly selected grid cells and is divided into two "passes" of the coast which "start operations from Newport, Oregon, heading north to Cape Flattery, Washington, and progress south along the coast, finishing south of San Diego, California" (Bradburn et al. 2011, p 3).

These groundfish surveys are designed to sample bottom dwelling species and to sample only over trawlable bottom topography; therefore, they only capture a small and erratic portion of the whole water column's distribution of eulachon. In addition, the questionable effectiveness of bottom trawls with large mesh nets in catching near-bottom or mid-water schooling eulachon, limits the usefulness of bottom trawl surveys to assess the eulachon population. It is thus uncertain how an index created from this survey relates to the actual abundance; however, the trends in this index may be informative. Applying the spatiotemporal tools (delta-GLM model with spatial random field) that are used to generate indices of groundfish abundance for stock assessment purposes, an estimated relative biomass index of eulachon derived from this fishery-independent trawl survey for years 2003–2013, shows an increasing temporal trend in eulachon (Fig. 8) from 2010–2013[7], consistent with other data sources summarized in this document. The biomass estimate was substantially higher in 2013 than in any recent period (Fig. 8)[8]. Survey data from 2014–2015 have been requested.

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[7] Eric Ward, Conservation Biology Division, NWFSC, NMFS. Pers. commun. 14 November 2014.

[8] Eric Ward, Conservation Biology Division, NWFSC, NMFS. Pers. commun. 14 November 2014.

## Columbia River Plume Studies

Since the 2010 eulachon status review, results of a study of pelagic forage fish presence in night-time surface trawls in the Columbia River plume has been published, which contains data on annual mean catch of eulachon (number per kilometer trawled) from 1999 to 2009 (Fig. 9) (Litz et al. 2013). Although of limited duration and now out-of-date, the data show a similar pattern to that observed in both the Fraser River eulachon SSB (see below) and the now-discontinued DFO offshore eulachon abundance indices (see above) of low abundance in the late 1990s, followed by a rapid increase in the early 2000s, and a subsequent return to low levels of relative abundance in the mid- to late-2000s (Fig. 9).

## Updated Abundance and Trend Data Specific to Individual Rivers

### Klamath River

The 2010 status review (Gustafson et al. 2010) cited numerous sources which reported that large spawning aggregations of eulachon regularly occurred in the Klamath River in the past and on occasion in the Mad River and Redwood Creek in northern California. The 2010 BRT concluded that the available information was most readily interpreted as indicating that noticeable, regularly returning runs of eulachon used to be present in the Klamath River, but had been rare or sporadic for a period of several decades. However, it was noted that they had not been totally absent from this area in recent years. In particular, reports from Yurok tribal fisheries biologists of a few eulachon being caught incidentally in other fisheries on the Klamath in 2007 indicated that eulachon still on occasion entered the Klamath River in low numbers.

Since the 2010 status review (Gustafson et al. 2010), there are reports of an estimated 7 (McCovey 2011), 40 (McCovey 2012), 112 (McCovey and Walker 2013), and ~1,000[9] adult eulachon being sampled by Yurok Indian tribal biologists in presence/absence surveys using seines and dip nets in the Klamath River in northern California in spring of 2011, 2012, 2013, and 2014, respectively. Figure 10 illustrates the date of capture and number of eulachon captured during Yurok Indian Tribe dip-net sampling surveys in the Klamath River in 2011–2013 (McCovey 2011, 2012; McCovey and Walker 2013).

### Big, Tenmile, and Cummins creeks, Oregon

The Oregon Department of Fish and Wildlife (ODFW) collected numerous plankton samples from Big Creek (n = 26), Cummins Creek (n = 61), and Tenmile Creek (n = 60) in late winter of 2014 and spring of 2015 with the intent to produce a eulachon SSB estimation for these coastal Oregon streams (Mallette 2015). Eulachon larvae were encountered in only two of the above samples, both collected in Big Creek on 10 March 2015. Eulachon densities in these samples ranged from 1.06 to 3.93 individuals/m$^3$ (Mallette 2015). An SSB estimate for these streams could not be produced for the 2015 season due to either lack of eulachon encounters (Cummins Creek), lack of discharge data (Tenmile Creek), or delays in receiving sampling permits that limited data collection to only part of the season (Big Creek) (Mallette 2015).

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[9] Barry McCovey, Yurok Indian Tribe, e-mail to Robert Anderson, NWR, NMFS. Pers. commun., 17 March 2014.

## Columbia River

**Spawning stock biomass**—At the time of the 2010 status review (Gustafson et al. 2010), fisheries-independent estimates of spawning stock abundance of Columbia River eulachon were unavailable. However, since the 2011 run year, Washington Department of Fish and Wildlife (WDFW) and ODFW have developed methodologies to provide a yearly retrospective fisheries-independent SSB estimate for the Columbia River eulachon sub-population, using similar methods to those applied by DFO since 1995 on the Fraser River to calculate SSB (Hay et al. 2002, James et al. 2014). Eulachon spawn from November to April in the Columbia River and in this document the spawn year is designated as the year beginning on January 1. Mean eulachon egg and larval densities (number per $m^3$) in the Columbia River Basin above Grays River are estimated from multiple stationary plankton tows at six stations along a standardized cross river transect at river kilometer 55 (James et al. 2014). The volume of water in cubic meters filtered through the plankton net is measured with a flowmeter mounted in the mouth of the net. Eulachon egg and larval density are sampled weekly during the tail ends of the out-migration and twice weekly during peak out-migration (James et al. 2014). Plankton net samples are returned to the laboratory and examined using a dissecting microscope for species identification and counting of fish eggs and larvae. Daily estimates of the discharge rate (cubic meters per day) of the Columbia River are obtained from the USGS stream-gage station located at river kilometer 86.6 (James et al. 2014). The discharge rate and mean egg and larval densities are then used to derive mean daily estimates of larval eulachon plankton outflow from the Columbia River. These plankton outflow data are then combined with a mean relative fecundity of 802.3 eggs per gram of female body weight, an assumed egg to larval survival of 100%, an assumed sex ratio of 1:1, and a mean fish weight of 40.6 g to derive SSB and spawner number estimates (James et al. 2014).

Estimates of eulachon SSB and number of spawning fish in the Columbia River Basin above Grays River from 2011 to 2015 are presented in Table 1 and Fig. 11. Mean SSB increased from about 1,500 mt in 2011 (95% CI, 900–2,200 mt) and 2012 (95% CI, 1,000–2,100 mt) to 4,400 mt in 2013 (95% CI, 2,600–6,500 mt) and 7,300 mt in 2014 (95% CI, 4,500–10,400 mt) (James et al. 2014, Langness et al. 2015). The 2015 Columbia River eulachon SSB was estimated at 5,000 mt (95% CI, 3,200–7,000 mt) **(**Langness 2015). Using average eulachon body weight data of 40.6 g and the 11.2 fish per pound estimate used in the WDFW SSB calculations, James et al. (2014) and Langness (2015) converted the above SSB estimates into mean numbers of adult spawners (Table 1). These numbers range from a low of 35.7 million (95% CI, 23.9–50.5 million) in 2012 to a high of 180 million (95% CI, 110–260 million) in 2014. Preliminary calculations indicate an estimated 123.6 million (95% CI, 79.4–172.7 million) adult eulachon spawned in the Columbia River Basin above Grays River in 2015 **(**Langness 2015) (Table 1, Fig. 11).

**Uncertainty of egg and larval identifications used in SSB estimates**—Recent attempts by the WDFW genetics laboratory to characterize population structure of eulachon in the Columbia River Basin, using putative eulachon larvae, revealed that most of the larvae (94 of 95 individuals) in a sample of the "pilot run" (aka, early winter run) from the Cowlitz River were not eulachon (Small et al. 2015). It is believed that these problematic larval samples are most likely longfin smelt, another anadromous osmerid species closely related to eulachon. To date, clear morphological differences between known eulachon larvae and putative longfin smelt larvae have not been identified. It is unknown how significant a problem misidentification of egg and larval samples may pose to the accuracy of eulachon SSB estimates in the Columbia River Basin[10], and elsewhere.

**Long-term larval density estimates**—A eulachon larval sampling program that measures larval densities (averaged across stations and depths at selected index sites) was initiated in 1994 for the Cowlitz River and was expanded to include the Kalama River in 1995, the mainstem Columbia River in 1996, Elochoman and Lewis rivers in 1997, and the Grays and Sandy rivers in 1998 (Figs. 12–13). JCRMS (2013, p. 43) stated that "Inter-annual comparisons of abundance [i.e., larval density] are tentative as sampling has not been systematic from year to year." JCRMS (2014, p. 17) stated that "Beginning in 2003, multiple collections were conducted at the mainstem Columbia River (Price Island and Clifton Channel) site throughout the outmigration season, which provide the data necessary to identify the peak timing and duration of the outmigration from the bulk of the production area."

Average and adjusted (February–April) eulachon larval densities in the mainstem Columbia River increased in 2013 and 2014 and subsequently declined slightly in 2015, reaching and remaining at levels not seen since 2001 and 2002 (Fig. 13). In 2015, average larval densities (larvae per cubic meter) in the mainstem Columbia River and in the Grays River were 21.1 and 9.6 larvae per cubic meter, respectively (JCRMS 2015, its table 18) (Fig. 12). WDFW last sampled larval densities in the Cowlitz, Elochoman, Kalama, or Lewis rivers in 2012 (JCRMS 2014, 2015). Although some larvae were encountered in the Sandy River in 2012, the larval density was not calculated, and additional larval sampling has not occurred since 2012 (JCRMS 2015). According to JCRMS (2013):

> Larval density values at the mainstem Columbia River index sites in 2011 were the highest since 2003, and the 2012 larval density values were nearly equal to those in 2011 [Fig. 9]. High larval production has not always corresponded to large adult returns, and poor ocean conditions during any part of the marine life-stage may negate favorable spawning and outmigration conditions (implied by high larval densities). For example, 2004-2008 adult returns were poor, despite good larval production during 2000-2003.

**Retrospective Columbia River SSB and run size**—Recently, data from the above eulachon larval density surveys and Columbia River water discharge rates have been used to generate historical SSB estimates for 2000–2010 (Table 2, Fig. 11)[11]. A survey was conducted in 2004; however, detailed daily larval density data for that year are unavailable. Pre-2011 expansions of historical larval densities have been adjusted for the shorter duration of the pre-2011 surveys[12]. These data when combined with historical commercial, recreational, and tribal

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[10] Olaf Langness, Washington Department of Fish and Wildlife. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., 21 August 2015.

[11] Brad James and Olaf Langness, Washington Department of Fish and Wildlife. Pers. commun., 20 November 2014.

[12] Brad James and Olaf Langness, Washington Department of Fish and Wildlife. Pers. commun., 20 November 2014.

fishery landings provide estimates of total run size and fishery exploitation rate of Columbia River eulachon from 2000–2015 (Table 2, Fig. 11). These estimates are based on the assumption that historical 2000–2010 recreational fishery landings were equal to tributary commercial dipnet landings[13]. The 2014–2015 recreational fishery landings are based on field surveys by WDFW.

Total run size of Columbia River eulachon averaged over 2,700 mt (~67 million fish) from 2001–2003, which coincides with the previous period of high eulachon abundance in the West Coast Vancouver Island offshore eulachon biomass index (Gustafson et al. 2010, their fig. 16). However, from 2005 to 2010, total run size of eulachon averaged about 133 mt (~3 million fish) and fewer than one million eulachon were estimated to have returned to the Columbia River in 2005 (Table 2, Fig. 11). For comparison, current SSB methodologies have estimated average run size of Columbia River eulachon from 2011–2015 at over 4,000 mt (~99 million fish) (Table 2, Fig. 11).

**Columbia River CPUE**— Historical trends in CPUE (pounds per delivery) in the Columbia River commercial eulachon fishery (Fig. 13) show similar patterns to both the WCVI offshore juvenile eulachon index (Fig. 1) and average eulachon larval density in the Columbia River (Figs. 12–13). Eulachon CPUE increased dramatically in 2001, stayed high in 2002–2004, and then dropped to under 200 pounds per delivery until the fishery was closed in 2011. No commercial fisheries occurred from 2011–2013; however, average CPUE in this fishery was approximately 460 pounds per delivery in 2014, the highest level since 2004 (Fig. 13). However, JCRMS (2014, p. 17) stated that "The modest commercial landings and CPUE … were not consistent with the [high level of] angler success in the sport fishery or with the [high] spawner biomass estimation for 2014." The commercial fishery CPUE for 2015 was approximately 435 pounds per delivery, only slightly lower than in 2014 (JCRMS 2015, their table 17) (Fig. 13).

### Grays River

As indicated in the 2010 status review (Gustafson et al. 2010, their table 7), commercial fishery landings have been recorded since 1936 in the Grays River, and WDFW and ODFW (2008, p. 4) indicated that eulachon "used [Grays River] more frequently than commercial landings would suggest." Because Grays River enters the Columbia below the mainstem Columbia River SSB index site (Price Island and Clifton Channel), WDFW produced a separate SSB estimate in 2011–2013 and 2015 for the Grays River (Table 3) (James et al. 2014, Langness et al. 2015, Langness 2015, James 2015). Average Grays River SSB from 2011–2013 was about 0.6 mt, which represents about 14,500 spawning adults averaged over those three years (Table 3). No SSB estimation was available for the 2014 season in the Grays River due to a funding lapse (Langness et al. 2015). Langness et al. (2015) stated that "Grays River SSB estimates were only about 0.02% of the corresponding mainstem Columbia River (above Clifton Channel/ Price Island) SSB estimates." Mean eulachon egg and larval production between 11 January and 9 May 2015 was estimated at. ~3.0 billion. Mean SSB was 7.5 mt (Langness 2015, James 2015),

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[13] Brad James and Olaf Langness, Washington Department of Fish and Wildlife. Pers. commun., 20 November 2014.

which equates to an estimated 185,400 adult eulachon spawning in the Grays River in 2015 (Table 3).

## Cowlitz River

According to Langness et al. (2015):

> During the current run year (2014-2015), the Cowlitz Tribe is carrying out systematic plankton tows in the Cowlitz River with the intent to develop an SSB estimate for that tributary of the Columbia River. The Cowlitz River SSB estimation can be compared to the mainstem Columbia River eulachon SSB estimation (being done by WDFW), to see how much of the Columbia River eulachon production during 2014-2015 is attributable to the Cowlitz River. The Cowlitz River SSB estimation will be based on the larvae and eggs passing through a cross river transect below the confluence of the Coweeman River (Cowlitz River Kilometer 2).

Preliminary estimates of the mean cumulative plankton flux of eulachon eggs and larvae in the Cowlitz River in 2015 was on the order of about 690 billion[14], which is about 34% of the calculated total eulachon plankton flux for the Columbia River Basin, above the Grays River, of about 2 trillion, as calculated by Langness (2015). Using a sex ratio of 4.33 males to females and an estimated fecundity of 35,155 eggs per female (derived from sampling in the Cowlitz River) an SSB of approximately 4,400 mt for the Cowlitz River in 2015 was calculated.[15] This equates to approximately 108 million spawning eulachon in the Cowlitz River in 2015[16] (Table 4).

The 2010 BRT (Gustafson et al. 2010, p. 41) pointed out that "Many studies have reported that sex ratios in eulachon are either biased in favor of males or are highly variable depending on time and location of sampling," and that "All reports of eulachon sex ratio should be viewed with caution, as proportions of male to female eulachon have been reported to vary with fishing gear type, distance upriver, distance from the river shoreline, time of the day, and migration time." Studies in the Fraser River (Hay and McCarter 2000) and Columbia River[17] estuaries have reported sex ratios of 1: 1 for eulachon. Use of a 1:1 sex ratio—as adopted by WDFW for mainstem SSB calculations—would significantly reduce the above estimates of SSB and number of spawning eulachon for 2015 in the Cowlitz River.

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[14] Nathan Reynolds, Cowlitz Indian Tribe. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR, 21 August 2015.

[15] Nathan Reynolds, Cowlitz Indian Tribe. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR, 21 August 2015.

[16] Nathan Reynolds, Cowlitz Indian Tribe. Powerpoint presentation at Eulachon State ,of the Science and Science to Policy Forum, Portland, OR, 21 August 2015.

[17] Jen Zamon, NWFSC, NMFS. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR, 21 August 2015.

### Naselle River

In 2015, WDFW began plankton tows in the Naselle River, a tributary of Willapa Bay, in order to produce a eulachon SSB estimate (Langness 2015). Using the same methods described above for estimating the Columbia River SSB, WDFW estimated that mean eulachon egg and larval production was over 592 million in 2015. Mean egg and larval density was ~12 per cubic meter over the 17 days of sampling, and mean estimated SSB amounted to 1.5 mt for the period between 11 January and 23 May 2015 (Table 5) (Langness 2015). An estimated 36,400 eulachon spawned in the Naselle River in 2015 (Table 5) (Langness 2015).

### Chehalis River

The Quinault Indian Tribe (QIN 2014) sampled for eulachon larvae during 2013 and 2014 in the Chehalis River, a tributary of Grays Harbor, Washington. In 2013 and 2014, 29 and 66 larval eulachon were captured, respectively. Putative eulachon larvae were captured in 5% of samples (19/360) in 2013 and in 9% of samples (34/377) in 2014 (QIN 2014). After normalization of data, (QIN 2014, p. 24) stated that:

> … eulachon were present in similar numbers in 2013 and 2014. The mean density of all daytime samples in 2013 was 0.021 larvae/$m^3$ and in 2014 it was 0.023 larvae/$m^3$.

WDFW produced a mean eulachon SSB estimate for the Chehalis River in 2015 of 11 mt, which at 11.2 fish per pound equates to a mean estimate of about 272,000 adult spawners (Table 6) (Langness 2015). This estimate was developed using methods similar to those outlined above for the Columbia River (Langness 2015). The mean eulachon egg and larval outflow from the Chehalis River was estimated at 4.4 billion (Table 6) (Langness 2015).

### Elwha River

In the 2010 status review, it was noted that Shaffer et al. (2007) reported upon the first formal documentation of eulachon in the Elwha River (58 fish captured between 18 March and 28 June 2005), although anecdotal observations suggested that eulachon “were a regular, predictable feature in the Elwha until the mid-1970s” (Shaffer et al. 2007, p. 80). Small numbers of adult eulachon (usually less than a couple dozen) continued to be captured in the spring during smolt outmigration studies in the mid- to late-2000s [18]. Over a hundred eulachon were captured during 2012 during two distinct runs, one in January and the other in April (Fig. 14). Many more eulachon than normal were observed in January 2015 [19]. During January 2015, hundreds of

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[18] Mike McHenry, Lower Elwha Klallam Tribe, e-mail to Rick Gustafson, NWFSC, NMFS. Pers. commun., 23 January 2015.

[19] Mike McHenry, Lower Elwha Klallam Tribe, e-mail to Rick Gustafson, NWFSC, NMFS. Pers. commun., 23 January 2015.

eulachon were documented in the lower Elwha River during long term sampling efforts of the lower estuary [20].

## Fraser River

The Fraser River spawning stock biomass data set is the longest running (since 1995) fisheries-independent abundance estimator of spawning biomass for any subpopulation in the DPS (Table 7, Figs. 15). The SSB is generated from counts of eggs and larvae in plankton tows, combined with river discharge rates, and relative fecundity (eggs produced per gram of eulachon) to estimate metric tons of spawning adults (Hay et al. 2002). The 2013/2014 Eulachon Integrated Fisheries Management Plan (DFO 2013a, p. 6) provided the following description of the Fraser River SSB estimator:

> To estimate SSB, an intensive sampling process takes place in the Fraser River during the seven to eight weeks following spawning (April/May). This survey uses towed, small mesh nets to gather samples of eulachon eggs and larvae. The number of eggs and larvae gathered in each tow are hand-counted at the Pacific Biological Station. The egg and larval count is then combined with data on the daily Fraser River discharge and historical data on eulachon fecundity (eggs produced/female) to generate an estimate of SSB. This estimate is generally produced in the summer following spawning. … The SSB provides an estimate of how many tonnes of eulachon successfully spawned the previous year.

Although spawner biomass for the 2014 eulachon run in the Fraser River was estimated at 66 mt, 34 mt lower than in 2013, the 2015 SSB estimate was 317 mt, 251 mt higher than in 2014[21] (Table 7, Fig. 15). These data suggest that the eulachon SSB from 2011–2015 in the Fraser River ranged from only 1% in 2014 to about 8% in 2012 of the estimated Columbia River SSB (Tables 1 and 7, Fig. 16). During the period from1936–1995, yearly eulachon landings in the Fraser River averaged about 11% of landings in the same year in the Columbia River (range of 1%–58%).

Adult eulachon in the Fraser River are thought to consist of mainly age-3 fish (Clarke et al. 2007, COSEWIC 2011, McAllister 2012). Assuming only a single age class of 3-year old spawners exists in the Fraser River, and strays from other populations are minor, it is then possible to calculate a spawner to spawner ratio based on the estimated number of spawners in one year compared to the number of spawners returning to the Fraser River three years later (Fig. 17). In the Fraser River, this generic productivity metric can be computed as the mean spawner estimate at year $t$ divided by the mean total spawner estimate at year $t - 3$. Although the SSB and the estimated numbers of eulachon in the Fraser River were at very low levels from 2008–2010, eulachon three years later in 2011, 2012, and 2013 were, respectively, approximately 3 times, 8.5 times, and 25 times as abundant as the parent broodyears (Fig. 17). In 2014 and 2015,

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[20] Anne Shaffer, Coastal Watershed Institute, Port Angeles, WA, e-mail to George Pess, NWFSC, NMFS. Pers. commun., 16 January 2015.

[21] Data available online at: http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/river1-eng.html

Fraser River eulachon were estimated to be about two times and two and a half times as abundant as the parent broodyears, respectively (Fig. 17). Thus, in spite of historically low SSB in the Fraser River, this subpopulation has exhibited high productivity in the recent past, again assuming minimal straying and all age-3 fish, likely in response to favorable rearing conditions both in the Strait of Georgia and over the nearshore continental shelf. At present, it is not possible to postulate similar spawner to spawner ratios based on the Columbia River SSB because this sub-population apparently consists of multiple year classes and no current validated age structure analyses have been applied to these recent broodyears in the Columbia River.

McAllister (2012) developed a Bayesian stock reduction model for the Fraser River eulachon sub-population, which was summarized in Schweigert et al. (2012, p. vi), as follows:

> The analysis suggested that the decline in population abundance could be explained most parsimoniously by the sequential historical impacts of directed in-river catch (prior to 1970), bycatch in the shrimp trawl fishery (1990 to 2000), and several consecutive years of anomalously low productivity (2002-2007 brood years). The model indicates that, under conditions of average historical productivity and current levels of bycatch mortality from shrimp trawling effort but no directed exploitation, the Fraser River population should rebuild to 33-49 percent (range for the three cohorts) of the unfished abundance over a period of 16-18 years. A directed catch of 30 tonnes would reduce rebuilding to 1-30 percent of the unfished population. The analysis suggests that the species is relatively unproductive and can sustain a maximum sustainable fishing mortality rate of only 0.10.

McAllister (2012, p. 75) determined that:

> The substantial drop in abundance in 2005 [of Fraser River eulachon]… occurred well after shrimping and commercial fishing had dropped to very low levels and suggest that some other sources of mortality are responsible for the severe decline in Fraser River eulachon in 2005 and continued low abundance. Stock recruit deviates for 1992-2011 were found to be uncorrelated with several different covariates including Pacific hake abundance in B.C. waters, zooplankton prey species *E. pacifica* and *T. spinifera*, and the Pacific Decadal Oscillation Index (PDO) (for lags of 0-3 yr all P-values > 0.1).

### Kingcome River

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kingcome River at the head of Kingcome Inlet on the British Columbia central coast. Peak spawn timing in the area occurs about the middle of April (Moody 2008). Since Moody's (2008) compilation of information on eulachon abundance, very little additional data on the status of eulachon in the Kingcome River has become available. Anecdotal information (Table 8) indicated that "tonnes of eulachon … [were] netted" in late April 2012 (Tsit'sak'ala_m 2012).

### Kemano River

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kemano River in Gardner Canal, and spawn in late March and early April (Moody 2008). Although First Nations catch and CPUE data for the Kemano River were presented in Moody (2008, figure 2.16) and this presentation was reviewed by the 2010 BRT (Gustafson et al. 2010, p. 129–130), the 2010 BRT did not have access to the actual Kemano River data presented by Moody (2008). Subsequently, these data were presented in a tabular form by COSEWIC (2011, their table 7 and figure 14) and are presented in this document in Table 9 and Fig. 18. The CPUE data indicate a substantial decline in abundance occurred over the period 1988–2007 (Fig. 18). Since Moody's (2008) compilation of information on eulachon abundance, very little additional data on the status of eulachon in the Kemano River has become available. Anecdotal information (Table 8) indicated that very few eulachon returned to the Kemano River from 2008–2012, but a "small run" was noted in 2014 (Dootilh 2014) and in 2015 there was a "conservative estimate of approximately 120 tons" of eulachon in the Kemano River "with about 40 ton[s] taken for food" (Dootilh 2015).

### Kitimat River

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kitimat River in Douglas Channel, where spawning peaks in mid to late March (Moody 2008). Although some First Nations catch and CPUE data for the Kitimat River were presented in Moody (2008, figure 2.14) and this presentation was reviewed by the 2010 BRT (Gustafson et al. 2010, p. 130–131), the 2010 BRT did not have access to the actual Kitimat River data presented by Moody (2008). Subsequently, these data, as well as additional catch data, were presented in a tabular form in COSEWIC (2011, their table 6 and figure 13) and are presented in this document in Table 10 and Fig. 19. The CPUE data indicate a steep decline in abundance occurred in the late 1990s, followed by continued low abundance through 2007 (Fig. 19). Since Moody's (2008) compilation of information on eulachon abundance, very little additional data on the status of eulachon in the Kitimat River has become available. Anecdotal information (Table 8) indicated small amounts of eulachon returned to the Kitimat River in 2012, 2014, and 2015.

### Skeena River

Hay and McCarter (2000) and Moody (2008) reported that an annual run of eulachon return on a regular basis to the Skeena River and its tributaries, which historically returned to the Skeena River around the first week of March, but in the recent past have occasionally returned as early as mid-February (Moody 2008). Since Moody's (2008) compilation of information on eulachon abundance very little additional data on the status of eulachon in the Skeena River has become available. Anecdotal information (Table 8) indicated that the Skeena River had a "very good run" of eulachon in 2010 and "good run" in 2011 and 2012 (COSEWIC 2013, p. 11). News reports have indicated that substantial numbers of eulachon returned to the Skeena River in 2014[22] and 2015[23] and according to North Coast Skeena First Nations Stewardship Society

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[22] Skeena Oolichan Run Strong, by Laryn Gilmour, 14 March 2014. Online news report: http://www.cftktv.com/News/Story.aspx?ID=2140210.

(NCSFNSS 2015), "the Skeena eulachon population appears stable." The Committee on the Status of Endangered Wildlife in Canada reassessed the status of the Nass/Skeena Rivers DU in 2013 and re-classified this unit's status from "Threatened" to "Special Concern" (COSEWIC 2013).

## Spatial Structure

### Marine distribution and mixed stock analysis

Beacham et al. (2005) used variation at 14 microsatellite DNA loci to examine the stock composition of trawl and research surveys in marine areas off British Columbia. Using a genetic baseline data set of eulachon populations in eight rivers in Washington and British Columbia, they estimated the proportional composition of three marine-caught samples. A sample of 184 eulachon was collected during a shrimp research survey near Nootka Sound off the west coast of Vancouver Island in May of 2000. The largest proportions of fish were estimated to be from the Columbia River (56.6%, SD = 10.4) and Fraser River (37.5%, SD = 10.1). Populations in other rivers were estimated to contribute less than 6% to the sample. A sample of 100 eulachon sampled as bycatch in a shrimp trawl fishery near Chatham Sound (off British Columbia's north coast) in March 2001 was estimated to be largely fish from the British Columbia central mainland (51.6%, SD = 13.8) and from the Nass River (37.4%, SD = 10.9). Columbia (1.7%, SD = 2.4) and Fraser (2.1%, SD = 3.6) rivers contributed a small fraction to the sample. A third sample of 200 fish taken in research shrimp surveys in Queen Charlotte Sound in March 2001 was comprised of substantial proportions of Columbia, Fraser, British Columbia central mainland, and Skeena rivers, all contributing between 22.1% (SD = 5.9) and 27.1% (SD = 6.9). Beacham et al. (2005) concluded that although eulachon migrations are largely unknown, there is spatial structure to the marine distributions of fish from different rivers.

Since the publication of Beacham et al. (2005), additional offshore eulachon samples collected during DFO multispecies small mesh bottom trawl surveys (aka, fishery-independent shrimp surveys) have been genetically assigned back to their rivers or populations of origin (Table 11). These percent assignments have been used by DFO scientists to apportion at-sea risks in different regions of the marine environment on a DU by DU basis (Schweigert et al. 2012).

### Columbia River tributaries

The Cowlitz Indian Tribe (2014) examined spawning distribution, run-timing and presence/absence of eulachon in numerous tributaries to the lower Columbia River during 2011–2013. Eulachon eggs and or larvae were reportedly found up to 16.1 km (10 miles) upstream on both the Grays and Elochoman rivers in 2011–2013; up to 8 km (5 miles) upstream on Skamokawa Creek in 2011–2013; up to 1.6 km (1 mile) upstream in Mill Creek in 2011–2012, but not in 2013; up to 3.2 km (2 miles) upstream in Abernathy Creek in 2011–2012; up to 1.6 km (1 mile) upstream in Germany Creek in 2011–2012; up to 12.9 km (8 miles) in the Kalama River

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[23] Eulachon fish run draws crowds along B.C.'s Skeena River, by The Early Edition, CBC News, 16 March 2015. Online news report: http://www.cbc.ca/news/canada/british-columbia/eulachon-fish-run-draws-crowds-along-b-c-s-skeena-river-1.2996991.

in 2011–2013; up to river kilometer 11.3 (7 miles) in the North Fork Lewis River in 2011–2012; at river kilometer 9.7 (6 miles) in the East Fork Lewis River in 2011; up to river kilometer 9.7 (6 miles) in the Washougal River in 2011–2012; and up to river kilometer 8 (5 miles) in the Sandy River in 2012–2013.

In 2011, WDFW sampled Skamokawa Creek; and Elochoman, Cowlitz, Kalama, and Lewis rivers for presence/absence and detected eulachon eggs or larvae in all locations sampled (Storch et al. 2014, their table 2). Eulachon eggs or larvae were also detected in all samples collected in the mainstem Columbia River and Grays River during 2011–2013 (Storch et al. 2014, their tables 1–2). As mentioned above, clear morphological differences between known eulachon larvae and putative longfin smelt larvae have not been identified. It is unknown how significant a problem misidentification of egg and larval samples may pose to the accuracy of eulachon presence/absence studies.

### Cowlitz River and tributaries

The Cowlitz Indian Tribe (2014) examined presence/absence of eulachon eggs and larvae during 2011–2013 in the Cowlitz River and two of its tributaries, the Coweeman and Toutle rivers. Putative eulachon larvae were reported as far upstream in the Cowlitz River as river kilometer 66.0–72.4 (mile 41–45) in 2011, river kilometer 74.0–80.5 (mile 46–50) in 2012, and no higher than river kilometer 1.6– 8.0 (mile 1–5) in 2013 (Cowlitz Indian Tribe 2014). Putative eulachon larvae were encountered at river kilometer 1.6 (mile 1) and river kilometer 3.2 (mile 2) in the Coweeman River in 2011 and 2012, respectively. Cowlitz Indian Tribe (2014) reportedly found eulachon larvae in the Toutle River up to river kilometer 9.7 (mile 6) and river kilometer 4.8 (mile 3) in 2011 and 2013, respectively. However, presence/absence plankton surveys did detect eulachon eggs or larvae in the Toutle River in 2012 (Cowlitz Indian Tribe 2014). As mentioned above, clear morphological differences between known eulachon larvae and putative longfin smelt larvae have not been identified. It is unknown how significant a problem misidentification of egg and larval samples may pose to the accuracy of eulachon presence/absence studies.

### Washington coastal streams

Storch et al. (2014, their table 3) summarized WDFW sampling efforts for presence/absence of eulachon eggs and larvae in 15 Washington state locations during either 2011 or 2012: Big Quilcene, Little Quilcene and Tahuya rivers in Hood Canal; Clallam and Elwha rivers along the Strait of Juan de Fuca; Moclips, Clearwater, Hoh, and Quillayute rivers, and Goodman Creek on the north outer coast of Washington; Humptulips and Chehalis rivers draining into Grays Harbor; North Fork of the Willapa, Naselle, and Bear rivers draining into Willapa Bay. Eulachon eggs and larvae were detected in the Naselle, Bear, Willapa, and Chehalis rivers (Storch et al. 2014, p. 72), but not in the other systems listed, perhaps because surveys "typically consisted of only a single plankton tow." Efforts by WDFW to estimate spawning stock biomass of eulachon in the Naselle and Chehalis rivers are summarized in the "Updated Abundance and Trends" section of this document.

The Quinault Indian Tribe (QIN 2014) reportedly demonstrated the presence of eulachon larvae in the Chehalis River in both 2013 (n =29) and 2014 (n =66), during January-

April. One eulachon larvae was obtained in the tributary Wishkah River in 2013, and 17 were obtained in the Hoquiam River in 2014 (QIN 2014). No eulachon larvae were detected during 2013 in the Hoquiam or Wynoochee rivers, or during 2014 in the Wishkah River (QIN 2014). Langness et al. (2015) stated that eulachon eggs were detected in the Wynoochee River on 17 February 2015, but there had been "no eulachon plankton presence so far in the Satsop River." Eulachon larvae were reportedly seen in the Humptulips River in 2015 (Langness et al. 2015). As mentioned above, clear morphological differences between known eulachon larvae and putative longfin smelt larvae have not been identified. It is unknown how significant a problem misidentification of egg and larval samples may pose to the accuracy of eulachon presence/absence studies.

### Oregon coastal streams

In 2011, ODFW opportunistically sampled for eulachon eggs and larvae in the Umpqua and Coos rivers; however, none of the specimens collected were identified as eulachon (Storch et al. 2014). ODFW reportedly sampled eulachon larvae in Big Creek on the Oregon coast on 10 March 2015 (Mallette 2015). As mentioned above, clear morphological differences between known eulachon larvae and putative longfin smelt larvae have not been identified. It is unknown how significant a problem misidentification of egg and larval samples may pose to the accuracy of eulachon presence/absence studies.

### Northern California coastal streams

In 2015, two adult eulachon were captured in Prairie Creek, a tributary of Redwood Creek, California during operations of a rotary screw trap from 26 February – 25 July (Sparkman et al. 2016). One of these two eulachon was captured on 30 April 2015 [24]. One additional eulachon was captured at river mile 4 on Redwood Creek, about 0.5 mile above its confluence with Prairie Creek[25].

## Miscellaneous Anecdotal Information

Since the 2010 status review, there have been numerous anecdotal observations of small numbers of eulachon reported from various locations that are either not normally thought to be spawning sites or have not supported eulachon for many years. There were reports of a single eulachon being captured in a screw trap on the Nisqually River, Washington on 4 February

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[24] Michael Sparkman, California Department of Fish and Wildlife, email to Leslie Wolff, NMFS. Pers. commun., 1 May 2015.

[25] Michelle M. Gilroy, California Department of Fish and Wildlife, Eureka, CA, email to Robert Anderson, WCR, NMFS. Pers. commun., 27 January 2016.

2013[26]. An unknown number of eulachon were caught in a smolt trap on the Salmon River, Oregon in April of 2015 [27].

## Biological Status Relative to Draft Recovery Goals

NMFS has filed a notice of intent to prepare a recovery plan for the southern DPS of eulachon (NMFS 2013) and has released a Recovery Plan Outline[28]. NMFS has also formed a Eulachon Recovery Team, led by Robert Anderson (Eulachon Recovery Coordinator, NMFS Northwest Regional Office), that consists of five additional members from both the Northwest and Southwest Fisheries Science Centers and Washington Department of Fish and Wildlife. The recovery plan for the Southern DPS of Eulachon is not yet complete, but is expected to be available before the next status review.

# 2010 BRT's Qualitative Threats Assessment

The 2010 BRT examined the potential roles that 16 identified threats (see list in Gustafson et al. 2010) may have played in the decline of the southern DPS of eulachon and scored the severity of these threats from 1 to 5 in four sub-areas of the DPS; the Klamath, Columbia, and Fraser rivers and in that portion of the DPS along the mainland coast of British Columbia. The severity of each threat was qualitatively scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. The results of the 2010 BRT's analysis of the severity of threats to eulachon were presented in the 2010 status review report (Gustafson et al. 2010) by rank order from most severe to least severe for each geographical subset as determined by the mean 2010 BRT threat scores. Also presented were the standard deviation about the mean threat scores, the modal score, the range of scores, and the number of 2010 BRT members scoring the threat (Gustafson et al. 2010, their table 15–18). In the present report, the modal scores of the 2010 BRT's analysis of the severity of threats to eulachon were used to present the results of the 2010 BRT's qualitative threats analysis (Table 12).

The 2010 BRT categorized climate change impacts on ocean conditions as the most serious threat to persistence of eulachon in all four subareas of the DPS: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp fisheries

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[26] Peter Topping, Washington Department of Fish and Wildlife, email to Rick Gustafson, NWFSC, NMFS. Pers. commun., 4 February 2013.

[27] Jason Kirchner, Oregon Department of Fish and Wildlife, email to Jeff Young, NMFS. Pers. commun., 5 May 2015.

[28] Aavailable online at: http://www.nwr.noaa.gov/publications/protected_species/other/eulachon/eulachon_recovery_outline_070113.pdf

were also ranked in the top four threats in all subareas of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers filled out the last of the top four threats. In most categories, some portion of the 2010 BRT felt that insufficient data were available to score the threat severity (thereby marking the threat severity as unknown).

# Update of Selected Threats Information

Limited new information has become available for two threats that were classified as of moderate to high severity in the eulachon 2010 status review (Gustafson et al. 2010), 1) eulachon bycatch in ocean fisheries and 2) climate change impacts on ocean conditions. New information related to these two threats is reviewed in the following section. New information on commercial and recreational fisheries, although viewed as low to very low threats by the 2010 BRT, are also presented in the following section.

In British Columbia, the recovery potential assessment (RPA) of eulachon (Schweigert et al. 2014, p. vii) stated that:

> No single threat could be identified as most probable for the observed decline in abundances among [eulachon] DUs or in limiting recovery. However, mortality associated with coastwide changes in climate, fishing (direct and bycatch) and marine predation were considered to be greater threats at the DU level, than changes in habitat or predation within spawning rivers.

In addition, Schweigert et al. (2014, p. 1) stated that "Some existing threats (e.g., food, social and ceremonial fisheries, marine mammal predation, and degradation of freshwater habitat) are unlikely to have been responsible for the recent widespread declines in abundance, but may now be preventing recovery from low abundance in some DUs."

## Eulachon Bycatch

### Eulachon Bycatch in West Coast Groundfish Fisheries 2002–2014

A number of previous reports (NWFSC 2009, 2010; Bellman et al. 2008, 2009, 2010, 2011; Al-Humaidhi et al. 2012; Gustafson et al. 2015a) have provided data on estimated bycatch of eulachon in U.S. west coast commercial fisheries. Data for these reports were derived from the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP), both of which are administered by the Fisheries Observation Science Program in the NWFSC's Fishery Resource Analysis and Monitoring (FRAM) Division.

Gustafson et al. (2015a) estimated eulachon bycatch for each individual groundfish fishery sector that encountered eulachon during 2002–2013. Eulachon were taken as bycatch in the following groundfish fishery sectors: (1) limited entry (LE) bottom trawl (2002–2010), (2) individual fishing quota (IFQ) bottom trawl (2011–2013), (3) IFQ non-hake midwater trawl (2011–2013), (4) IFQ shoreside hake fishery (2011–2013), (5) at-sea Pacific hake mothership fishery (2002–2013), (6) at-sea Pacific hake catcher-processor fishery (2002–2013), and (7) at-sea Pacific hake tribal mothership fishery (2002–2011, no effort in this sector occurred in 2013, and data for 2012 is confidential as fewer than 3 vessels participated). Table 13 presents a summary of the permits, gear used, target groups, vessel length range, fishing depth range, and management of fishery sectors and sub-sectors in U.S. west coast fisheries that have had documented eulachon bycatch. Data sources and bycatch estimation methods for eulachon bycatch in west coast groundfish fisheries in 2002–2013 are detailed in Gustafson et al. (2015a).

Eulachon were not reported as bycatch in the LE bottom trawl fishery in Washington from 2002–2010 (Gustafson et al. 2015a); however, during 2011, 2012, and 2013 an estimated 12, 1, and 137 individual eulachon, respectively, were estimated as fleet-wide bycatch in the Washington IFQ bottom trawl fishery (Gustafson et al. 2015a). Within the Oregon portion of the LE bottom trawl fishery, eulachon bycatch occurred in four of the nine years from 2002–2010 with 80% (783/974) of this estimated bycatch occurring in the year 2002 (Gustafson et al. 2015a). However, no eulachon bycatch was recorded in the Oregon LE bottom trawl fishery in 2004, 2005, 2006, 2008, or 2010 (Gustafson et al. 2015a). Between 2011 and 2013, the Oregon IFQ bottom trawl fishery had an estimated eulachon bycatch of 816 individual fish with nearly 64% of this total occurring in the year 2013 (Gustafson et al. 2015a). Eulachon are rarely caught in the California LE bottom trawl fishery; 5 fish in 2004 and 22 fish in 2010 (Gustafson et al. 2015a). Not a single eulachon was recorded as bycatch in the California IFQ bottom trawl fishery from 2011–2012; 2013 data are confidential and thus cannot be reported (Gustafson et al. 2015a).

Eulachon appear to be encountered sporadically in the at-sea Pacific hake fishery as bycatch. The at-sea catcher-processor sector of the Pacific hake fishery has caught more eulachon than other at-sea Pacific hake sectors (Gustafson et al. 2015a). No eulachon bycatch was reported in the catcher-processor sector from 2002–2005, or in 2010. The estimated eulachon bycatch in the catcher-processor sector was 147 and 1,271 fish in 2006 and 2011, respectively (Gustafson et al. 2015a). The bycatch estimate in 2011 amounted to 82% of the total eulachon bycatch estimate of 1,547 fish between 2002 and 2013. In all other years, fewer than 40 individual eulachon were observed in the catcher-processor Pacific hake sector as bycatch (Gustafson et al. 2015a).

The non-tribal mothership Pacific hake sector had an estimated eulachon bycatch of 355 individual fish between 2002 and 2013, with 78% of this bycatch occurring in 2013. No eulachon bycatch occurred in 2002–2006 or in 2010, and fewer than 10 individual fish were estimated caught in 2007, 2008, 2009 and 2012 (Gustafson et al. 2015a). The eulachon bycatch estimate in the tribal mothership Pacific hake fishery in 2009 was 32 fish and 160 fish in 2011. Eulachon bycatch was not reported in this sector from 2002–2008 or in 2010. The tribal mothership sector did not participate in the Pacific hake fishery in 2013 and fewer than three vessels participated in 2012 (Gustafson et al. 2015a). The WCGOP began observing bycatch in the shoreside Pacific hake fishery in 2011 and did not observe eulachon bycatch discarded at-sea in this fishery in 2011 or 2012. However, 4,139 individual eulachon were estimated to have been landed as bycatch in this fishery in 2013, although effort was similar to the years 2011 and

2012 (Gustafson et al. 2015a). Bycaught fish, other than salmon, are not counted by shore-based catch monitors in this fishery. The 83.5 kg of eulachon recorded by catch monitors was estimated to represent 4,139 individual eulachon based on the average weight, over all years, of at-sea eulachon that appear as bycatch in other fisheries observed by the WCGOP.

A summary of eulachon bycatch in all U.S. west coast groundfish fisheries observed by the WCGOP and the A-SHOP that reported eulachon catch from 2002–2013 is provided in Table 14 and Fig. 20. This summary is based on data presented in Gustafson et al. (2015a). From 2002–2013 all groundfish sectors caught an estimated 8,199 individual eulachon. About 88% of this bycatch of eulachon occurred during 2011–2013, when efforts to identify eulachon in the bycatch of these fisheries became a priority and when other indices of eulachon abundance were highly positive (see Table 14, Fig. 20, and Gustafson et al. 2015a).

Updated data on observed bycatch of eulachon in U.S. west coast groundfish fisheries for 2014 has been released[29], including the bottom and midwater trawl catch share fisheries in Washington, Oregon, and California (Table 15), and the three sectors of the at-sea Pacific hake fishery (Table 16). Because almost all tows are observed in these fisheries, the data reported represents nearly 100% of all eulachon bycatch for these fisheries (Tables 14–15). As in recent years (2011–2013), no eulachon were caught in the California sector of the bottom and midwater trawl catch share fishery during 2014 (Table 15). However, during operation of the Washington and Oregon sectors of the bottom and midwater trawl catch share fishery, bycatch of eulachon increased substantially over bycatch reported in 2013. Between 2013 and 2014, bycatch more than doubled from 135 to 278 eulachon in the Washington sector, and was nearly five times as great in Oregon, increasing from 507 in 2013 to 2,473 in 2014 (Table 15). Although many more eulachon were caught as bycatch in Oregon than in Washington in 2014, the estimated bycatch ratio (number of eulachon per mt of observed and retained groundfish) was actually higher in the Washington sector (0.3148) than in the Oregon sector (0.2210) (Table 15).

In the catcher processor sector of the at-sea Pacific hake fishery, bycatch also increased substantially between 2013 and 2014, from 39 to 242 individual eulachon (Table 16). In contrast, eulachon bycatch in the non-tribal mothership Pacific hake sector fell from 277 in 2013 to 25 in 2014 (Table 16). Once again, as in 2013, the tribal mothership sector did not participate in the at-sea hake fishery in 2014 (Table 16).

The WCGOP began sampling bycatch in the shoreside Pacific hake fishery in 2011 and did not observe eulachon bycatch in this fishery in 2011, 2013 (Table 14), or 2014[30]. However, 4,139 individual eulachon were estimated to have been landed as bycatch in the shoreside Pacific hake fishery in 2013 (Table 14).

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[29] NWFSC, FRAM Division, Fisheries Observation Science, Annual Tables of Observed Bycatch of Protected Species, Eulachon observed bycatch (2002-2014). Available at: http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/protected_species.cfm

[30] Shoreside Hake Observed Catch, 2011-2014. NWFSC, FRAM Division, Fisheries Observation Science, Sector Data Products. Available at: http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/sector_products.cfm.

Based on the overall magnitude of bycatch in U.S. west coast groundfish fisheries, either there is limited interaction with eulachon in these fisheries or most eulachon encounters result in fish escaping or avoiding trawl gear. Given that federal regulations in the commercial groundfish fishery mandate minimum trawl mesh sizes in the bottom and midwater trawl fisheries of 11.4 cm (4.5 inches) and 7.6 cm (3.0 inches), respectively (West Coast Region 2014), it is likely that most eulachon would be able to escape trawl nets by swimming or falling through mesh of this dimension, either during the tow or during haul-back operations. This is illustrated by the fact that eulachon appear to easily pass between the 0.75 inch (19.1 mm) wide rigid-grate bars of bycatch reduction devices installed in shrimp trawl nets (see Gustafson et al. 2015b). Thus the low levels of observed eulachon bycatch in the groundfish fishery sectors reported in this document may represent a small fraction of all eulachon encounters with bottom and midwater trawl fishing gear in the groundfish fishery. In fact, it is difficult to imagine how eulachon are retained in groundfish trawl nets unless the codend becomes plugged, because fish the size of eulachon should readily pass through the mesh openings of groundfish trawl nets.

From a conservation biology perspective it is important to examine not only estimated bycatch and discard mortality but also the fate of non-target organisms that escape from trawl nets prior to being hauled aboard fishing vessels. Davis and Ryer (2003) stated that "… the fact that bycatch does not appear on deck, does not mean that those fish have been released from the gear unimpaired and are capable of surviving." Various terms are used for these unobserved but ultimately lethal interactions with fishing gear, including: "unaccounted fishing mortality" (Chopin and Arimoto 1995, Suuronen 2005, ICES 2005, Suuronen and Erickson 2010); "collateral mortality" (Broadhurst et al. 2006); "cryptic fishing mortality" (Gilman et al. 2013); and "post release mortality" (Raby et al. 2014); among others. Looking beyond mortality, Wilson et al. (2014) have recently reviewed the available literature on sub-lethal effects on fitness of individual trawl escapees and classified these as either immediate sub-lethal effects (e.g., physiological impairment, physical injury, and reflex impairment) or delayed sub-lethal effects (e.g., impairment of behavior, growth and reproduction, or immune function). Wilson et al. (2014) argue that sub-lethal effects of encounters with fishing gear may reduce future reproductive output; however, possible fitness consequences have yet to be adequately investigated.

Currently, we have no direct data to estimate escape or avoidance mortality of eulachon in any sector of the groundfish fishery and we are unaware of any studies that have directly investigated the fate of osmerid smelt species passing through groundfish trawl nets. Although data on survivability of passing through trawl nets by small forage fishes such as eulachon are scarce, results of several studies have shown a direct relationship between fish length and survival of various fish species escaping trawl nets through the codend mesh (Sangster et al. 1996; Suuronen et al. 1996a, b; Ingólfsson et al. 2007), indicating that smaller fish with their poorer swimming ability and endurance may be more likely to suffer greater injury and stress during their escape from trawl gear than larger fish (Broadhurst et al. 2006, Ingólfsson et al. 2007, Suuronen and Erickson 2010, Gilman et al. 2013).

## Eulachon Bycatch in Ocean Shrimp Trawl Fisheries 2004–2014

Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur off the west coast of North America from the west coast of Vancouver Island (WCVI) to Cape Mendocino, California

(Hannah and Jones 2007) and in British Columbia, Canada. *Pandalus jordani* is known as the smooth pink shrimp in British Columbia, ocean pink shrimp or smooth pink shrimp in Washington, pink shrimp in Oregon, and Pacific ocean shrimp in California. Herein we use the common name "ocean shrimp" in reference to *P. jordani* as suggested by the American Fisheries Society (McLaughlin et al. 2005). The common name "pink shrimp" has been assigned by the American Fisheries Society to *Farfantepenaeus duorarum*, a commercial species in the South Atlantic and Gulf of Mexico (McLaughlin et al. 2005). Numerous publications have documented eulachon bycatch levels in shrimp trawl fisheries off the coasts of Washington, Oregon, California, and British Columbia (Hay et al. 1999a, b; Olsen et al. 2000; NWFSC 2008, 2009, 2010; Bellman et al. 2011; Al-Humaidhi et al. 2012; Gustafson et al. 2015b).

## Canada

Following recognition that large numbers of eulachon were occurring as bycatch in Queen Charlotte Sound shrimp fisheries (Hay and McCarter 2000, Olsen et al. 2000) and of a concurrent decline in central coast British Columbia eulachon stocks, DFO closed the Queen Charlotte Sound shrimp trawl fishery in 1999, which has remained closed (DFO 2014). In addition, concerns over eulachon bycatch in offshore west coast Vancouver Island shrimp trawl fisheries also led DFO to set eulachon bycatch action levels for west coast Vancouver Island. Bycatch reduction gear has been mandatory since 2000. Catch composition results of the at-sea observer program for 2002 to 2011 are available in Rutherford et al. (2013).

The most recent DFO Shrimp Trawl Integrated Fisheries Management Plan for 2014–2015 (DFO 2014, p. 13) stated that:

> The incidental bycatch of an anadromous smelt, eulachon (*Thaleichthys pacificus),* is of concern to First Nations since the returns of eulachon to many of the Central Coast rivers, and the Fraser River have declined. First Nations organizations in the North Coast and Central Coast have requested that the shrimp trawl fishery be closed to avoid eulachon bycatch. The Department is working with the shrimp trawl industry to minimize eulachon bycatch. Area closures, seasonal closures, and an eulachon action level with an at-sea observer program were implemented to monitor eulachon bycatch in West Coast Vancouver Island areas. Bycatch reduction devices (including rigid grates) are mandatory coastwide.

These BRDs consist of:

> … an exclusion grate (or Nordmore grate) inserted into the forward end of the cod end of the trawl net at an angle so that it entirely blocks access to the cod end, except for the spaces between the bars. A maximum spacing of 44.5 mm (1.75 inches) on the rigid grate has been implemented as a Condition of Licence. The shrimp trawl caucus recommends the spacing for grates be 25 mm to more effectively reduce bycatch. The netting directly above the grate shall have a triangular opening (escape hole) the full width of the grate.

Appendix A to DFO (2014, Appendix 1, p. 13) stated that:

> Specific management measures for eulachon bycatch have been developed for West Coast Vancouver Island (WCVI) [Shrimp Management Areas] SMAs. An at-sea observer program (50 days) is funded by active industry vessel owners. The primary goal of the observer program is to monitor eulachon bycatch in WCVI SMAs. Observers are deployed by the Service Provider when the vessel master obtains a hail number to go fishing. The observer travels with the vessel when fishing and records information on all species in the catch, the configuration of the gear and specific tow location and duration. This information is used to monitor the eulachon-to-shrimp ratio and the eulachon catch rates. … An eulachon bycatch action level is set annually for WCVI … to encourage active shrimp trawl fish harvesters to adjust their gear to minimize eulachon bycatch. The 2014/15 eulachon action level (EAL) for the WCVI will be 6 tonnes [3.0 tonnes in SMA groups 124OFF, 125OFF and 126OFF and 3.0 tonnes in SMA groups 23OFF+21OFF and 23IN].

Furthermore, DFO (2014, Appendix 1, p. 13-14) stated that:

> In the event the estimate of eulachon bycatch in a given WCVI area reaches the Eulachon Action Level the commercial fishery will likely close. The Department may consider allowing the fishery to continue if other options can be identified that will ensure minimal or no further eulachon bycatch. Management actions could include:
>
> 1) Restricting trawling to beam trawlers (lower eulachon bycatch rate than otter trawlers)
> 2) Closure of certain shrimp management areas to shrimp trawling
> 3) Closure of the shrimp trawl fishery in portions of the coast.

**Washington, Oregon, and California**

Ocean shrimp fisheries began in California in 1952 and expanded into Oregon and Washington by the mid- to late-1950s (Frimodig et al. 2009). Ocean shrimp in commercial quantities are found from Point Arguello, California north to Queen Charlotte Sound, British Columbia, typically over well-defined beds of green mud or green mud and sand (Frimodig et al. 2009). Because ocean shrimp undergo a vertical diel migration, dispersing into surface waters during nighttime hours and returning to near-bottom aggregations in the daytime (Zirges and Robinson 1980, Frimodig et al. 2009), ocean shrimp vessels generally trawl in depths ranging from 91–256 m (50–140 fathoms) during daylight hours. Vessels that currently operate in the state-permitted ocean shrimp trawl fisheries in Washington, Oregon, and California range in size from 11.6–32 m (38–105 feet), with an average length of 19.9 m (65 feet), and can use single or double-rigged shrimp trawl gear (Table 13).

The ocean shrimp season is open 1 April through 31 October in Washington, Oregon, and California and vessels deliver catch to shore-based processors. Total coastwide ocean shrimp landings have ranged from a low of 1,888 mt in 1957 to a high of 41,418 mt in 2014 (Gustafson et al. 2015b). The portion of the bycatch that is not marketable or for which regulations prohibit landing is discarded at-sea and all discarded eulachon in this fishery results in 100% mortality. Additional information on ocean shrimp fisheries can be found for Washington online at http://wdfw.wa.gov/fishing/commercial/shrimp/, for Oregon online at http://www.dfw.state.or.us/MRP/shellfish/commercial/shrimp/index.asp, and for California in Frimodig et al. (2007, 2009).

Currently, ocean shrimp vessels are required to use bycatch reduction devices (BRDs) that serve as deflecting grids to guide fin-fish towards an escape opening, which is usually on the top of the net. The primary goal of mandatory BRDs is to reduce bycatch of groundfish species, and more recently, protected species such as eulachon. Although not mandatory, it was reported that by 2015 nearly 100% of the ocean shrimp trawl fleet was using some form of LED (Light Emitting Diode) lights to illuminate portions of shrimp trawl nets to reduce bycatch of eulachon (Hannah and Jones 2016). These efforts to reduce bycatch of eulachon through use of lighted trawl nets will be further discussed below. BRDs became mandatory in California in 2002 (Frimodig 2008, Frimodig et al. 2009) and in Washington and Oregon in 2003. Current 2014–2015 regulations in Washington and Oregon, adopted by both states in 2012, require ocean shrimp trawl fishery BRDs to consist of a rigid panel or grate of narrowly spaced bars (usually constructed of aluminum) with no gaps between the bars exceeding 0.75 inches (19.1 mm). Further details on shrimp BRD requirements and fishery regulations for Washington can be found at http://apps.leg.wa.gov/wac/default.aspx?cite=220-52-050; and for Oregon at http://www.dfw.state.or.us/fish/commercial/docs/2015_commercial_synopsis.pdf. Approved BRDs for use in the ocean shrimp fishery in California include: (1) rigid- or semi-rigid grate excluders consisting of vertical bars with no gaps between the bars exceeding 2 inches (50.8 mm); (2) soft-panel excluders, usually made of a soft mesh material "with individual meshes no large than 6 inches;" and (3) fisheye excluders, which have a forward facing escape opening that is maintained by a rigid frame[31].

Gustafson et al. (2015b) reported observed and estimated bycatch of eulachon in ocean shrimp trawl fisheries for the years 2004, 2005, and 2007–2013. The observed tows were in waters shallower than 250 m and deeper than 80 m. The ocean shrimp trawl fishery did not carry WCGOP observers in 2006. Data sources and bycatch estimation methods for eulachon bycatch in west coast ocean shrimp fisheries in 2004–2013 are detailed in Gustafson et al. (2015b).

The WCGOP began observing eulachon bycatch in the Washington ocean shrimp fishery in 2010 and the estimated bycatch in terms of weight and numbers of eulachon has increased in each year up to 2013, while the percentage of total shrimp landings observed has fluctuated between just less than 10% to nearly 15% (Gustafson et al. 2015b). Total estimated bycatch of eulachon in the Washington ocean shrimp fisheries ranged from a low of over 64 thousand (95% CI; 23,361–132,532) fish in 2010 to a high of over 17.2 million (95% CI; 12,077,308–21,444,581) fish in 2013 (Fig. 21; Gustafson et al. 2015b). Mean estimated total biomass of eulachon bycatch in the Washington fishery during this time period (2010–2013) ranged from 2.1–203.7 mt (Gustafson et al. 2015b).

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[31] California Fishing Regulations Commercial Digest 2014-2015, online at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=88056&inline.

Eulachon bycatch in the Oregon ocean shrimp fishery was estimated at well under a million individual fish (range of 146–845 thousand) from 2004–2011 (the fishery was not observed in 2006); however, estimated bycatch expanded dramatically in 2012 and 2013 to over 28.1 million (95% CI; 17,948,671–39,302,622 million) and 35.1 million (95% CI; 20,316,467–52,991,571), respectively (Fig. 21; Gustafson et al. 2015b). Similarly, total weight of estimated eulachon bycatch in Oregon increased from 20.5 mt (95% CI; ~14.7–27.4 mt) in 2011 to nearly 428 mt (95% CI; ~285–588 mt) in 2012 and to over 540 mt (95% CI; ~348–759 mt) in 2013.

Bycatch ratios, measured as both kg of eulachon and numbers of fish, per metric ton of ocean shrimp observed also increased dramatically in both the Washington and Oregon ocean shrimp fisheries from 2011 to 2012, and remained high in 2013 (Fig. 21; Gustafson et al. 2015b). Bycatch ratios were higher in Washington than in the Oregon fishery in both 2012 and 2013 (Fig. 21; Gustafson et al. 2015b).

Eulachon bycatch in the California ocean shrimp fishery has followed a very different trajectory from that observed in Washington and Oregon during the last three years (2011–2013) of available data. Eulachon bycatch in California remained below 25,000 fish prior to 2008 (the fishery was not observed in 2006), rose dramatically in 2010 to over 267,000 (95% CI; 40,040–714,661) fish; fell to its lowest observed level of just 471 (95% CI; 197–826) fish in 2011, increased again dramatically in 2012 to over 337,000 (95% CI; 151,822–616,148) fish, and then fell to just over 16,000 (95% CI; 3,768–33,610) fish in 2013 (Fig. 21; Gustafson et al. 2015b). Biomass of eulachon bycatch and bycatch ratios have shown similar fluctuations over the time period from 2010–2013 (Fig. 21; Gustafson et al. 2015b). The tonnage of observed ocean shrimp and of fleet-wide landings were relatively stable over the last three to four years, indicating that yearly differences in eulachon distribution, or in the catchability of eulachon, likely contributed to the extreme fluctuations in eulachon bycatch in the California ocean shrimp fishery.

Combined WCGOP estimates of the weight and number of eulachon caught in the Oregon and California ocean shrimp trawl fishery as bycatch from 2004–2013 (except for 2006 when these fisheries were not observed) and in Washington from 2010–2013 are presented in Table 17 (from Gustafson et al. 2015b). Total estimated bycatch of eulachon in the Oregon and California ocean shrimp fisheries ranged from nearly 158,000 fish (95% CI; 11,642–492,844) in 2004 to a high of over 959,000 (95% CI; 238,075–2,147,772) fish in 2009. Estimated eulachon bycatch in the Washington ocean shrimp fishery in 2010 (its first year of observation) was nearly 65,000 fish and the total 2010 estimated eulachon bycatch for all three states combined was over 1,072,000 (95% CI; 532,268–1,891,424). Total three-state eulachon bycatch decreased to about 602,000 (95% CI; 394,343–875,107) fish in 2011 (Table 17, Fig. 21). However, as seen earlier, eulachon bycatch increased dramatically in all three states in 2012, topping out at over 42.8 million (95% CI; ~26.9–59.1 million) individual eulachon. Bycatch increased again in Washington and Oregon, but not California in 2013 resulting in an estimated total eulachon bycatch for all three states combined of over 52.3 million (95% CI; ~32.4–74.5 million) fish (Table 17, Fig. 21). Estimated weight of these bycaught eulachon in 2013 was over 744 mt (95% CI; ~498–1,008 mt) (Table 17).

Recently, the WCGOP released updated data on observed bycatch of eulachon in Washington, Oregon, and California ocean shrimp trawl fisheries for 2014[32] (Table 18). Approximately, 7.1%, 9.7%, and 15.5% of ocean shrimp landings were observed in the Washington, Oregon, and California sectors of this fishery during 2014 (Table 18). Over the past three years (2012–2014), the bycatch ratio (measured as the number of eulachon caught per mt of observed ocean shrimp), and the number of eulachon caught in this fishery, have declined in Washington, increased in Oregon, and fluctuated up and down in California (Table 18). During 2014, approximately 968; 2,322; and 159 eulachon were caught per mt of observed ocean shrimp landings in Washington, Oregon, and California, respectively (Table 18).

Ward et al. (2015) applied spatiotemporal models to both fishery-dependent observations of eulachon bycatch and eulachon fisheries-independent survey data to 1) estimate population trends of eulachon, 2) understand eulachon bycatch risk in shrimp fisheries, and 3) identify persistent bycatch hotspots that may be used in future management actions to reduce eulachon bycatch rates. Two spatial data sets for the period from 2007–2012 were examined: WCGOP catch data of shrimp and eulachon in the California, Oregon, and Washington ocean shrimp trawl fisheries and fishery-independent incidental eulachon catch in the WCBTS (Ward et al. 2015). Ward et al. (2015) found support for a greater than 40% annual increase in eulachon density based on the bycatch dataset and a greater than 55% annual increase based on the fisheries-independent survey dataset over the duration of the datasets. The later dataset also suggested that eulachon density was "substantially higher in 2012 than in any recent period" (Ward et al. 2015). These data also imply "that increases in bycatch [are] not due to an increase in incidental targeting of eulachon by fishing vessels, but likely because of an increasing population size of eulachon." Ward et al. (2015, their figures 4–5) also presented mapped representations of both the spatial distribution of eulachon bycatch risk and areas of highest bycatch encounters. Ward et al. (2015) found that the coastal areas just south of Coos Bay, Oregon; between the Columbia River and Grays Harbor, Washington; and just south of La Push, Washington were consistent hotspots of eulachon bycatch across years.

The previously depressed and currently increasing abundance of the southern DPS of eulachon (James et al. 2014; Fig. 11) are likely contributing to the increased levels of eulachon bycatch reported for 2012–2014. The dramatic increases in the level of eulachon bycatch in both the Washington and Oregon ocean shrimp trawl fisheries in 2012 and 2013 occurred in spite of regulations, enacted in 2012, requiring the use of BRDs with a minimum 19 mm (0.75 inch) bar spacing. It is unclear why bycatch ratios were highest in the Washington, intermediate in the Oregon, and lowest in the California sectors of the ocean shrimp trawl fishery in 2012 and 2013. However, the bycatch ratio increased in Oregon and decreased in Washington in 2014 compared to the previous two year period (Table 18).

Although speculative, it may be that BRDs in the ocean shrimp trawl fisheries operate at greatly reduced efficiency when eulachon reach high densities. Winger et al. (2012, p. 91) stated that:

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[32] NWFSC, FRAM Division, Fisheries Observation Science, Annual Tables of Observed Bycatch of Protected Species, Eulachon observed bycatch (2002-2014). Available at: http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/protected_species.cfm

> Fish density is also expected to affect the performance of BRDs installed within the net. When large pulses of fish are encountered, devices such as selection windows, sorting grids, or separator panels may be temporarily masked by neighboring conspecifics. This reduces the probability of fish encountering the devices and thus reduces the potential sorting efficiency.

The Washington ocean shrimp fishery was also observed separately in 2011 and 2012 by a team of state-deployed fishery bycatch observers (Wargo et al. 2014). Wargo et al. (2014) reported a fleetwide eulachon bycatch in the Washington state ocean shrimp fishery of "7.8 mt (17,132 pounds) for 2011 and 171 mt (378,011 pounds) for 2012." These bycatch estimates are approximately 30% and 10% greater than the estimates for the Washington ocean shrimp fishery as reported in the present document of 5.5 and 156.8 mt in 2011 and 2012, respectively. In the 2011 Washington ocean shrimp trawl fishery 24% of trips were observed by the state observers (Wargo et al. 2014), whereas the WCGOP observed 16.6% of the total ocean shrimp landings (Gustafson et al. 2015b). In 2012, 16% of trips were observed by the state observer program (Wargo et al. 2014) and 14.8% of shrimp landings were observed by the WCGOP (Gustafson et al. 2015b).

Many early exploratory surveys of ocean shrimp distribution and abundance off the U.S. west coast commented upon the species of bycatch taken during these cruises (Pruter and Harry 1952, Schaefers and Johnson 1957, Tegelberg and Smith 1957, Alverson et al. 1960, Ronholt and Magill 1961, Robinson 1966), but few attempted to quantify bycatch biomass. Tegelberg and Smith (1957, p. 28) found eulachon to be "common in some catches" during exploratory shrimp cruises off the Washington coast in 1955 and 1956. Alverson et al. (1960) reported that osmerid smelt along with eelpouts (Zoarcidae) and small sole "dominated incidental catches of fish in numbers and were taken in most drags" off Washington and Oregon in 1958. Ronholt and Magill (1961) listed eulachon as among the numerous species incidentally taken during a 1960 exploratory shrimp cruise off central Oregon. Robinson (1966, p. 3) also reported that, in addition to several other species taken as bycatch, "in a few tows considerable numbers of smelt … were captured" off Oregon in March 1966 during studies of abundance and distribution of ocean shrimp (Robinson 1966, p. 3).

Prior to the mandated use of bycatch reduction devices (BRDs), 32–61% of the total catch in the Oregon ocean shrimp fishery consisted of non-shrimp biomass, including various species of smelt (Hannah and Jones 2007). Krutzikowsky (2001, p. 2) evaluated bycatch in this fishery and stated that:

> Bycatch discards in this fishery can range from relatively low to very high levels that can affect the efficiency and, possibly, the value of the fishery. Bycatch of Pacific whiting, *Merluccius productus*, in particular, can become high enough on the shrimp grounds to preclude efficient shrimping. … The majority of bycatch is discarded, such as … smelt Osmeridae sp. …

Reducing bycatch in this fishery has long been an active field of research (Hannah et al. 1996, 2003, 2011; Hannah and Jones 2000, 2003, 2007, 2012; Frimodig et al. 2009) and great progress has been made in reducing bycatch, particularly of larger-bodied fishes. Use of BRDs in offshore shrimp trawl fisheries, which was mandated beginning in 2002 in California and 2003 in Washington and Oregon has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig et al. 2009). As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch and osmerid smelt bycatch was reduced to an estimated average of 0.73% of the total catch across all BRD types (Hannah and Jones 2007).

Although data on survivability of BRDs by small pelagic fishes such as eulachon are scarce, many studies on trawl net escape mortality for other fishes indicate that "among some species groups, such as small-sized pelagic fish, mortality may be high" and "the smallest escapees often appear the most vulnerable" (Suuronen 2005, p. 13–14). A workshop (Pickard and Marmorek 2007, p. 31–33) to determine research priorities for eulachon in Canada recommended the need to research the effectiveness of BRDs and the need to estimate mortality, not just bycatch. Partly in response to these concerns, Hannah and Jones (2012) used underwater video technology to examine behavior of eulachon when encountering rigid-grate BRDs in an ocean shrimp trawl net. The purpose of this research was to determine fish condition and survival following exclusion by the BRDs and the effectiveness of these types of BRDs at reducing mortality rates. Hannah and Jones (2012) stated that:

> Almost 80% of the large eulachon maintained an upright vertical orientation throughout their escape and exited the trawl in a forward-swimming orientation. Large eulachon maintained distance from the deflecting grid better than the other species encountered ($P < 0.001$) and typically showed no contact or only minimal contact with it (63%). Only about 20–30% of the large eulachon showed behaviors indicating fatigue, such as laying on or sliding along the grid.

Hannah and Jones (2012) concluded that:

> … data on behavior of large eulachon escaping from a shrimp trawl show that most have enough residual swimming ability to minimize their physical contact with the deflecting grid, maintain their vertical orientation and to continue actively swimming in a forward direction as they exit. This suggests that the use of deflecting grids in the ocean shrimp fishery is likely reducing eulachon mortality rates, as well as bycatch.

Hannah and Jones (2012) also noted that large eulachon are excluded at a higher efficiency than are small eulachon and behavior of eulachon in this study, both large and small, may have been influenced by the use of artificial video lighting.

### Conservation implications and the promise of lighted trawl nets

None of the shrimp trawl BRDs in use today eliminate all incidental catch, and residual bycatch of fish (Hannah et al. 2011), especially of eulachon, remains a problem. Recent experimentation with artificial light to illuminate portions of trawl nets in the Oregon ocean shrimp fishery has shown great promise for significantly reducing bycatch of eulachon (Hannah and Jones 2014, 2015; Hannah et al. 2015). Researchers compared bycatch levels over 42 paired trials between lighted and unlighted trawl nets using double-rigged vessels that could tow paired shrimp trawl nets. When 10 green LED lights were placed along the trawl fishing line of ocean shrimp trawl nets with rigid-grate BRDs with 0.75 inch (19.1 mm) bar spacing installed and then were compared with identical trawls nets without lights, the bycatch of eulachon was reduced by 91%, with little or no effect on shrimp catch. Hannah et al. (2015, p. 60) stated that "How the addition of artificial light is causing these changes in fish behavior and bycatch reduction is not known," but the authors speculated that illumination of the trawl fishing line may possibly allow the fish to see the approaching net sooner and react in time to avoid being entrained, and "likely encouraged some species to also move downwards, perhaps exploiting a natural tendency to move towards the seafloor when threatened" (Hannah et al. 2015, p. 66).

Hannah and Jones (2016, p. 6) stated that to their knowledge "all shrimpers that fished in 2015 [in the Oregon ocean shrimp fishery] used LED (Light Emitting Diode) lights when trawling" and that "all said they used lights and were happy with the resulting bycatch reduction." Hannah and Jones (2016) also discussed several technical developments concerning types of lights that have been used and lighting configurations that are being tried to increase eulachon avoidance of shrimp trawl nets. Although use of LED lights on ocean shrimp trawl nets is not currently regulated in U.S. waters, Hannah and Jones (2016, p. 9) proposed regulations in Oregon be imposed to require use of footrope lighting devices such as the "Lindgren-Pitman Electralume Light Emitting Diode (LED) lights" or "other footrope lighting devices that are deemed by the Department to have comparable or greater total illumination may be approved for use, on a case-by-case basis, through issuance of an Experimental Gear Permit (EGP)."

# Commercial, Recreational and Subsistence Fisheries

## California

The current California Code of Regulations for fishing in inland waters states that "Candlefish or Eulachon may not be taken or possessed" (current through June 12, 2015)[33]

## Oregon/Washington

### Fishery landings

Table 19 presents commercial fishery landings of eulachon in the Columbia River Basin since 1990. The complete data set beginning in 1888 is presented in Gustafson et al. (2010, their table 7 and figure 22). Commercial and recreational fisheries continued to operate in the 2009-2010 season but all commercial and recreational fisheries in the Columbia River and its

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[33] Available online at: https://govt.westlaw.com/calregs/Document/IE27C2FA057DB11E29076D3281F28AB91?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).

tributaries were closed for the three years from the 2010–2011 season through the 2012–2013 season (JCRMS 2014).

In 2014–2016, WDFW and ODFW reinstated a reduced Level-I eulachon fishery in the Columbia River, and select tributaries of the Columbia River. Consultations between NMFS-WCR, WDFW, and ODFW resulted in development of eulachon fisheries in the Columbia River Basin for 2014–2016, which were designed to take no more than 1% of the spawning stock biomass. It was expected that a limited eulachon fishery would benefit eulachon recovery efforts by:

- Providing essential context for interpreting historical harvest data to better understand trends and variability in eulachon abundance
- Filling critical information gaps such as the length and age structure of spawning eulachon, as well as the temporal and spatial distribution of the run
- Supporting the cultural traditions of Northwest tribes who relied on eulachon as a seasonally important food source and valuable trade item
- Providing a limited public and commercial opportunity for eulachon harvest to maintain a connection between people and the eulachon resource. This connection is important to sustaining public engagement in eulachon conservation and recovery.

A commercial gill-net fishery opening occurred in the mainstem Columbia River on Mondays and Thursdays for seven hours each day from 10 February to 6 March in 2014, from 2–26 February in 2015, and from 1–25 February in 2016, for a total opening each year of 56 h (JCRMS 2014, ODFW 2015, 2016). Approximately 8.4, 7.5, and 2.2 metric tons of eulachon were commercially harvested in 2014, 2015, and 2016, respectively (Table 20) (ODFW 2014, 2015, 2016). Recreational sport fisheries were also permitted on the Cowlitz and Sandy rivers in 2014, which harvested an estimated 89.7 and 2.7 metric tons[34], respectively (Table 20). Likewise, recreational dip-net fisheries operated on the Cowlitz and Sandy rivers in 2015. The Cowlitz River recreational dip-net fishery, which was open for two Saturdays in February 2015, harvested an estimated 131.4 mt of eulachon (Table 20) (ODFW 2015)[35]. Less than 100 pounds of eulachon were reported as taken in the recreational dip-net fishery in the Sandy River during 2015. Although landings are preliminary, recreational harvest was estimated at about 64 mt in the single day opening of the sport or recreational fishery on the Cowlitz River in 2016 (Table 20). A decision on opening a sport fishery on the Sandy River in 2016 is still pending as of 7 March 2016. Catch records were not maintained for eulachon recreational fisheries in the Columbia River Basin prior to 2014, although in the past it had been estimated at times to equal the historical commercial catch (WDFW and ODFW 2001).

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[34] Olaf Langness, Washington Department of Fish and Wildlife. Pers. commun., 24 July 2014.

[35] Olaf Langness, Washington Department of Fish and Wildlife. Powerpoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., 21 August 2015.

## British Columbia

The Fraser River commercial fishery for eulachon has essentially been closed since 1997, opening only briefly in 2002 and 2004, when 5.76 and 0.44 mt were landed, respectively (see Gustafson et al. 2010). In regards to eulachon fishing opportunities on the Fraser River, DFO (2013a, p. 28) stated that:

> First Nation Fisheries: First Nations access to eulachon for food, social and ceremonial (FSC) purposes is managed through a communal Aboriginal fishing licence on the Fraser River. In 2012, harvest opportunities targeting 50 pounds per Band on a case by case basis were provided for up to eight Bands. However, the target of 400 pounds total was exceeded; the total eulachon harvest in 2012 was 1,037 pounds.
>
> Recreational Fisheries: There were no recreational fisheries for eulachon on the Fraser River in 2012 [–2015].
>
> Commercial Fisheries: There were no commercial fisheries for eulachon on the Fraser River in 2012 [–2015].
>
> New Westminster Test Fishery: The New Westminster test fishery was not conducted in 2012 [–2015].

Furthermore, DFO (2013, p. 28) stated that:

> Due to conservation concerns and the recovery process, only limited Fraser River FSC [food, social, and ceremonial] fisheries for eulachon will be considered on a case by case basis by the Lower Fraser area office for 2013.
>
> The Department is managing the LFA [lower Fraser area] eulachon fisheries to ensure harvests do not exceed 800 pounds in 2013. This limited harvest will provide access to First Nations for FSC purposes while maintaining conservation objectives.

Additional landings and effort statistics for most First Nations fisheries within the southern DPS of eulachon are unavailable. Recreational fishing for eulachon with dip nets, gillnets, minnow nets, or cast nets in fresh water, is prohibited throughout British Columbia[36]. Recreational harvest of eulachon is also prohibited in all marine areas of British Columbia due to conservation concerns[37].

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[36] See regulations online at: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/fns/index.cfm?pg=view_notice&lang=en&DOC_ID=115494&ID=r

[37] See regulations online at: http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/species-especes/fintable-tableaupoisson-eng.htm#Eulachon

# Environmental Impacts On Ocean Conditions

As part of the threats analysis narrative, the 2010 status review (Gustafson et al. 2010, p. 143–147) provided an analysis of environmental impacts on ocean and freshwater conditions and the expected impact on eulachon. The increasing trend in eulachon spawner abundance since 2011 in the Columbia River Basin and in 2015 in the Fraser River, and apparent increase in other less well monitored regions of the DPS at least partially reflect favorable environmental conditions in marine waters of the northern California Current in recent years. It is well established that ocean conditions during the first weeks or months of marine life have a large influence on overall marine survival for salmon (Pearcy 1992, Pearcy and McKinnell 2007). Although not as thoroughly documented for eulachon as for Pacific salmon, it is likely that ocean conditions also exert a large influence on early marine survival of eulachon. Accordingly, a large portion of the short-term variation in population productivity of eulachon may be due to ocean conditions, which fluctuate at short time scales.

These productive conditions likely resulted in high marine survival rates of eulachon and subsequent high adult returns for the Columbia River and increase in occurrence in other parts of the DPS, such as the Klamath and Elwha rivers, since 2011–2012. However, changes in ocean and freshwater conditions beginning in early 2014 due to exceptionally warm ocean waters and associated terrestrial impacts, plus a strengthening El Niño event, suggest that this period of high marine survivals will not persist, and eulachon returns in the next few years may be considerable lower than those experienced recently.

This chapter summarizes what is known about marine and terrestrial conditions since the development of the “warm blob” in the winter of 2013–2014, and their likely influence on eulachon productivity in the southern DPS. Since we do not yet understand how environmental conditions directly or indirectly influence eulachon survival, it is impossible to predict exactly how the currently anomalous conditions will affect individual eulachon populations. It is also unknown how long these unfavorable conditions will last.

## Methods and Description

We use a variety of published and unpublished sources to document the current anomalous conditions in both freshwater and marine environments. Given the recent onset of these conditions (late fall 2013), only a few peer-reviewed papers have been published on the phenomena to date. For marine conditions, our primary sources are the NWFSC’s Ocean Indicators annual report (Peterson et al. 2014a), the State of the California Current Report (CCIEA 2015), the Fisheries and Oceans Canada report on Pacific marine ecosystems in 2014 (Chandler et al. 2015), and Bond et al. (2015). Information on freshwater conditions includes NOAA’s National Center for Environmental Information (NOAA NCEI), U.S. Geological Survey’s National Water Information System, and U.S. Department of Agriculture’s Natural Resource Conservation Service (USDA NRCS).

Our intent with this summary is not to provide an exhaustive review of what is known about current conditions, but instead provide an overview, with a particular emphasis on environmental factors that are important to eulachon productivity and survival. In many cases, current environmental conditions in marine and freshwater habitats are outside the range of prior observations, therefore their biological effects are difficult to predict. Only in hindsight will we be able to tell how these conditions affected eulachon survival.

## Observed Environmental Conditions

Environmental conditions in both fresh and marine waters inhabited by the southern DPS of eulachon are influenced, in large part, by two ocean-basin scale patterns, the Pacific Decadal Oscillation (PDO; Mantua et al. 1997) and the El Niño-Southern Oscillation (ENSO). Starting in late 2013, however, abnormally warm conditions in the Central NE Pacific Ocean known as the "warm blob" (Bond et al. 2015) has also had a strong influence on both terrestrial and marine habitats. Here, we briefly describe the features as they affect both marine and terrestrial environments.

### The warm blob

Surface waters in the North Pacific ocean have been warmer than average since late fall 2013, when the "warm blob" first developed in the central Gulf of Alaska (Bond et al. 2015). The warm blob was caused by lower than normal heat loss from the ocean to the atmosphere and of relatively weak mixing of the upper ocean, due to unusually high and persistent sea level pressure. Temperature anomalies of the near-surface (upper ~100 m) waters exceeded 3°C in January 2014, or four standard deviations (Freeland and Whitney 2014). These anomalies were the greatest observed in this region and season since at least the 1980s and possibly as early as 1900 (Bond et al. 2015).

The region of warm sea-surface temperature (SST) anomalies was isolated to offshore waters during winter 2013–2014 (Fig. 22). It spread into the coastal domain of Alaska and northern British Columbia in May 2014, and then into the nearshore waters of the Pacific Northwest in September 2014, causing rapid increases in SSTs (Chandler et al. 2015). For example, surface temperatures recorded at Stonewall Bank (NOAA Buoy 46050; 20 nautical miles west of Newport, Oregon), increased by 5.6°C during a 21 hour period on 14–15 September 2014 (Fig. 23), as the warm blob moved ashore[38]. Sea surface temperatures across the NE Pacific have continued to be 1–3°C above average during winter and spring of 2015[39].

### Pacific Decadal Oscillation

The PDO describes the most prominent mode of variability in the North Pacific sea surface temperature field (Mantua et al. 1997). Positive values are characterized by warm SSTs along the West Coast of North America and cold SSTs in the central North Pacific, while negative values have the opposite pattern (cold along the coast and warm in the central North Pacific). The PDO also influences freshwater habitats, especially during winter. Positive PDO values are associated with warm and dry Pacific Northwest winters and therefore low snowpack, while negative values are associated with cold wet winters (high snowpack) (Mantua et al. 1997).

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[38] Available online at: www.ndbc.noaa.gov/.

[39] Available online at: http://polar.ncep.noaa.gov/sst/ophi/.

Because the PDO is a measure of SSTs and the eastern North Pacific Ocean has been extremely warm, the PDO has been positive since January 2014. It reached the highest monthly levels ever observed during December 2014 (+2.51), and January (+2.45) and February (+2.3) 2015 (Fig. 24). As long as marine water remains warm along the West Coast, the PDO will remain positive. Current forecasts of global water temperatures (from the NOAA NCEP coupled forecast system model version 2)[40] indicate SSTs along the West Coast will remain 0.5-1.0°C above average through July-August-September 2016, and slightly above average (0.25-0.5°C) through the fall (September-October-November 2016). If this occurs, the PDO will remain positive at least through summer 2016. Model predictions, that take into account persistence of the past year's PDO index value and a forecast of the next year's El Niño status, also indicate the PDO will remain strongly positive until at least June 2016[41].

## El Niño-Southern Oscillation

El Niño-Southern Oscillation (ENSO) is a tropical phenomenon that influences climate patterns around the globe. Much like the PDO, the warm phase (El Niño) is characterized by warm SSTs along the West Coast of North America, while negative values (La Niña) produce cold SSTs along the coast. Like the PDO, ENSO also influences terrestrial environments, and Pacific Northwest winter snowpack is low during warm El Niño events and high during cool La Niña years.

The Oceanic Niño Index (ONI) is the three-month running-mean SST departures in the Niño 3.4 region[42] (Fig. 25). El Niño events are defined as positive ONIs greater than or equal to +0.5ºC, while La Niña events have a negative ONI less than or equal to -0.5ºC. These thresholds must be exceeded for a period of at least 5 consecutive overlapping 3-month seasons. The ONI first exceeded +0.5 ºC during the September–October–November period, and has remained above 0.5 ºC since then (Fig. 24). Based on this criterion, a weak El Niño was declared in April 2015.

The current status (as of 21 March 2016) is that a strong El Niño is present, with a likely transition to El Niño neutral conditions in spring or early summer 2016. Maximum SST anomalies in the Niño 3.4 region reached 3.1ºC in mid-November 2015, making it comparable in strength to the 1997/98 event, which was the strongest of the previous century. The current forecast indicates over a 50% chance that a La Niña will develop in the fall of 2016.

## Freshwater environments

As described above, sea surface temperatures across the Northeast Pacific Ocean were anomalously warm during 2014 and 2015. This warm water offshore contributed to above average terrestrial temperatures in the Pacific Northwest (Bond et al. 2015). Mean air temperatures for Washington, Oregon, and Idaho were the warmest on record for the 36 month

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[40] Available online at: http://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml.

[41] Nate Mantua, SWFSC, NOAA Fisheries. Pers. commun. to Laurie Weitkamp, NWFSC, NMFS, 6 October 2015.

[42] Available online at: http://www.cpc.ncep.noaa.gov/.

period ending in February 2016 (from a 119 year record starting in 1895). These exceptionally warm air temperatures were most pronounced during the second half of 2014 (warmest July–December on record), and the first half of 2015 (warmest January–June on record), and less extreme during the first half of 2014 (12th warmest during January–June 2014) and 2nd half of 2015 (7th warmest during July-December 2015)[43].

In contrast, precipitation in the Pacific Northwest has generally been higher than normal since January 2014. Specifically, precipitation in the three state area was above average in the first half of 2014 (33rd wettest), the 2nd half of 2014 (also 33rd wettest), and the second half of 2015 (14th wettest). The notable exception was the first half of 2015, when precipitation from January to June 2015 was the 7th driest on record[44].

The exceptionally warm air during the winter of 2014/2015 and below average precipitation from January–April resulted in anomalously low snow pack conditions in the Olympic and Cascade Mountains, with most areas having less than 25% of average snow pack in April 2015 (compared to the 1981–2010 record). Many areas—especially in the southern Oregon Cascades and Sierra Nevada—that typically have continuous snow coverage during the winter had no measurable snow. Consequently, by June 2015, most basins in Washington, Idaho, Oregon, California and Nevada had 0% of normal snow pack[45]. A similar pattern was observed in southern British Columbia, where snow pack in coastal drainages of the Strait of Georgia had less than 50% of average snowpack in winter 2014/2015. Basins farther inland (interior Fraser River and upper Columbia River) were closer to average but no areas had above average snow pack[46].

This lack of snowpack and anomalously low precipitation from January to June had large impacts on river discharge throughout the Pacific Northwest. Stream flow in June 2015 in most small and large Washington and Oregon rivers was below average[47]. During June, the Columbia River near Quincy, WA (USGS Station 14246900) was flowing at roughly 70% of its normal rate (230 KCFS vs the long term average of 330 KCFS; Fig. 27). Flow in the Fraser River was also much lower than average during July and August of 2015, when rates measured at Hope, British Columbia, were 28%–33% of average[48]. These low flow rates throughout the Northwest remained below normal through fall 2015[49].

The combined effects of low flows and high air temperatures are expected to result in higher than normal stream temperatures, although the extent to which this is true is not presently

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[43] Available online at: http://www.ncdc.noaa.gov/cag/.

[44] Available online at: http://www.ncdc.noaa.gov/temp-and-precip/climatological-rankings.

[45] Available online at: www.wcc.nrcs.usda.gov/gis/snow.html.

[46] Available online at: http://bcrfc.env.gov.bc.ca/bulletins/watersupply/SnowIndexMap.htm.

[47] Available online at: waterdata.usgs.gov/or/nwis/sw.

[48] Available online at: http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/index-eng.html.

[49] Available online at: www.nwrfc.noaa.gov/ws/.

known because most water temperature time series formerly available from the USGS have been terminated. In June 2015, when larval eulachon may still have been out-migrating, the Columbia River at the Dalles Dam was 3.6°C above normal (19.1°C vs. 15.3°C) and the Willamette River at Portland (USGS Station 14211720) was 5.3°C above average (Fig. 27). The Fraser River was 3.2°C above average in early June (15.4°C vs. 12.2°C)[50].

## Biological Consequences of Marine Environmental Conditions

Eulachon are a cold water species, therefore current elevated temperatures in both freshwater and marine habitats are expected to be detrimental to their growth and survival. In marine environments, however, environmental conditions also have large indirect effects on eulachon. This occurs because temperature changes are typically associated with different parcels of water, which come with their own planktonic ecosystem, including eulachon prey and predators.

### Pacific decadal oscillation

As part of the original description of PDO, Mantua et al. (1997) demonstrated that changes in the PDO were related to changes in Pacific salmon populations from Alaska to California in an inverse pattern: positive PDO values were associated with high salmon catches in Alaska and low catches in the Columbia River and Washington, Oregon, and California, while negative PDO values had the opposite effect: low salmon catches to the north and high in the south. Since the original publication, many additional studies have related the phase of the PDO to the dynamics of marine species indicating it describes conditions that are important for survival. For example, species in the Northern California Current that benefit from negative PDOs (cool water off the Washington/Oregon coast) include Columbia River salmon and northern copepods, and recruitment of both northern anchovies and Dungeness crab, whereas species that prosper during positive PDOs include southern copepods and sardines (Peterson and Schwing 2003, Lindegren et al. 2013, Shanks 2013). Clearly, the PDO captures important variability in physical environments that drive the productivity of the coastal ecosystem and likely has profound effects on eulachon marine survival.

### El Niño events

The biological effects at higher trophic levels of large El Niño events in the California Current are less predictable and poorly understood than changes in the PDO. This occurs because large El Niño events are relatively infrequent (the last two large events occurred in 1982/83 and 1997/98), and El Niño events are tropical phenomena with variable impacts on extra-tropical systems such as the California Current (Huyer et al. 2002). That said, the typical El Niño year impacts in the California Current are similar to those associated with the warm phases of the PDO, and in some extreme cases much more dramatic (like those associated with the extreme 1982/83 and 1997/98 El Niño events).

Several important biological impacts were noted during the last two extreme El Niño events. During both events, there were dramatic increases in poleward flow, elevated

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[50] Available online at: http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/index-eng.html

temperatures to 200 m depth, and reduced upwelling and greatly reduced nutrient levels (Pearcy and Schoener 1987, Huyer et al. 2002). The biological impact of these conditions resulted in changes throughout the ecosystem. During the 1982/83 event, primary and secondary production was greatly reduced from southern California to Vancouver Island, especially in 1983 (Pearcy and Schoener 1987). During the 1997/98 event, the copepod assemblage along the Newport Hydrographic (NH) line became dominated by southern and offshore species starting in late summer 1997, while normally dominant boreal species had almost completely disappeared; the overall abundance of copepods was also greatly reduced. These changes to the copepod assemblage persisted for roughly a year, although some boreal species did not recover to normal levels until the summer of 1999 (Peterson et al. 2002).

Changes were also observed at higher trophic levels during both strong El Niño events. There were unusual sightings of a variety of subtropical (and largely predatory) fishes along the Coast of Oregon, including Dorado (*Coryphaena hippurus*), Yellowtail (*Seriola lalandi*), California barracuda (*Sphyraena argentea*), and striped marlin (*Tetrapturus audux*), many of which were range extensions (Pearcy and Schoener 1987, Pearcy 2002). The 1997/98 event was also the first time Humboldt squid (*Dosidicus gigas*) had been observed so far north, although it has since been found as far north as Sitka, Alaska (Wing 2006, Litz et al. 2011). Like the influx of warm water fishes to the Oregon Coast, there was also influx of warm-water cetaceans to Monterey Bay during 1997 and concurrent decline of cold-water cetaceans during the El Niño (Benson et al. 2002). Sea bird numbers were also negatively impacted by the 1983 El Niño (Pearcy and Schoener 1987).

The impacts of these strong El Niño events on the southern DPS of eulachon are difficult to evaluate in retrospect, because there was no monitoring of eulachon population abundance at the time of the 1982/83 event and the only population undergoing monitoring during the 1997/98 event was the Fraser River subpopulation. In addition, the general decline of eulachon began in 1993 in the Columbia River, and abundance and fisheries collapsed in the mid 2000's in the Fraser River and in Central and Northern British Columbia rivers (JCRMS 2014). These declines apparently occurred independently of the various El Niño events.

As noted above, Pacific Northwest ocean conditions became unusually warm early in 2014, and are currently at or near record warm temperatures for much of the northeast Pacific Ocean. There is an abundance of evidence highlighting impacts on coastal marine ecosystems, including sea bird die offs, range shifts for subtropical fish and plankton, etc. Eulachon entering the coastal ocean in 2015 may have experienced especially poor ocean conditions. The expected impacts of the 2015/16 El Niño include intense winter downwelling, increased northward moving currents, increased upper ocean stratification, and overall reduced productivity. These conditions will likely prime the Pacific Northwest's coastal ocean for very poor productivity in spring 2016. Combining the expected El Niño effects over the next 6 to 8 months with existing warm ocean conditions will likely lead to poor or perhaps very poor early marine survival for eulachon going to sea in spring 2016[51].

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[51] Nate Mantua, SWFSC, NMFS. Pers. commun., 6 October 2015.

## NWFSC ocean indicators

The NWFSC has been using of a suite of physical and biological ocean indicators to describe the conditions experienced by juvenile salmon entering marine waters in the Northern California Current. These indicators—both individually and collectively—have been shown to influence juvenile salmon growth and survival (see Peterson et al. 2014a). While these indicators were selected specifically for juvenile salmon, a recent analysis suggests they capture ecosystem variation important to the recruitment of non-salmonid species, including sablefish, rockfish and sardines (Peterson et al. 2014b). These indicators include physical processes or conditions at ocean-basin scales (PDO, ONI), and regional/local scales (water temperature and salinity at surface and depth), and biological conditions (copepod composition, winter ichthyoplankton) (Peterson et al. 2014a).

The copepod community on the Newport Hydrographic (NH) line has received particular emphasis in the NWFSC indicators because copepods are planktonic and drift with the ocean currents. Therefore, the type of copepods found on the NH line reflects the type of water being transported into the Northern California Current: the presence of subtropical (southern) species off Oregon indicates transport of subtropical water from the south, while subarctic (northern) species indicates transport of coastal, subarctic waters from the north. Southern copepods typically dominate the winter copepod community and northern copepods dominate the summer community, with the "biological spring transition" index defining when it switches from one to the other. Northern copepods have much higher lipid levels than southern copepods (Peterson et al. 2014a), and therefore likely produce food webs that promote high growth and survival in eulachon.

During winter/spring of 2015, 17 species of copepods were caught within 25 miles of shore on the NH line that had never been observed on the line in 20 years of biweekly sampling (Bill Peterson, NWFSC, unpubl. data). These species were all subtropical or pelagic species, suggesting that subtropical offshore water was present on the continental shelf. Unusual copepods were also observed on the NH line during the 1997/98 El Niño, but the observations in 2015 far surpass the 1997/98 El Niño event. The biological transition in spring 2015 was also extremely late (late June), and the abundance of northern copepods was extremely low during summer 2015, suggesting a poor base for the food chain[52]. In addition to changes in the copepod community, during summer 2015 there was also a notable absence of adult euphausiids and an increase in gelatinous species including pelagic tunicates (doliolids), molluscs (Carinariidae), and cnidaria (jellyfish)[31].

Although diets of postlarval and juvenile (20–69 mm FL) eulachon have only been examined in the Strait of Georgia, stomach contents included phytoplankton, barnacle eggs, barnacle nauplii, copepod eggs, copepod nauplii, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Acartia* sp., *Microcalanus pygmaeus*, *Calanus* sp.), cladocerans, ostracods, mysiids, and larvaceans (*Oikopleura* sp.) (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968a, 1968b). Larger specimens of eulachon (91–157 mm FL) collected in the Strait of Georgia had consumed barnacle eggs, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Calanus* sp.), cladocerans, and gammaridean amphipods (Robinson et al. 1968a, 1968b).

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[52] Bill Peterson, NWFSC, NMFS. Pers. commun. to Laurie Weitkamp, NWFSC, NMFS.

Elsewhere, adult eulachon have variously been reported to consume cumaceans (Smith and Saalfeld 1955); euphausiids and copepods (Hart 1973); euphausiids, crustaceans, and cumaceans (Scott and Crossman 1973); and the euphausiid *Thysanoessa spinifera* (Hay 2002). Thus eulachon, not only directly consume various life stages of copepods, but are also dependent on other species in food webs whose productivity depends on the abundance of northern copepods.

### State of the California Current report

Many of the ocean indicators used by NWFSC are also described in the annual State of the California Current Report (SCCR), which is focused on the entire California Current, from the US-Canada border to the US-Mexico border (CCIEAT 2015, 2016). The SCCR also describes the current state of additional indicators, including the North Pacific Gyre Oscillation (NPGO), upwelling, dissolved oxygen levels, and ocean acidification, and abundances of forage fish, salmon, groundfish, marine mammals, and seabirds. Notable changes in these indicators during 2014 were a decrease in the NPGO index and weaker than normal downwelling during winter 2014 and a late physical spring transition (when the slope of cumulative upwelling becomes positive) at 45°N. Both the decline in the NPGO and the late timing of the spring transition are associated with reduced productivity.

The SCCR covering conditions in 2015 (CCIEAT 2016) describe a continuation of many of the trends observed in 2014. For example, the NPGO remained strongly negative, indicating reduced flow in the California Current and a reduction of cold, productive subarctic waters. Unlike 2014, the spring transition was early in 2015 and upwelling at 45°N was strong throughout the summer, although exceptionally warm waters offshore compressed the zone of cold upwelled water along the coast.

### State of Pacific Canadian marine ecosystems report

Many of the unusual conditions in the California current described above were also present in Canadian waters off the west coast of British Columbia (Chandler et al. 2015). This includes reduced nutrient levels in offshore waters, rapid rise in SSTs as the warm water mass moved onshore, and unusually high abundances of southern copepods during summer 2014. At higher trophic levels, harvest of ocean shrimp off the WCVI was nearly twice as high as the previous maximum, and estimated herring biomass was higher in 2014 than 2013, although there was a marked absence of Pacific sardine in Canadian waters for a second year in a row (Chandler et al. 2015). The warm water was also the likely cause for the extremely high diversion rate of sockeye salmon bound for the Fraser River in 2014, which returned around the north end of Vancouver Island via Johnstone Strait (versus around the south end via Strait of Juan de Fuca) at the highest rate ever recorded.

In contrast to unusual conditions observed off the West Coast of British Columbia, conditions within the Strait of Georgia were not particularly unusual. For example, salinity and temperature of water within the Strait of Georgia was fairly typical to other years during most of 2014, the timing of the phytoplankton bloom was also normal, and juvenile salmon survival was comparable to other recent years. One notable difference was that waters of the Strait of Juan de Fuca were warmer than normal in September and October, reflecting the influence of warm coastal waters off Vancouver Island.

## Expectations for Eulachon

All the above documented changes will likely influence the growth, productivity, survival, and migration of eulachon. Larval and juvenile eulachon are planktivorous and are likely adapted to feed on a northern or boreal suite of copepods during the critical larval/juvenile transition. Warmer ocean conditions may be expected to contribute to a mismatch between eulachon life history and preferred prey species. These conditions would likely have significant negative impacts on marine survival rates of eulachon, and recruitment failure of eulachon may be traced to mortality during this critical period. Eulachon returns to spawning rivers in the southern DPS were poor during the previous period of unfavorable ocean conditions from 2004 to 2008 (JCRMS 2008) and may portend how eulachon will respond to the recent warming ocean conditions.

Pacific hake undergo seasonal migrations from their winter spawning grounds off southern California to their northern feeding grounds off the west coast of Vancouver Island in summer (Ware and McFarlane 1995, Benson et al. 2002). Large adult Pacific hake are known to prey on eulachon and the dominant prey of both small Pacific hake and eulachon are euphausiids (Rexstad and Pikitch 1986, Buckley and Livingston 1997). Beamish et al. (2008, p. 34) stated that “The projected long-term increase in temperatures may result in more offshore hake moving into the Canadian zone, and in the spawning and rearing area off California moving north.” Thus projected ocean warming is likely to result in an altered distribution of both predators on eulachon and competitors for food resources.

## Conclusion

It is likely that current anomalously warm marine and freshwater conditions have been and will be unfavorable in the future for the southern DPS of eulachon. How extreme the effects will be is difficult to predict, although decreased productivity and abundance of the southern DPS of eulachon observed during prior warm periods provide a useful guide.

How long the current conditions will last is also unknown, but NOAA’s coupled forecast system model (CFS version 2) suggests that the warm conditions associated with the strengthening El Niño will persist at least through fall 2016. The model currently predicts temperature anomalies during the September–October–November 2016 period will exceed 1°C at the equator and 0.25–1°C in the Northeast Pacific. Unfortunately, longer forecasts are not available.

However, following the extreme El Niño period of 1997/98 the entire eastern Pacific (Northeast and tropical) went cold for multiple years due to a strong La Niña event and there were also relative increases in eulachon fishery landings in the Columbia River and in Fraser River SSB estimates following those sequential cold year periods. The effects of the current strong El Niño are warming of the coastal North East Pacific that will persist into spring 2016. This spring’s (2016) ocean migrants will likely encounter an ocean strongly influenced by (if not dominated by) a subtropical food-web that favors poor early marine survival for the southern-distributed ocean migrants. However, if the current forecast for a change to La Niña conditions in fall 2016 is correct, outmigrating larval eulachon in spring 2017 will likely encounter conditions that are much more favorable for growth and survival.

Eulachon are a cold water species: they flourish in cold and productive marine ecosystems, such as those present in the early 2010s, resulting in increased abundance in the Columbia River. The exceptionally warm marine waters in 2014, 2015 and early 2016 are likely unfavorable for high marine survival. The overall effects of these environmental conditions will not be known until adults begin returning in late winter of 2015/2016 and early spring of 2016, and continuing for the next few years.

# Risk Summary

## 2010 Status Review

The 2010 BRT determination of overall risk to the southern DPS of eulachon, as reported in the 2010 status review (Gustafson et al. 2010), used these categories: at "high risk of extinction," at "moderate risk of extinction," or "not at risk of extinction." The 2010 BRT adopted a 100-year time frame as the period over which it had confidence in evaluating risk, similar to what other quantitative and qualitative conservation assessments for other species had used in their extinction risk evaluations (Morris et al. 1999, McElhany et al. 2000). The 2010 BRT assessment was guided by the results of a risk matrix analysis that integrated information about demographic risks with expectations about likely interactions with threats and other factors.

The 2010 BRT's scores for overall risk to the southern DPS of eulachon, throughout all of its range, were heavily weighted to moderate risk with this category receiving 60% of the likelihood points. High risk received 32% of the likelihood points and not at risk received 8% of the points. The likelihood methodology was described in Gustafson et al. (2010, p. 171–173). The 2010 BRT was concerned that, although eulachon were a relatively poorly monitored species, most of the available information indicated that the southern DPS of eulachon had experienced an abrupt decline in abundance throughout its range. The 2010 BRT was particularly concerned that two large spawning populations—in the Columbia and Fraser rivers—had declined to what appeared to be historically low levels in the Fraser River and nearly so in the Columbia River. The 2010 BRT was also concerned that there was very little monitoring data available for northern California eulachon, but determined that the available information suggested that eulachon in northern California had experienced an abrupt decline several decades prior to when the 2010 BRT met. The 2010 BRT was also concerned that attempts to estimate actual spawner abundance in some rivers in British Columbia that were known to have supported significant First Nations fisheries in the past had resulted in very low estimates of spawning stock.

In addition, the 2010 BRT was concerned that the then current abundance of the many individual populations within the DPS were sufficiently low to be an additional risk factor, even for populations (such as the Columbia and Fraser) where the absolute population size seems large compared to many other at-risk fish populations. Indeed, the 2010 BRT considered a central question to be whether a DPS or subpopulation may be at risk of extinction when there may be hundreds of thousands or perhaps millions of individuals remaining in the population. In evaluating this issue, the 2010 BRT concluded that eulachon (and other similar forage fishes) (see Dulvy et al. 2004) may be at significant risk at population sizes that are a fraction of their historical levels but are still large compared to what would be considered normal for other ESA listed species.

The 2010 BRT also had concerns about risks related to spatial structure and distribution. In particular, the BRT was concerned that if formerly significant populations in northern California, such as the Klamath River, become extirpated, there would be less opportunity for successful recolonization and this might result in contraction of the southern portion of the DPS's range. In terms of threats related to diversity, the 2010 BRT was also concerned about the apparently very low abundance of the Klamath River subpopulation, which might be expected to have unique adaptations to conditions at the southernmost extent of the range. The 2010 BRT noted that several populations that used to support significant First Nations fisheries on the British Columbia coast had declined to very low levels (e.g., Bella Coola and Wannock rivers). The 2010 BRT also noted some positive signs including observations that eulachon continued to display variation in spawn timing, age-at-maturity, and spawning locations and a high degree of biocomplexity (i.e., many spawning locations and spawn-timing variation) in the Columbia River, which may buffer this stock from freshwater environmental perturbations.

The 2010 BRT was concerned that climate change may have contributed to a mismatch between timing of ocean entry of eulachon larvae and availability of crucial prey species. However, the ability of the Columbia River eulachon stock to respond rapidly to the good ocean conditions of the late 1999–early 2002 period illustrated the species' resiliency, and the 2010 BRT viewed this resiliency as providing the species with a buffer against future environmental perturbations. Cold ocean conditions in the California Current Province in the fall of 2007 and spring-summer of 2008 were considered to be favorable for eulachon[53], and the 2010 BRT postulated that this indicated that elevated levels of eulachon were expected to return starting with the 2011 run year (Gustafson et al. 2010, p. 174). In fact, the year 2011 is when elevated eulachon abundance was first detected in several indices of abundance reviewed in the current document. However, the 2010 BRT was concerned that these changes in the ocean, favorable to eulachon larval survival, might be of short-term duration, similar to the late 1998-early 2002 period.

## Updated Biological Risk Summary

Adult spawning abundance of the southern DPS of eulachon has clearly increased since the listing occurred in 2010. A number of data sources including: 1) SSB estimates in the Columbia and Fraser rivers; 2) CPUE in small mesh bottom trawl surveys off WCVI; 3)

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[53] PDO data available online at: http://jisao.washington.edu/pdo/

incidental catch in the WCBTS; and 4) estimated bycatch in ocean shrimp trawl fisheries, indicate that eulachon abundance in some subpopulations within the southern DPS were substantially higher from 2011–2015 compared to indications of very low abundance from 2005–2010. The improvement in estimated abundance in the Columbia River, relative to the time of listing, reflects both changes in biological status and improved monitoring. The documentation of eulachon returning to the Naselle, Chehalis, Elwha, and Klamath rivers over the 2011–2015 also likely reflects both changes in biological status and improved monitoring.

The 2010 BRT was concerned: 1) that abundance had declined to what appeared to be historically low levels in the Fraser River and nearly so in the Columbia River; 2) that the very limited available monitoring data suggested that eulachon in northern California had experienced an abrupt decline several decades previously; and 3) that attempts to estimate actual spawner abundance in some rivers in British Columbia that were known to have supported significant First Nations fisheries in the past had resulted in very low estimates of spawning stock.

Since the 2010 status review (Gustafson et al. 2010), monitoring of annual abundance of eulachon in several areas of the DPS has increased substantially. Annual monitoring of SSB has continued in the Fraser River (1995–2015), expanded to the Columbia (2011–2015), Grays (2011–2013, 2015), Cowlitz (2015) Naselle (2015), and Chehalis (2015) rivers. In addition, WDFW has retrospectively estimated historical SSB in the Columbia River for 2000–2010 using pre-2011 expansions of eulachon larval densities. These retrospective estimates indicate that total eulachon run biomass in the Columbia River may have been as high as 3,150 mt in 2001 and as low as 35 mt in 2005. Mean SSB over the five-year period (2006–2010) immediately prior to the 2010 BRT's analysis was estimated at 20 mt in the Fraser River and 153 mt in the Columbia River. In contrast, mean SSB over last five years (2011–2015) was estimated at 127 mt in the Fraser River and 4,007 mt in the Columbia River.

The situation in the Klamath River is also more positive than it was at the time of the 2010 status review with adult eulachon presence being documented in the Klamath River in the spawning seasons of 2011–2014, although it has not been possible to calculate estimates of SSB in the Klamath River. However, since Moody's (2008) compilation of information on eulachon abundance, very little additional data on the status of eulachon in coastal rivers north of the Fraser River has become available. Newly obtained CPUE estimates for the Kemano (Fig. 18) and Kitimat (Fig. 19) rivers suggest substantial recent declines without apparent recovery (COSEWIC 2011). Anecdotal observations as reported in several First Nations' newsletters and in annual environmental reports are compiled in Table 8 for this area of the DPS. The Skeena (2010–2015), Kemano (2015), and Kingcome (2012) rivers have apparently supported substantial runs of spawning eulachon in recent years; however, eulachon in the Kitimat River (2012, 2014) have reportedly remained at low levels (Table 8).

Although eulachon abundance in monitored populations has generally improved, especially in the 2013–2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years. Therefore, it is too early to tell whether recent improvements in the southern DPS of eulachon will persist or whether a return to the severely depressed abundance years of the mid-late 1990s and late 2000s will reoccur.

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Table 1. Estimated spawning stock biomass (SSB) in metric tons in the Columbia River Basin above Grays River from 2011 to 2015 (eulachon spawn from November to April in the Columbia River and the spawn year is designated as the year beginning on January 1). Data from James et al. (2014), Langness (2015).

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| | | | | Estimated biomass (mt) | | | Estimated number of spawners | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Days sampled | Mean egg and larval density (#/$m^3$) | Mean egg and larval outflow | Mean | Lower 95% CI | Upper 95% CI | Mean | Lower 95% CI | Upper 95% CI |
| 2011 | 29 | 6.64 | 6.0 x $10^{11}$ | 1,500 | 900 | 2,200 | 36,800,000 | 22,600,000 | 55,400,000 |
| 2012 | 34 | 4.88 | 5.8 x $10^{11}$ | 1,500 | 1,000 | 2,100 | 35,700,000 | 23,900,000 | 50,500,000 |
| 2013 | 43 | 14.56 | 1.8 x $10^{12}$ | 4,400 | 2,600 | 6,500 | 107,700,000 | 63,500,000 | 159,700,000 |
| 2014 | 27 | 33.83 | 3.0 x $10^{12}$ | 7,300 | 4,500 | 10,400 | 180,000,000 | 110,000,000 | 260,000,000 |
| 2015 | 33 | 22.57 | 2.0 x $10^{12}$ | 5,000 | 3,200 | 7,000 | 123,582,000 | 79,400,000 | 172,700,000 |

Table 2. Estimated eulachon spawning stock biomass (SSB), harvest in Columbia River Basin fisheries, and estimated run size biomass in metric tons in the Columbia River Basin above Grays River from 2000 to 2015 (eulachon spawn from November to April in the Columbia River and the spawn year is designated as the year beginning on January 1). Data from James et al. (2014), Langness et al. (2015), Langness (2015), and B. James and O. Langness (WDFW, pers. commun.,). B. James and O. Langness (WDFW, pers. commun.) assume historical 2000–2010 recreational fishery landings were equal to tributary commercial dipnet landings, 2014 recreational fishery landings are on field surveys by WDFW. Pre-2011 adjusted SSB estimates are based on historical Columbia River water discharge rates and expansions of historical larval densities adjusted for the shorter duration of the pre-2011 surveys (B. James and O. Langness, WDFW, pers. commun.).

| Year | Mainstem commercial fishery (mt) | Tributary commercial fishery (mt) | Recreational fishery (mt) | Tribal fisheries (mt) | All fisheries total (mt) | Mean SSB (mt) | Adjusted SSB (mt) | Total run biomass (mt) | Total number of fish at 11.2/lb. | Exploitation rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 13.06 | 0.00 | 0.00 | | 13.06 | -- | 207 | 220 | 5,440,960 | 5.9 |
| 2001 | 72.03 | 69.99 | 69.99 | | 212.01 | -- | 2,938 | 3,150 | 77,790,720 | 6.7 |
| 2002 | 26.31 | 300.82 | 300.82 | | 627.95 | -- | 1,775 | 2,403 | 59,326,400 | 26.1 |
| 2003 | 30.35 | 461.08 | 461.08 | | 952.50 | -- | 1,676 | 2,628 | 64,901,760 | 36.2 |
| 2004[1] | 6.71 | 98.07 | 98.07 | | 202.85 | -- | -- | -- | -- | -- |
| 2005 | 0.05 | 0.05 | 0.05 | | 0.14 | -- | 35 | 35 | 875,840 | 0.4 |
| 2006 | 5.94 | 0.00 | 0.00 | | 5.94 | -- | 53 | 59 | 1,464,960 | 10.0 |
| 2007 | 3.95 | 0.54 | 0.54 | | 5.03 | -- | 112 | 117 | 2,879,520 | 4.3 |
| 2008 | 5.17 | 2.68 | 2.68 | | 10.52 | -- | 100 | 110 | 2,723,840 | 9.5 |
| 2009 | 2.49 | 5.49 | 5.49 | | 13.47 | -- | 381 | 395 | 9,746,240 | 3.4 |
| 2010 | 1.59 | 0.00 | 0.00 | | 1.59 | -- | 80 | 81 | 2,020,480 | 1.9 |
| 2011[2] | -- | -- | -- | -- | -- | 1,495 | na | 1,495 | 36,926,400 | 0.0 |
| 2012[2] | -- | -- | -- | -- | -- | 1,451 | na | 1,451 | 35,825,440 | 0.0 |
| 2013[2] | -- | -- | -- | 2.72 | 2.72 | 4,374 | na | 4,377 | 108,074,400 | 0.1 |
| 2014 | 8.44 | -- | 92.49 | 7.94 | 108.86 | 7,435 | na | 7,544 | 186,279,520 | 1.4 |
| 2015 | 7.48 | -- | 131.90 | 4.63 | 144.02 | 5,021 | na | 5,165 | 127,540,000 | 2.8 |
| 2016[3] | 2.16 | -- | 63.98 | | | | na | | | |

[1] A **larval** survey was conducted in 2004; however, detailed daily larval density data for that year is unavailable.

[2] Columbia River Basin Commercial and recreational fisheries were closed in 2011-2013.

3 Columbia River Basin SSB and tribal fisheries data for 2016 are not yet available.

Table 3. Estimated spawning stock biomass (SSB) in metric tons in Grays River from 2011 to 2015 (eulachon spawn from November to April; however, the spawn year is designated as the year beginning on January 1). Data from James et al. (2014), Langness et al. (2015), Langness (2015) and James (2015).

| | | | | Estimated biomass (mt) | | | Estimated number of spawners | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Days sampled | Mean egg and larval density (#/$m^3$) | Mean egg and larval outflow | Mean | Lower 95% CI | Upper 95% CI | Mean | Lower 95% CI | Upper 95% CI |
| 2011 | 13 | 0.31 | $1.8 \times 10^8$ | 0.3 | | | 8,200 | | |
| 2012 | 13 | 1.53 | $1.6 \times 10^8$ | 0.4 | | | 9,700 | | |
| 2013 | 19 | 1.61 | $4.2 \times 10^8$ | 1.0 | | | 25,800 | | |
| 2014 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2015 | 17 | 12.06 | $3.0 \times 10^9$ | 7.5 | 5.1 | 10.2 | 185,400 | 125,800 | 251,500 |

Table 4. Estimated spawning stock biomass (SSB) in metric tons in Cowlitz River in 2015 (eulachon spawn from November to April; however, the spawn year is designated as the year beginning on January 1). Data from Nathan Reynolds, Cowlitz Indian Tribe, PowerPoint presentation at Eulachon State of the Science and Science to Policy Forum, Portland, OR., 21 August 2015.

| | | | | Estimated biomass (mt) | | | Estimated number of spawners | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Days sampled | Mean egg and larval density (#/$m^3$) | Mean egg and larval outflow | Mean | Lower 95% CI | Upper 95% CI | Mean | Lower 95% CI | Upper 95% CI |
| 2015 | 37 | -- | $690.4 \times 10^9$ | 4,412.6 | 2,961.1 | 5,998.8 | 108,604,000 | 72,880,000 | 147,645,000 |

Table 5. Estimated spawning stock biomass (SSB) in metric tons in the Naselle River in 2015 (eulachon spawn from November to April; however, the spawn year is designated as the year beginning on January 1). Data from Langness (2015).

| Year | Days sampled | Mean egg and larval density (#/$m^3$) | Mean egg and larval outflow | Estimated biomass (mt) Mean | Estimated biomass (mt) Lower 95% CI | Estimated biomass (mt) Upper 95% CI | Estimated number of spawners Mean | Estimated number of spawners Lower 95% CI | Estimated number of spawners Upper 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2012 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2013 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2014 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2015 | 19 | 2.63 | $5.9 \times 10^8$ | 1.5 | 1.1 | 1.9 | 36,400 | 27,400 | 46,000 |

Table 6. Estimated spawning stock biomass (SSB) in metric tons in the Chehalis River in 2015 (eulachon spawn from November to April; however, the spawn year is designated as the year beginning on January 1). Data from Langness (2015).

| Year | Days sampled | Mean egg and larval density (#/$m^3$) | Mean egg and larval outflow | Estimated biomass (mt) Mean | Estimated biomass (mt) Lower 95% CI | Estimated biomass (mt) Upper 95% CI | Estimated number of spawners Mean | Estimated number of spawners Lower 95% CI | Estimated number of spawners Upper 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2012 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2013 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2014 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2015 | 21 | 1.18 | $4.4 \times 10^9$ | 11.0 | 7.2 | 15.4 | 272,000 | 177,400 | 379,700 |

Table 7. Estimated eulachon spawner biomass (metric tons) in the North and South Arm of the Fraser River and total number of eulachon, assuming a range of 9.9 to 13.3 eulachon to the pound, based on the mean reported weight of eulachon in the Fraser River of 34 to 46 g. Biomass data online at: http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/river1-eng.html. New information in bold.

| Year | South Arm | North Arm | Total biomass (mt) | Total biomass (pounds) | Number of fish at 9.9 per pound | Number of fish at 13.3 per pound |
|---|---|---|---|---|---|---|
| 1995 | 258 | 44 | 302 | 665,796 | 6,591,381 | 8,855,087 |
| 1996 | 1,582 | 329 | 1,911 | 4,213,034 | 41,709,035 | 56,033,350 |
| 1997 | 57 | 17 | 74 | 163,142 | 1,615,107 | 2,169,790 |
| 1998 | 107 | 29 | 136 | 299,829 | 2,968,304 | 3,987,721 |
| 1999 | 392 | 26 | 418 | 921,532 | 9,123,169 | 12,256,379 |
| 2000 | 76 | 54 | 130 | 286,601 | 2,837,349 | 3,811,793 |
| 2001 | 422 | 187 | 609 | 1,342,615 | 13,291,890 | 17,856,782 |
| 2002 | 354 | 140 | 494 | 1,089,084 | 10,781,927 | 14,484,812 |
| 2003 | 200 | 66 | 266 | 586,430 | 5,805,653 | 7,799,514 |
| 2004 | 24 | 9 | 33 | 72,753 | 720,250 | 967,609 |
| 2005 | 14 | 2 | 16 | 35,274 | 349,212 | 469,144 |
| 2006 | 24 | 5 | 29 | 63,934 | 632,947 | 850,323 |
| 2007 | 34 | 7 | 41 | 90,390 | 894,856 | 1,202,181 |
| 2008 | 8 | 2 | 10 | 22,046 | 218,258 | 293,215 |
| 2009 | 12 | 2 | 14 | 30,865 | 305,561 | 410,501 |
| **2010** | **4** | **<1** | **4** | **8,818** | **87,303** | **117,286** |
| **2011** | **19** | **12** | **31** | **68,343** | **676,599** | **908,966** |
| **2012** | **78** | **42** | **120** | **264,554** | **2,619,092** | **3,518,578** |
| **2013** | **59** | **41** | **100** | **220,462** | **2,182,576** | **2,932,148** |
| **2014** | **53** | **13** | **66** | **145,505** | **1,440,500** | **1,935,218** |
| **2015** | **185** | **132** | **317** | **698,865** | **6,918,767** | **9,294,909** |

Table 8. Qualitative assessments of eulachon run strength for rivers north of the Fraser River, 1991–2014. New Information in bold.

| Year | Klinaklini River | Kingcome River | Bella Coola River | Rivers Inlet | Kemano River | Kitimat River | Skeena River |
|---|---|---|---|---|---|---|---|
| 1991 | | | | | | Last strong run[a] | |
| 1992 | | | | | | | |
| 1993 | | | | | | | |
| 1994 | | | | | | | |
| 1995 | ≈15% of the historic run size[a] | | | | | | |
| 1996 | | | Last large run[a] | | | | |
| 1997 | | | | | | | |
| 1998 | | | Average run[a] | | | Nonexistent[b] | Very few[a] |
| 1999 | | | No run[a]<br>Small run[b] | No run[b]<br>Run failed[a] | Negligible[b] | Nonexistent[b] | Very few[a] |
| 2000 | None or poor[b]<br>Very low[c] | No run[b] | No run[c] | No run[b] | Kowesas–low[b]<br>Kemano–low[b]<br>Kitlope–low[b] | Very low in 2000[c] | Little activity observed[c] |
| 2001 | | Improved run[a] | | No catch[a] | Low catch[a] | | |
| 2002 | | Good run[a] | | No catch[a] | Low catch[a] | | |
| 2003 | | Poor run[a] | | No catch[a] | | Good[c] | |
| 2004 | Low returns[a] | Poor run[a] | Run virtually gone[c] | No catch[a] | Good spawning success[d] | | |
| 2005 | Low returns[a] | Average run[a] | | Run size of 2,700[a] | Almost no eulachon returned[e] | | Good run[a] |
| 2006 | | Run absent[a] | Run virtually gone[c] | Run size of 23,000[a] | No significant eulachon returns[f] | Lowest on record, <1,000 spawners[a] | Virtually no run[a] |
| 2007 | Very good run[a] | Small returns[a] | | | In estuary but did not ascend the river[a]<br>**- very low spawning eulachon return**[g] | Small run of short duration[h] | |
| **2008** | | | | | **almost no spawning eulachon returned**[i] | | |
| **2009** | | | | | | | |

| Year | Klinaklini River | Kingcome River | Bella Coola River | Rivers Inlet | Kemano River | Kitimat River | Skeena River |
|---|---|---|---|---|---|---|---|
| **2010** | | | | | | | **Very good run, comparable to the 1930s**[j] |
| **2011** | | | | | **No observable adults**[k] | | **Good run**[j] |
| **2012** | | **Tonnes of eulachon … [were] netted [in late April]**[l] | | | | **Less than 40 adults**[k] | **Good run**[j] |
| **2013** | | | | | | | |
| **2014** | | | | | **Small run on 9 March 2014**[k] | **Three adults caught on 22 March**[k] | |
| **2015** | | | | | **Conservative estimate of approximately 120 ton[s] … with about 40 ton[s] taken for food**[m] | **First eulachon was caught … on March 1, 2015**[m] | |

[a] Moody and Pitcher (2010)
[b] Hay and McCarter (2000)
[c] Appendix C in Pickard and Marmorek (2007)
[d] Alcan (2005)
[e] Alcan (2006)
[f] Alcan (2007)
[g] Alcan ( 2008)
[h] Kitamaat Village Council (2007)
[i] Alcan ( 2009)
[j] COSEWIC (2013)
[k] Dootilh (2014)
[l] Tsit’sak’ala_m (2012)
[m] Dootilh (2015)

Table 9. Estimated eulachon fishery catch (mt) on the Kemano River (data from COSEWIC 2011 and sources sited therein). According to COSEWIC (2011, table 7) “adjusted catch” means that hailed catch information was adjusted by the ratio of measured over hailed catches, based on a subset of measured catches. More recent anecdotal information on the run strength of Kemano River eulachon is summarized in Table 7. New information in bold.

| Year | Adjusted catch (mt) | Effort (sets) | CPUE (mt per set) |
|---|---|---|---|
| 1969 | **30.8** | | |
| 1970 | **45.4** | | |
| 1971 | **18.1** | | |
| 1972 | **45.4** | | |
| 1973 | **81.7** | | |
| 1974 | | | |
| 1975 | | | |
| 1976 | | | |
| 1977 | | | |
| 1978 | | | |
| 1979 | | | |
| 1980 | | | |
| 1981 | | | |
| 1982 | | | |
| 1983 | | | |
| 1984 | | | |
| 1985 | | | |
| 1986 | | | |
| 1987 | | | |
| 1988 | 43.2 | **20** | **2.2** |
| 1989 | 50.2 | **18** | **2.8** |
| 1990 | 44.1 | **25** | **1.8** |
| 1991 | 57.2 | **18** | **3.2** |
| 1992 | 65.4 | **19** | **3.4** |
| 1993 | 93.0 | **34** | **2.7** |
| 1994 | 20.6 | **23** | **0.9** |
| 1995 | 69.2 | **79** | **0.9** |
| 1996 | 81.0 | **57** | **1.4** |
| 1997 | 41.9 | **22** | **0.8** |
| 1998 | 61.7 | **27** | **2.3** |
| 1999 | | | |
| 2000 | **1.8** | **11** | **0.2** |
| 2001 | **5.1** | **13** | **0.4** |
| 2002 | **2.9** | **15** | **0.2** |
| 2003 | **73.9** | **62** | **1.0** |
| 2004 | **59.0** | **64** | **0.5** |
| 2005 | | | |
| 2006 | | | |
| 2007 | **0.2** | **<1** | **0.1** |

Table 10. Estimated eulachon fishery catch (numbers of fish) and CPUE of gillnet collections on the Kitimat River. Data from COSEWIC (2011, table 6) and sources sited therein. More recent anecdotal information on the run strength of Kitimat River eulachon is summarized in Table 7. New information in bold.

| Year | Total catch (numbers of fish) | CPUE |
|---|---|---|
| 1985 | | |
| 1986 | | |
| 1987 | | |
| 1988 | | |
| 1989 | | |
| 1990 | | |
| 1991 | | |
| 1992 | | |
| 1993 | | |
| 1994 | **1,257** | **59.86** |
| 1995 | **2,157** | **56.76** |
| 1996 | **1,547** | **49.87** |
| 1997 | | |
| 1998 | **27** | **0.90** |
| 1999 | **25** | **0.61** |
| 2000 | **31** | **0.25** |
| 2001 | **174** | **1.54** |
| 2002 | **41** | **0.44** |
| 2003 | **121** | **1.17** |
| 2004 | **33** | **0.27** |
| 2005 | **141** | **0.96** |
| 2006 | **5** | **0.04** |
| 2007 | **92** | **0.37** |

Table 11. Estimated average contribution of eulachon from each DU (designatable unit) and the Columbia River in samples from offshore areas between 2002 and 2014 based on genetic assignment of samples to updated baseline data using 14 microsatellite loci for population identification. Data from S. MacConnachie, Fisheries and Oceans Canada, Nanaimo, BC, Canada. Powerpoint presentation at Eulachon State of the Science to Policy Forum, Portland, OR, 21 August 2015.

| | | | Estimated percentage genetic assignment by population | | | |
|---|---|---|---|---|---|---|
| Offshore Sampling Region | Year | | Nass-Skeena | Central Coast Rivers | Fraser River | Columbia River |
| BC North Coast | 2002 | | 39.3 | 58.3 | 1.0 | 1.1 |
| | 2003 | | 40.2 | 50.2 | 8.7 | 0.9 |
| | | **Mean** | **39.8** | **54.3** | **4.9** | **1.0** |
| BC Central Coast | 2002 | | 76.8 | 22.2 | 0.4 | 0.7 |
| | 2006 | | 53.8 | 27.8 | 10.5 | 7.9 |
| | 2007 | | 44.1 | 35.0 | 19.2 | 1.7 |
| | 2008 | | 27.9 | 20.3 | 20.4 | 31.4 |
| | 2009 | | 17.7 | 9.0 | 38.9 | 34.4 |
| | 2010 | | 18.7 | 12.1 | 35.2 | 34.0 |
| | 2011 | | 46.5 | 28.4 | 13.3 | 11.8 |
| | 2012 | | 68.0 | 28.7 | 0.9 | 2.4 |
| | 2013 | | 15.9 | 5.3 | 28.9 | 49.9 |
| | | **Mean** | **41.0** | **21.0** | **18.6** | **19.4** |
| WCVI | 2002 | | 1.5 | 1.0 | 29.2 | 68.3 |
| | 2006 | | 4.1 | 6.1 | 31.6 | 58.3 |
| | 2007 | | 7.2 | 0.7 | 7.2 | 69.2 |
| | 2008 | | 0.6 | 0.6 | 40.3 | 58.6 |
| | 2009 | | 1.6 | 0.8 | 18.9 | 78.8 |
| | 2010 | | 2.2 | 1.9 | 39.9 | 56.0 |
| | 2011 | | 0.5 | 0.6 | 22.4 | 76.6 |
| | 2012 | | 1.5 | 0.9 | 29.5 | 68.1 |
| | 2013 | | 0.5 | 0.4 | 26.8 | 72.3 |
| | 2014 | | 1.6 | 1.5 | 34.8 | 62.2 |
| | | **Mean** | **2.1** | **1.5** | **28.1** | **66.8** |

Table 12. Qualitative threat level and numerical and color coding. The level of threat severity is based on the 2010 BRT's modal score for each threat in each subpopulation.

| **Threat** | **Klamath** | **Columbia** | **Fraser** | **Mainland BC** |
|---|---|---|---|---|
| Climate change impacts on ocean conditions | high | high | high | high |
| Dams /water diversions | moderate | moderate | very low | very low |
| Eulachon by-catch | moderate | high | moderate | high |
| Climate change impacts on freshwater habitat | moderate | moderate | moderate | moderate |
| Predation | moderate | moderate | moderate | moderate |
| Water quality | moderate | moderate | moderate | low |
| Catastrophic events | very low | low | very low | low |
| Disease | very low | very low | very low | very low |
| Competition | low | low | low | low |
| Shoreline construction | very low | moderate | moderate | low |
| Tribal/First Nations fisheries | very low | very low | very low | low |
| Non-indigenous species | very low | very low | very low | very low |
| Recreational harvest | very low | low | very low | very low |
| Dredging | very low | moderate | low | very low |
| Commercial harvest | very low | low | low | very low |
| Scientific monitoring | very low | very low | very low | very low |
| **Qualitative threat level** | **Color code** | | | |
| very low | 🟩 | | | |
| low | 🟦 | | | |
| moderate | 🟨 | | | |
| high | 🟧 | | | |
| very high | 🟥 | | | |

Table 13. Generalized descriptions of U.S. west coast fisheries that have had observed bycatch of eulachon.

| | | | | | | | **Management** | |
|---|---|---|---|---|---|---|---|---|
| **Sector** | **Sub-Sector** | **Permits** | **Gear(s)** | **Target(s)** | **Vessel length (m)** | **Depths (m)** | **2002-2010** | **2011-2013** |
| **Limited Entry (LE) Trawl** | | Federal LE permit with trawl endorsement | Bottom trawl, Midwater trawl | Groundfish assemblage | 11–29 | Wide range | Cumulative two month trip limits; depth-based closures; 14-23% observer coverage | Individual Fishing Quotas (IFQ); 100% observer coverage |
| **At-Sea Hake** | Mothership-Catcher Vessel (MSCV) | LE permit with MSCV endorsement | Midwater trawl | Pacific hake | 26–45 | 53–460 | Seasonal quotas for target and bycatch species of concern; 100% observer coverage | IFQ; seasonal; 100% observer |
| | Catcher-processors (CP) | LE permit with CP endorsement | Midwater trawl | Pacific hake | 82–115 | 60–570 | Same as At-Sea Hake MSCV | IFQ; seasonal; 100% observer |
| | Tribal | (none) | Midwater trawl | Pacific hake | | 53–460 | Tribal; 100% observer coverage | Tribal; 100% observer coverage |
| **Shoreside Hake** | | LE permit with trawl endorsement | Midwater trawl | Pacific hake | 17–29 | Wide range | Same as At-Sea Hake MSCV; electronic monitoring | IFQ; Seasonal; 100% observer coverage of landed catch |
| **Ocean Shrimp (aka pink shrimp)** | | WA, OR, or CA state ocean shrimp permit | Shrimp trawl | Ocean shrimp (*Pandalus jordani*) | 11.5–33 | 91–256 | WA, OR, or CA state ocean shrimp regulations; Bycatch Reduction Devices required; trip limits on groundfish landed; 4-14% observer coverage | |

Table 14. Estimated bycatch of eulachon (number of individual fish) in U.S. west coast groundfish fisheries that are part of the Groundfish BiOp and that were observed by the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP) from 2002–2013. Data from Gustafson et al. (2015a).

| | **Non-hake bottom and midwater groundfish fisheries** | | | **Shoreside hake** | **At-sea hake fisheries** | | | |
|---|---|---|---|---|---|---|---|---|
| Year | WA | OR | CA | | Tribal Mothership | Non-Tribal Mothership | Catcher Processor | Total bycatch estimate |
| 2002 | 0 | 783 | 0 | -- | 0 | 0 | 0 | 783 |
| 2003 | 0 | 52 | 0 | -- | 0 | 0 | 0 | 52 |
| 2004 | 0 | 0 | 5 | -- | 0 | 0 | 0 | 5 |
| 2005 | 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | -- | 0 | 0 | 147 | 147 |
| 2007 | 0 | 72 | 0 | -- | 0 | 4 | 6 | 82 |
| 2008 | 0 | 0 | 0 | -- | 0 | 6 | 37 | 43 |
| 2009 | 0 | 67 | 0 | -- | 32 | 6 | 30 | 135 |
| 2010 | 0 | 0 | 22 | -- | 0 | 0 | 0 | 22 |
| 2011 | 12 | 127 | 0 | 0 | 160 | 54 | 1,271 | 1,624 |
| 2012 | 1 | 167 | 0 | 0 | 0 | 7 | 16 | 191 |
| 2013 | 137 | 522 | 0 | 4,139 | na | 278 | 39 | 5,115 |
| Total | 150 | 1,790 | 27 | 4,139 | 192 | 355 | 1,546 | 8,199 |

Table 15. Observed bycatch numbers of eulachon from bottom and midwater trawl catch share fishery (2011–2014). Acronyms are state names: WA = Washington, OR = Oregon, and CA = California. Data from "Annual Tables of Observed Bycatch of Protected Species, Eulachon observed bycatch (2002-2014)" available online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/protected_species.cfm.

| State | Year | Fleet total groundfish landings (mt) | Observed groundfish landings (mt) | Number of observed tows | Percent groundfish landings observed | Number of observed bycaught eulachon | Bycatch ratio (number of eulachon per mt of observed groundfish) |
|---|---|---|---|---|---|---|---|
| WA | 2011 | 1,859.6 | 1,849.3 | 941 | 99.5 | 11 | 0.0059 |
| | 2012 | 2,220.9 | 2,189.6 | 905 | 98.6 | 1 | 0.0005 |
| | 2013 | 1,554.0 | 1,552.2 | 901 | 99.9 | 135 | 0.0869 |
| | 2014 | 885.7 | 883.1 | 439 | 99.7 | 278 | 0.3148 |
| OR | 2011 | 10,893.7 | 10,810.0 | 5,976 | 99.2 | 122 | 0.0113 |
| | 2012 | 10,735.3 | 10,668.6 | 5,607 | 99.4 | 163 | 0.0153 |
| | 2013 | 12,473.0 | 12,437.6 | 6,432 | 99.7 | 507 | 0.0408 |
| | 2014 | 11,217.1 | 11,189.7 | 5,190 | 99.8 | 2,473 | 0.2210 |
| CA | 2011 | 4,601.8 | 4,596.5 | 2,282 | 99.9 | 0 | 0.0000 |
| | 2012 | 4,451.4 | 4,443.0 | 2,493 | 99.8 | 0 | 0.0000 |
| | 2013 | 5,043.7 | 5,029.9 | 2,764 | 99.7 | 0 | 0.0000 |
| | 2014 | 4,877.6 | 4,853.0 | 2,843 | 99.5 | 0 | 0.0000 |

Table 16. Observed bycatch numbers of eulachon from at-sea hake fishery (2002–2014). Asterisks (*) signify strata with fewer than three observed vessels. Tribal mothership sector did not participate in this fishery during 2013–2014, which are indicated with “na”. Data from “Annual Tables of Observed Bycatch of Protected Species, Eulachon observed bycatch (2002–2014)” available online at: [http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/protected_species.cfm](http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/protected_species.cfm).

| Sector | Year | Observed hake landings (mt) | Number of sampled tows | Percent hake tows observed | Number of observed bycaught eulachon | Bycatch ratio (number of eulachon per mt of observed hake) |
|---|---|---|---|---|---|---|
| Catcher Processor | 2002 | 36,332.9 | 556 | 99.8 | 0 | 0.00000 |
| | 2003 | 41,468.6 | 766 | 99.9 | 0 | 0.00000 |
| | 2004 | 72,858.7 | 1,492 | 99.7 | 0 | 0.00000 |
| | 2005 | 78,497.5 | 1,332 | 99.9 | 0 | 0.00000 |
| | 2006 | 78,246.3 | 1,488 | 99.9 | 145 | 0.00185 |
| | 2007 | 72,898.1 | 1,566 | 99.7 | 6 | 0.00008 |
| | 2008 | 107,754.4 | 1,864 | 99.0 | 37 | 0.00034 |
| | 2009 | 34,590.8 | 863 | 100.0 | 30 | 0.00087 |
| | 2010 | 54,217.3 | 1,063 | 99.9 | 0 | 0.00000 |
| | 2011 | 71,336.7 | 1,530 | 99.7 | 1,268 | 0.01777 |
| | 2012 | 55,522.6 | 1,100 | 99.8 | 16 | 0.00029 |
| | 2013 | 78,004.8 | 1,439 | 99.7 | 39 | 0.00050 |
| | 2014 | 103,171.3 | 1,683 | 99.9 | 242 | 0.00235 |
| Non-tribal Mothership | 2002 | 26,502.9 | 573 | 99.8 | 0 | 0.00000 |
| | 2003 | 25,332.9 | 522 | 97.4 | 0 | 0.00000 |
| | 2004 | 24,010.1 | 569 | 99.6 | 0 | 0.00000 |
| | 2005 | 48,600.6 | 1,038 | 99.9 | 0 | 0.00000 |
| | 2006 | 54,138.8 | 1,243 | 96.9 | 0 | 0.00000 |
| | 2007 | 47,276.3 | 1,135 | 99.0 | 4 | 0.00008 |
| | 2008 | 57,687.4 | 1,346 | 99.8 | 6 | 0.00010 |
| | 2009 | 24,066.4 | 597 | 99.5 | 6 | 0.00025 |
| | 2010 | 35,726.9 | 908 | 100.0 | 0 | 0.00000 |
| | 2011 | 49,970.6 | 1,246 | 99.8 | 54 | 0.00108 |
| | 2012 | 38,042.1 | 931 | 98.1 | 7 | 0.00018 |
| | 2013 | 52,348.3 | 1,249 | 99.4 | 277 | 0.00529 |
| | 2014 | 61,793.7 | 1,288 | 98.6 | 25 | 0.00040 |
| Tribal Mothership | 2002 | 21,629.0 | 625 | 98.7 | 0 | 0.00000 |
| | 2003 | 19,430.8 | 537 | 99.4 | 0 | 0.00000 |
| | 2004 | 23,511.4 | 632 | 100.0 | 0 | 0.00000 |
| | 2005 | 23,561.6 | 632 | 99.8 | 0 | 0.00000 |
| | 2006 | 5,405.4 | 154 | 96.2 | 0 | 0.00000 |
| | 2007 | 5,129.4 | 156 | 100.0 | 0 | 0.00000 |
| | 2008 | 14,977.3 | 380 | 99.5 | 0 | 0.00000 |
| | 2009 | 13,469.4 | 403 | 99.8 | 32 | 0.00238 |
| | 2010 | 16,206.2 | 516 | 100.0 | 0 | 0.00000 |
| | 2011 | 6,146.9 | 228 | 100.0 | 160 | 0.02603 |
| | 2012 | * | * | 75.0 | * | * |
| | 2013 | na | na | na | 0 | 0.00000 |
| | 2014 | na | na | na | 0 | 0.00000 |

Table 17. Total estimated bycatch of eulachon (number of individuals and mt) in ocean shrimp fisheries observed by the West Coast Groundfish Observer Program (WCGOP) from 2004–2013. Ocean shrimp fisheries were not observed in 2006. Italicized bycatch estimates result from bootstrapping due to fewer than three observed vessels in those strata. Dashes (--) signify years when the sector was not observed. Methods detailed in Gustafson et al. (2015b). Data for 2014 in this format is not available at this time.

| | **Eulachon bycatch (mt)** | | | | | **Eulachon bycatch (numbers of fish)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Washington | Oregon | California | Coastwide bycatch | 95% CI | Washington | Oregon | California | Coastwide bycatch | 95% CI |
| 2004 | -- | 2.88 | 0.21 | 3.09 | 0.24<br>8.94 | -- | 146,388 | 11,403 | 157,742 | 11,642<br>492,844 |
| 2005 | -- | 4.95 | 0.18 | 5.14 | 0.77<br>10.63 | -- | 207,362 | 9,788 | 217,150 | 21,457<br>454,700 |
| 2006 | -- | -- | -- | -- | --<br>-- | -- | -- | -- | -- | --<br>-- |
| 2007 | -- | 3.90 | 0.16 | 4.06 | 0.29<br>10.58 | -- | 197,807 | 11,548 | 209,355 | 15,062<br>562,006 |
| 2008 | -- | 10.33 | 0.34 | 10.67 | 2.49<br>22.58 | -- | 389,604 | 24,962 | 414,566 | 110,723<br>796,433 |
| 2009 | -- | 8.71 | 1.10 | 9.81 | 2.40<br>22.38 | -- | 845,081 | 113,983 | 959,065 | 238,075<br>2,147,772 |
| 2010 | 2.06 | 13.70 | 2.45 | 18.22 | 10.96<br>27.81 | 64,735 | 740,501 | 267,057 | 1,072,294 | 532,268<br>1,891,424 |
| 2011 | 5.54 | 20.45 | 0.03 | 26.03 | 18.02<br>36.28 | 120,671 | 480,907 | 471 | 602,049 | 394,343<br>875,107 |
| 2012 | 156.80 | 427.95 | 6.88 | 591.63 | 392.03<br>808.68 | 14,359,862 | 28,138,728 | 337,344 | 42,835,935 | 26,951,527<br>59,071,452 |
| 2013 | 203.66 | 540.06 | 0.70 | 744.42 | 498.21<br>1,008.12 | 17,167,047 | 35,129,318 | 16,320 | 52,312,685 | 32,397,543<br>74,469,761 |

Table 18. Observed bycatch numbers of eulachon from pink shrimp trawl fishery (2002–2014). Asterisks (*) signify strata with fewer than three observed vessels. Double dashes (--) signify unobserved strata. Acronyms are state names: WA = Washington, OR = Oregon, and CA = California. Data from "Annual Tables of Observed Bycatch of Protected Species, Eulachon observed bycatch (2002-2014)" available online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/protected_species.cfm.

| State | Year | Fleet total ocean shrimp landings (mt) | Observed ocean shrimp landings (mt) | Number of observed tows | Percent ocean shrimp landings observed | Number of observed bycaught eulachon | Bycatch ratio (number of eulachon per mt of observed shrimp) |
|---|---|---|---|---|---|---|---|
| WA | 2010 | 4,295.6 | 412.4 | 334 | 9.6 | 6,214 | 15.1 |
| | 2011 | 4,211.9 | 697.2 | 566 | 16.6 | 19,976 | 28.7 |
| | 2012 | 4,242.3 | 626.0 | 516 | 14.8 | 2,099,376 | 3,353.9 |
| | 2013 | 6,157.9 | 626.8 | 384 | 10.2 | 1,740,163 | 2,776.2 |
| | 2014 | 13,876.2 | 980.9 | 393 | 7.1 | 948,397 | 966.9 |
| OR | 2004 | 5,537.0 | 427.2 | 734 | 7.7 | 11,291 | 26.4 |
| | 2005 | 7,159.4 | 402.9 | 482 | 5.6 | 11,669 | 29.0 |
| | 2006 | 5,531.8 | -- | -- | -- | -- | -- |
| | 2007 | 9,128.6 | 650.0 | 921 | 7.1 | 14,084 | 21.7 |
| | 2008 | 11,575.9 | 672.5 | 768 | 5.8 | 22,634 | 33.7 |
| | 2009 | 10,048.7 | 751.2 | 631 | 7.5 | 63,175 | 84.1 |
| | 2010 | 14,290.4 | 1,705.4 | 1,186 | 11.9 | 88,373 | 51.8 |
| | 2011 | 21,915.1 | 2,986.0 | 1,819 | 13.6 | 65,524 | 21.9 |
| | 2012 | 22,291.6 | 3,020.9 | 2,046 | 13.6 | 3,794,927 | 1,256.2 |
| | 2013 | 21,537.8 | 2,313.2 | 1,353 | 10.7 | 3,725,425 | 1,610.5 |
| | 2014 | 23,550.5 | 2,291.3 | 1,424 | 9.7 | 5,320,324 | 2,321.9 |
| CA | 2004 | 996.8 | * | * | * | * | * |
| | 2005 | 860.6 | * | * | * | * | * |
| | 2006 | 63.6 | -- | -- | -- | -- | -- |
| | 2007 | 289.1 | * | * | * | * | * |
| | 2008 | 945.5 | * | * | * | * | * |
| | 2009 | 1,183.5 | * | * | * | * | * |
| | 2010 | 1,771.0 | 265.5 | 134 | 15.0 | 40,040 | 150.8 |
| | 2011 | 3,333.0 | 420.6 | 194 | 12.6 | 59 | 0.1 |
| | 2012 | 2,790.7 | 347.6 | 169 | 12.5 | 42,018 | 120.9 |
| | 2013 | 3,915.4 | 359.8 | 179 | 9.2 | 1,533 | 4.3 |
| | 2014 | 3,845.0 | 597.5 | 311 | 15.5 | 94,976 | 158.9 |

Table 19. Eulachon landings (pounds) from the Columbia River and tributary commercial fisheries. New information in bold. The full data series, beginning in 1888, can be found in the 2010 status review (Gustafson et al. 2010, tables 7–8).

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Total | Source |
|---|---|---|---|---|---|---|---|---|
| 1990 | 6,400 | 0 | 2,756,200 | 0 | 21,600 | 0 | 2,784,200 | JCRMS (2013) |
| 1991 | 5,800 | 0 | 2,944,600 | 0 | 0 | 0 | 2,950,400 | JCRMS (2013) |
| 1992 | 800 | 0 | 3,673,000 | 0 | 0 | 0 | 3,673,800 | JCRMS (2013) |
| 1993 | 33,200 | 0 | 413,900 | 66,800 | 0 | 0 | 513,900 | JCRMS (2013) |
| 1994 | 200 | 0 | 43,200 | 0 | 0 | 0 | 43,400 | JCRMS (2013) |
| 1995 | 7,700 | 0 | 431,400 | 900 | 0 | 0 | 440,000 | JCRMS (2013) |
| 1996 | 7,100 | 0 | 2,000 | 0 | 0 | 0 | 9,100 | JCRMS (2013) |
| 1997 | 37,100 | 0 | 21,500 | 0 | 0 | 0 | 58,600 | JCRMS (2013) |
| 1998 | 11,900 | 0 | 200 | 0 | 0 | 0 | 12,100 | JCRMS (2013) |
| 1999 | 20,900 | 0 | 0 | 0 | 0 | 0 | 20,900 | JCRMS (2013) |
| 2000 | 31,000 | 0 | 0 | 0 | 0 | 0 | 31,000 | JCRMS (2013) |
| 2001 | 158,800 | 0 | 154,300 | 0 | 0 | 0 | 313,100 | JCRMS (2013) |
| 2002 | 58,000 | 0 | 169,600 | 0 | 493,600 | 0 | 721,200 | JCRMS (2013) |
| 2003 | 70,385 | 0 | 464,400 | 0 | 529,100 | 23,000 | 1,086,885 | (ODFW 2003, JCRMS 2013) |
| 2004 | 15,959 | 0 | 216,200 | 0 | 0 | 0 | 232,159 | (ODFW 2004, JCRMS 2013) |
| 2005 | 108 | 0 | 100 | 0 | 0 | 0 | 208 | (ODFW 2005, JCRMS 2013) |
| 2006 | 13,099 | 0 | 0 | 0 | 0 | 0 | 13,099 | (ODFW 2006) |
| 2007 | 7,087 | 0 | 1,200 | 0 | 0 | 0 | 8,327 | (ODFW 2007, JCRMS 2013) |
| 2008 | 11,381 | 0 | 5,900 | 0 | 0 | 0 | 17,281 | (ODFW 2008, JCRMS 2013) |
| 2009 | 5,539 | 0 | 12,093 | 0 | 0 | 0 | 17,632 | (ODFW 2009, JCRMS 2013) |
| **2010** | **3,624** | **0** | **0** | **0** | **0** | **0** | **3,624** | **(ODFW 2010)** |
| **2011** | **Closed** | | | | | | **Closed** | **JCRMS (2013)** |
| **2012** | **Closed** | | | | | | **Closed** | **JCRMS (2013)** |
| **2013** | **Closed** | | | | | | **Closed** | **JCRMS (2013)** |
| **2014** | **18,558** | **0** | **0** | **0** | **0** | **0** | **18,558** | **(ODFW 2014)** |
| **2015** | **16,546** | **0** | **0** | **0** | **0** | **0** | **16,546** | **(ODFW 2015)** |
| **2016** | **4,770** | **0** | **0** | **0** | **0** | **0** | **4,770** | **(ODFW 2016)** |

Table 20. Estimated 2014–2015 eulachon catch in pounds (as reported), and metric tons and numbers of fish, from the Columbia River and tributary commercial, sport, and tribal fisheries. Source: ODFW (2014, 2015) and JCRMS (2015). Total number of eulachon in the catch was calculated using an average of 11.2 eulachon per pound as reported by James et al. (2014).

| | Mainstem commercial fishery catch | | | Sport fishery - Cowlitz River | | | Sport fishery - Sandy River | | | Tribal fishery catch | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | (pounds) | (mt) | (number) | (pounds) | (mt) | (number) | (pounds) | (mt) | (number) | (pounds) | (mt) | (number) |
| 2014 | 18,558 | 8.42 | 207,872 | 197,900 | 89.76 | 2,209,158 | 6,000 | 2.72 | 66,978 | 17,500[1] | 7.94 | 195,353 |
| 2015 | 16,546 | 7.51 | 185,360 | 287,400 | 131.36 | 3,208,246 | <100 | <0.05 | <1,116 | 10,170 | 4.61 | 113,904 |
| 2016[2] | 4,770 | 2.16 | 53,248 | 141,050 | 63.98 | 1,574,541 | | | | | | |

[1] Tribal catch in 2014 consists of Yakama Nation (10,000 lbs.) and Warm Springs Nation (7,500 lbs.).

[2] Sport and tribal fishery catch for 2016 are not yet available.

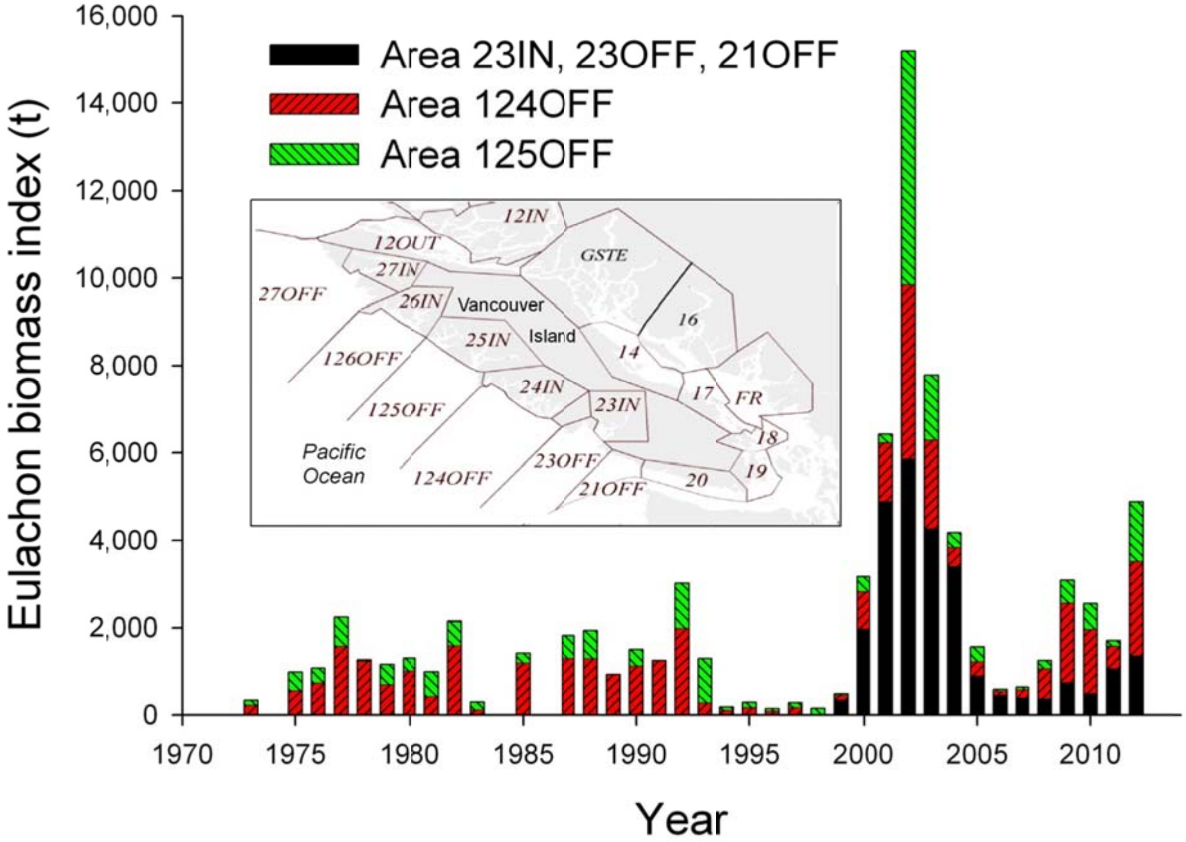

Figure 1. Eulachon biomass indices within various Shrimp Management Areas (SMAs) off the west coast of Vancouver Island (see map inset). Data from Hay et al. (2003, p. 23), DFO Shrimp Survey Bulletins (2000–2011; available online at: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm, DFO (2012a), and Bruce McCarter (DFO, Pacific Biological Station, Nanaimo, BC, Canada, pers. commun.). Biomass indices are no longer being produced; data for 2013 and 2014 are unavailable.

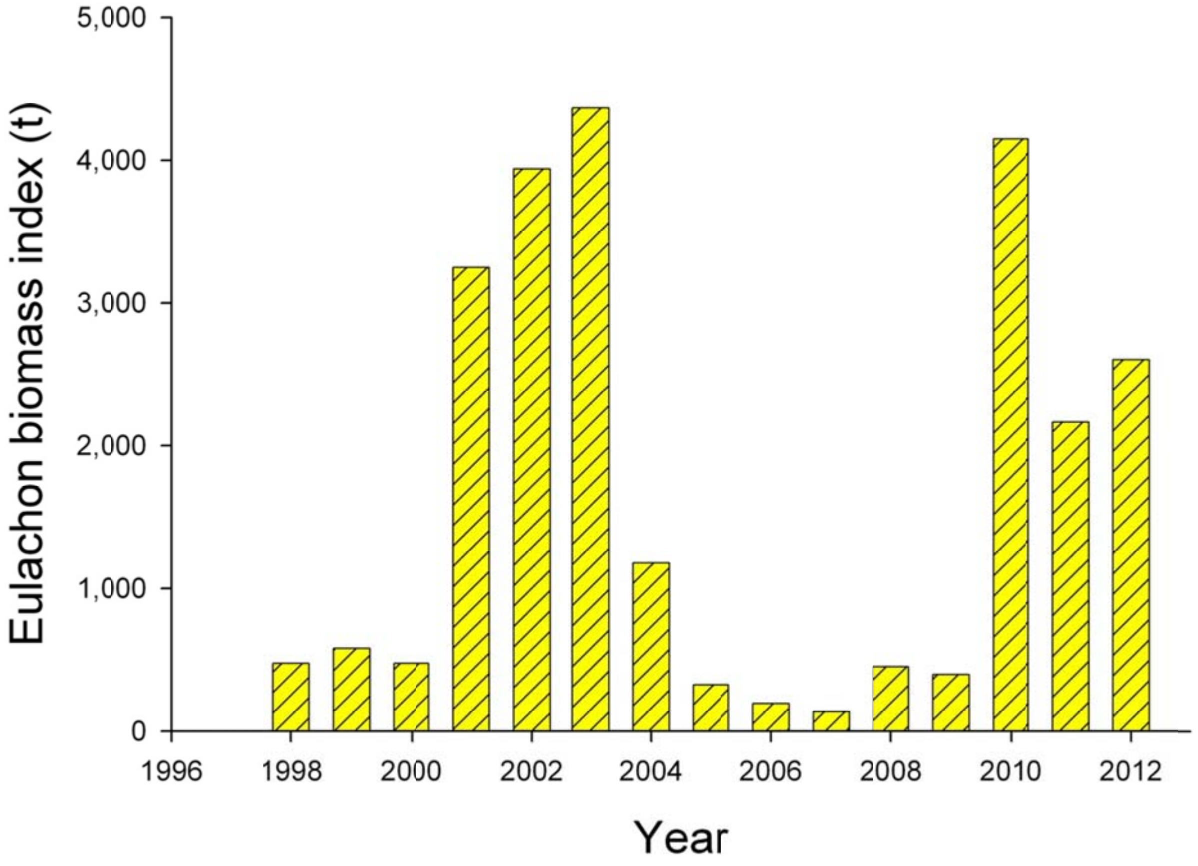

Figure 2. Eulachon biomass index as determined from shrimp trawl surveys in Shrimp Management Area (SMA) Queen Charlotte Sound. Data from DFO Shrimp Survey Bulletins (2000-2011; available online at: http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm, DFO (2012b), and Bruce McCarter (DFO, Pacific Biological Station, Nanaimo, BC, Canada, pers. comm.). Biomass indices are no longer being produced; data for 2013 and 2014 are unavailable.

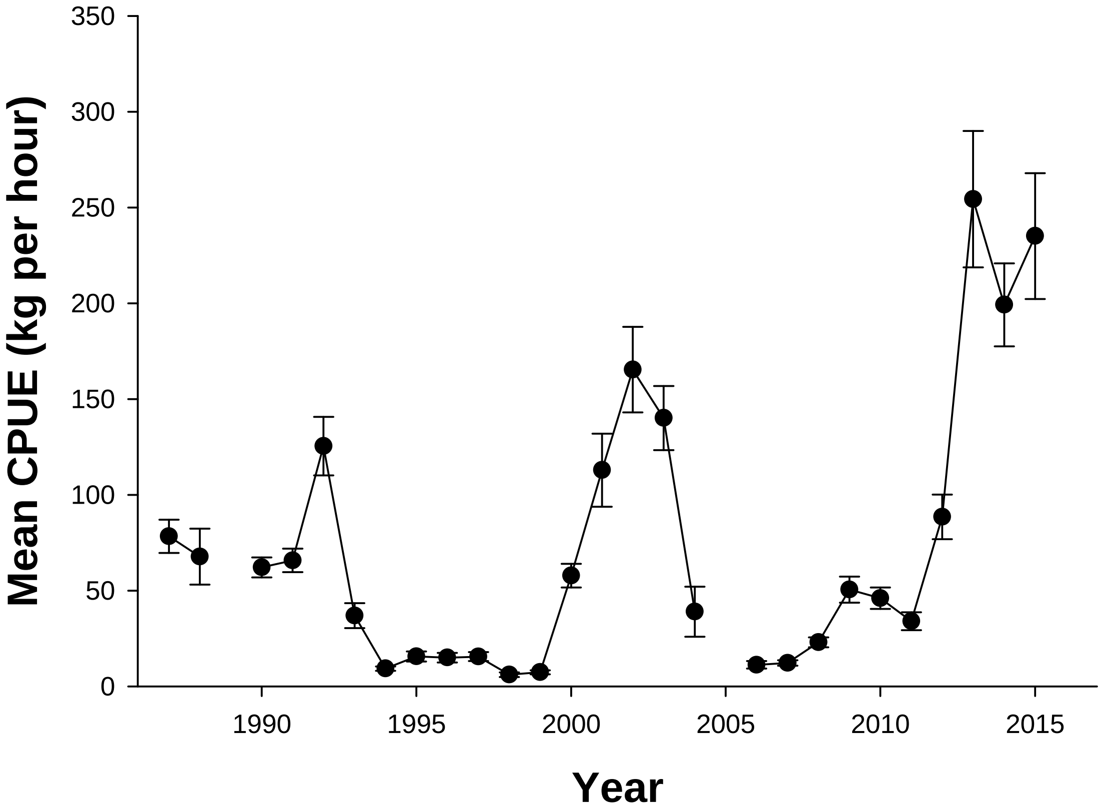

Figure 3. Total mean (± SE) catch per unit effort (CPUE; kg/h) of eulachon across all surveyed Shrimp Management Areas (SMAs) (125 OFF, 124 OFF, 23 OFF, 21 OFF, and 21 IN ) off West Coast Vancouver Island (WCVI). CPUE is based on bycatch of eulachon in multispecies small mesh bottom trawl surveys (aka, fishery-independent shrimp surveys) offshore of the WCVI (see map inset in Fig. 1). Data courtesy of Sean MacConnachie (Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, pers. commun., 3 September 2015).

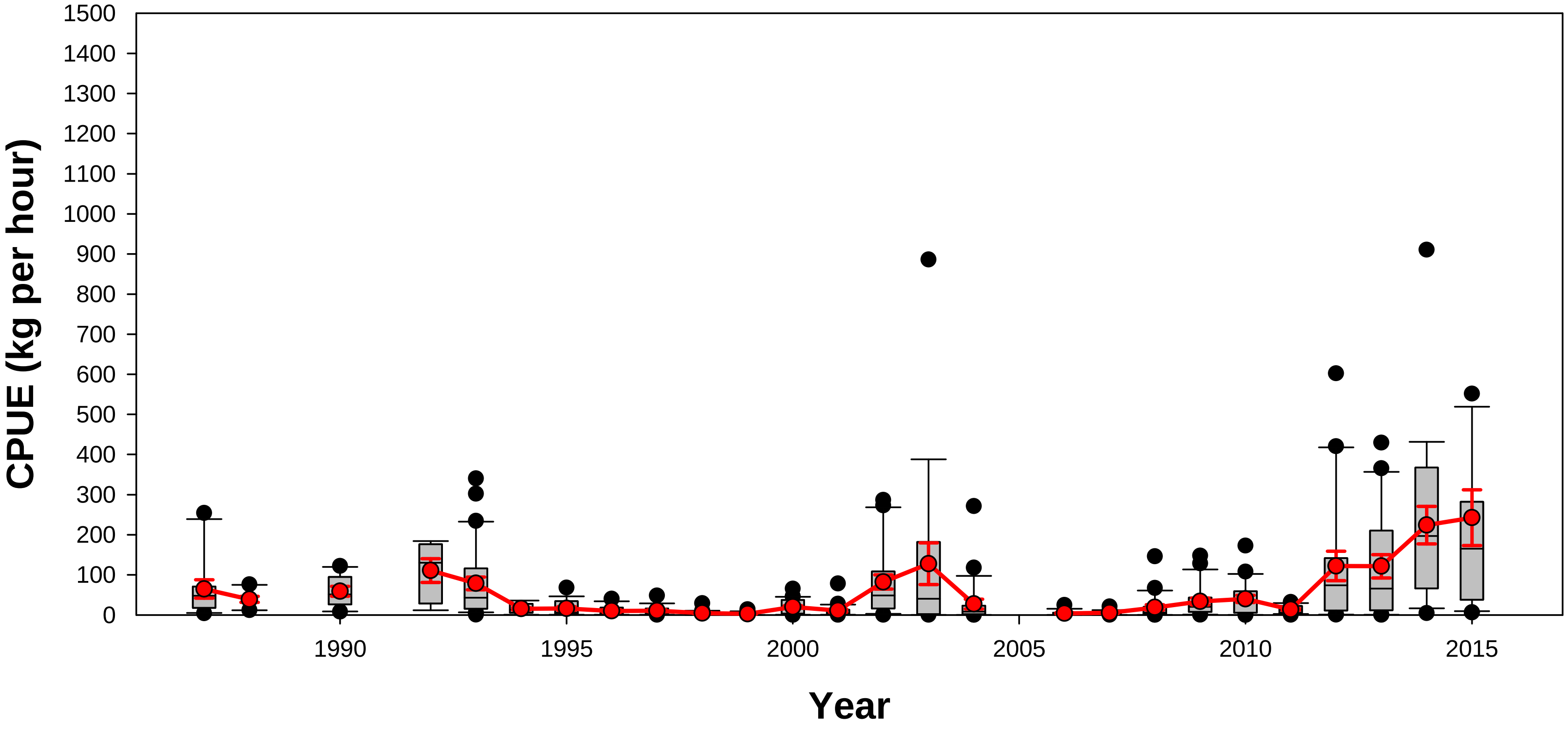

Figure 4. Eulachon catch per unit effort (CPUE) based on bycatch of eulachon in multispecies small mesh bottom trawl surveys (aka, fishery independent shrimp surveys) off West Coast Vancouver Island (WCVI) within Shrimp Management Area 125 (125OFF) offshore of the west coast of Vancouver Island (see map inset in Fig. 1). Length of each box shows the range within which the central 50% of the CPUE values fall, the center line in each box marks the median CPUE of that year's tows, and error bars above and below the box indicate the 90th and 10th percentiles of the CPUE. Solid circles beyond the box represent far outside CPUE values. Mean CPUE (± SE) are plotted in red and yearly mean values are connected by a solid red line. Data courtesy of Sean MacConnachie (Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, pers. commun., 3 September 2015).

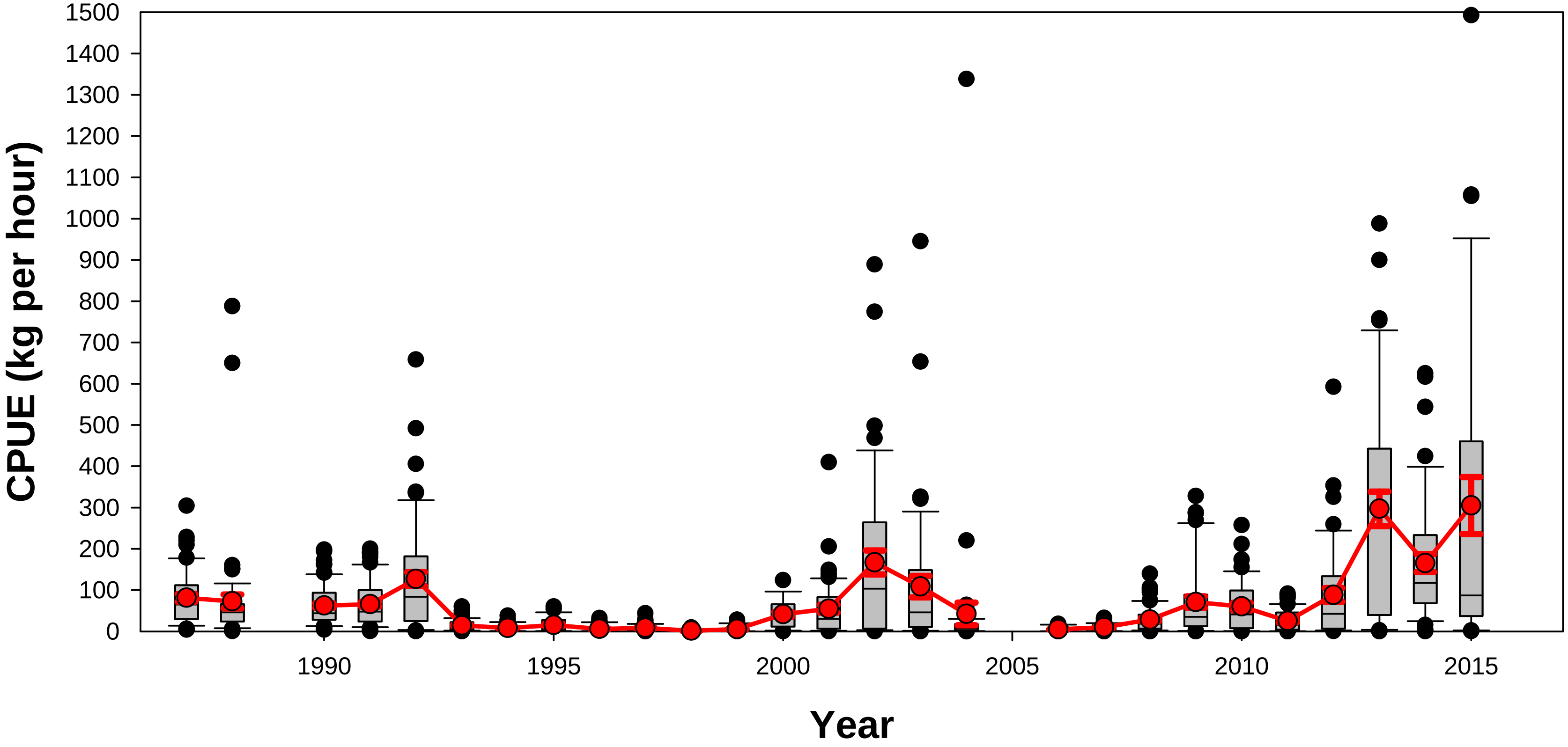

Figure 5. Eulachon catch per unit effort (CPUE) based on bycatch of eulachon in multispecies small mesh bottom trawl surveys (aka, fishery independent shrimp surveys) off West Coast Vancouver Island (WCVI) within Shrimp Management Area 124 (124OFF) offshore of the west coast of Vancouver Island (see map inset in Fig. 1). Length of each box shows the range within which the central 50% of the CPUE values fall, the center line in each box marks the median CPUE of that year's tows, and error bars above and below the box indicate the 90th and 10th percentiles of the CPUE. Solid circles beyond the box represent far outside CPUE values. Mean CPUE (± SE) are plotted in red and yearly mean values are connected by a solid red line. Data courtesy of Sean MacConnachie (Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, pers. commun., 3 September 2015).

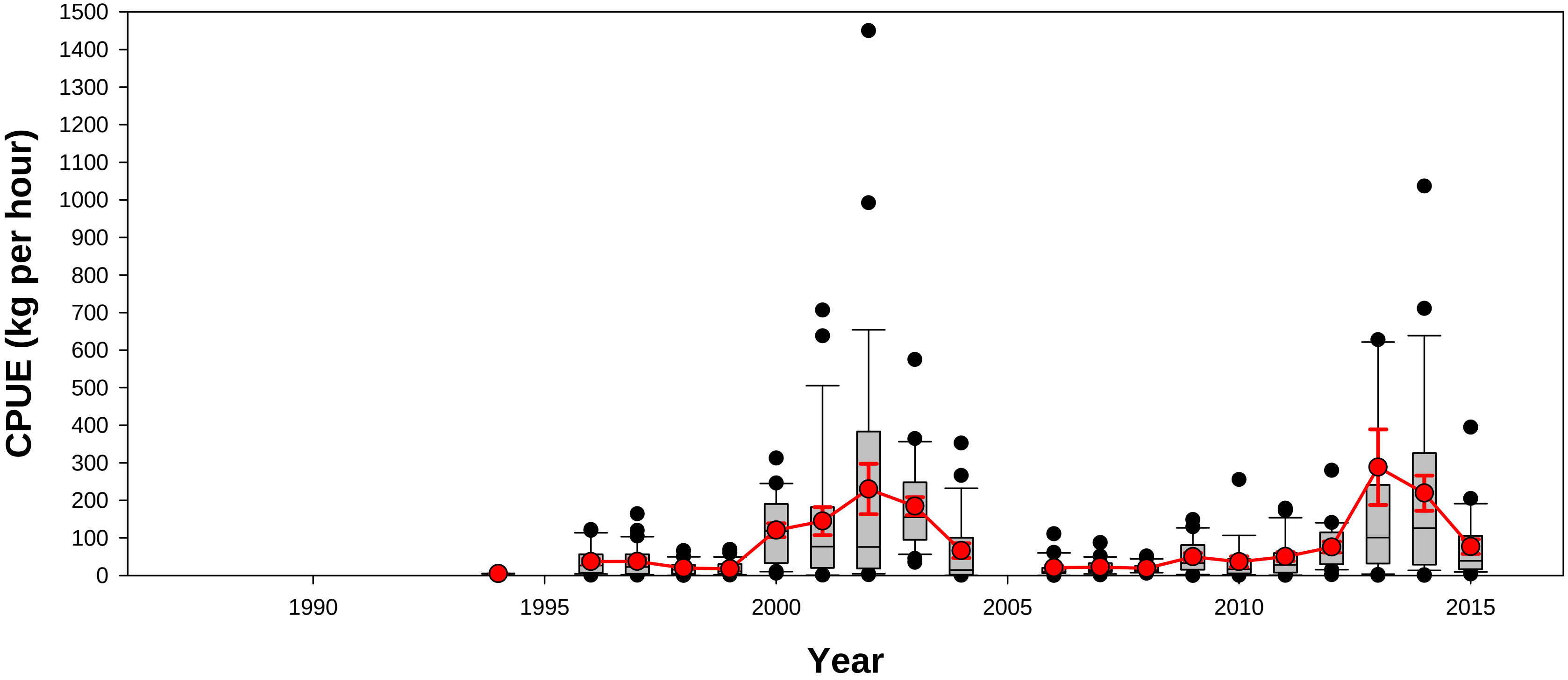

Figure 6. Eulachon catch per unit effort (CPUE) based on bycatch of eulachon in multispecies small mesh bottom trawl surveys (aka, fishery independent shrimp surveys) off West Coast Vancouver Island (WCVI) within Shrimp Management Area 123 (23OFF) offshore of the west coast of Vancouver Island (see map inset in Fig. 1). Length of each box shows the range within which the central 50% of the CPUE values fall, the center line in each box marks the median CPUE of that year's tows, and error bars above and below the box indicate the 90th and 10th percentiles of the CPUE. Solid circles beyond the box represent far outside CPUE values. Mean CPUE (± SE) are plotted in red and yearly mean values are connected by a solid red line. Data courtesy of Sean MacConnachie (Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, pers. commun., 3 September 2015).

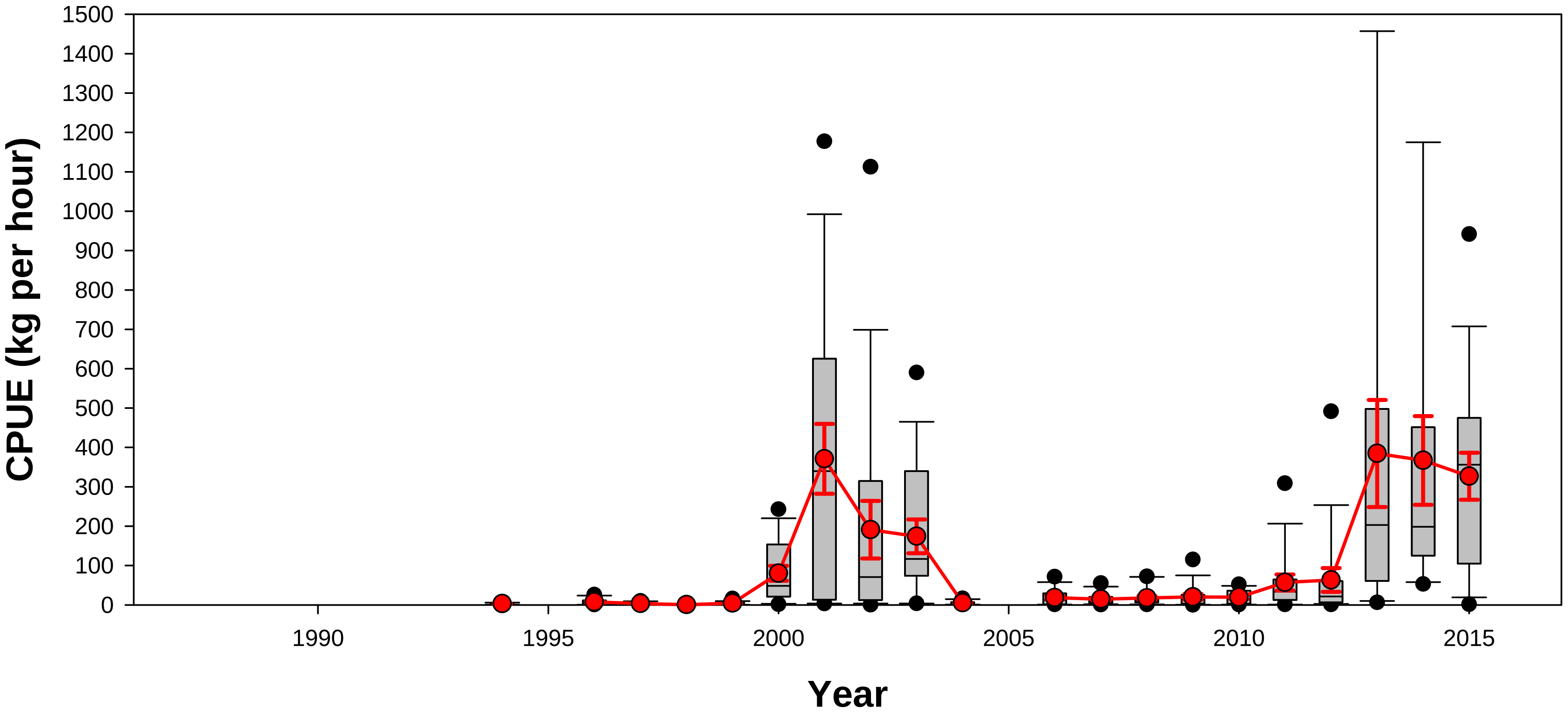

Figure 7. Eulachon catch per unit effort (CPUE) based on bycatch of eulachon in multispecies small mesh bottom trawl surveys (aka, fishery independent shrimp surveys) off West Coast Vancouver Island (WCVI) within Shrimp Management Area 121 (21OFF) offshore of the west coast of Vancouver Island (see map inset in Fig. 1). Length of each box shows the range within which the central 50% of the CPUE values fall, the center line in each box marks the median CPUE of that year's tows, and error bars above and below the box indicate the 90th and 10th percentiles of the CPUE. Solid circles beyond the box represent far outside CPUE values. Mean CPUE (± SE) are plotted in red and yearly mean values are connected by a solid red line. Data courtesy of Sean MacConnachie (Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, pers. commun., 3 September 2015).

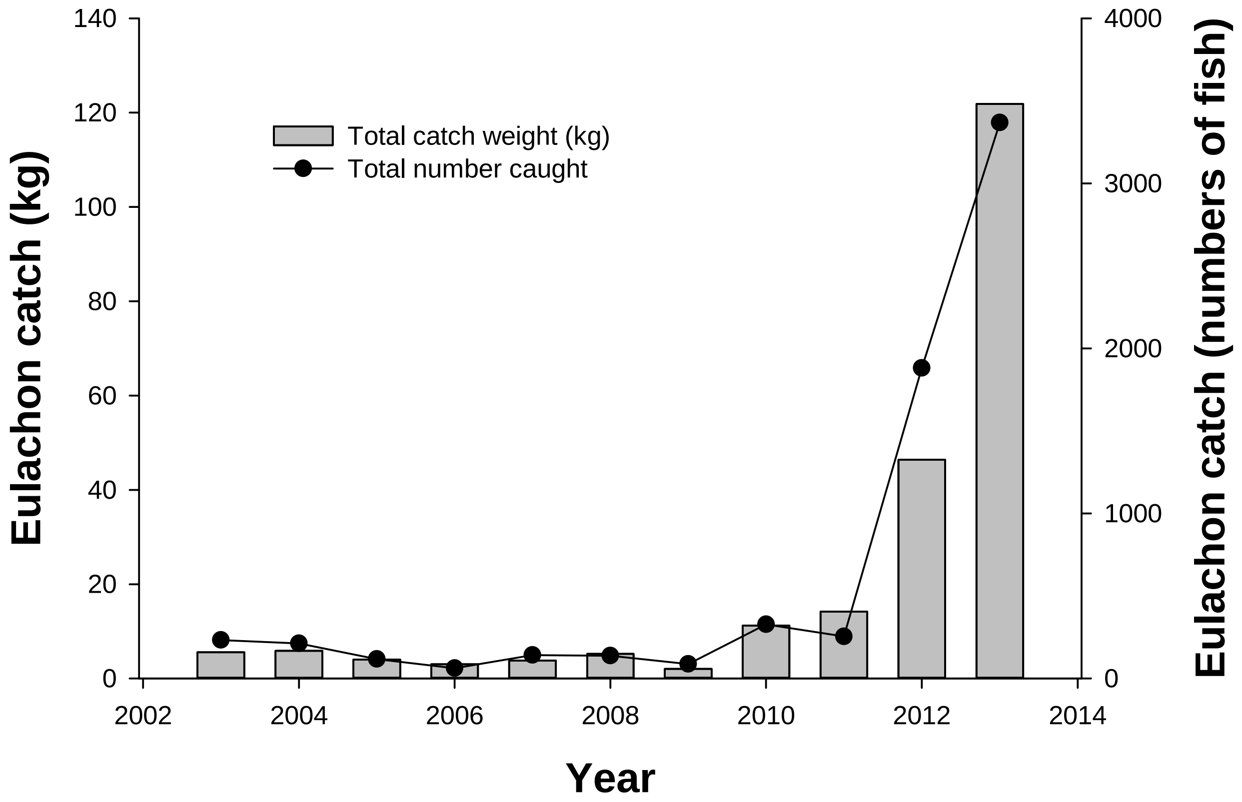

Figure 8. Eulachon incidental catch in the West Coast Bottom Trawl Survey (WCBTS) from 2003–2013. Data for 2014 and 2015 are not available at this time.

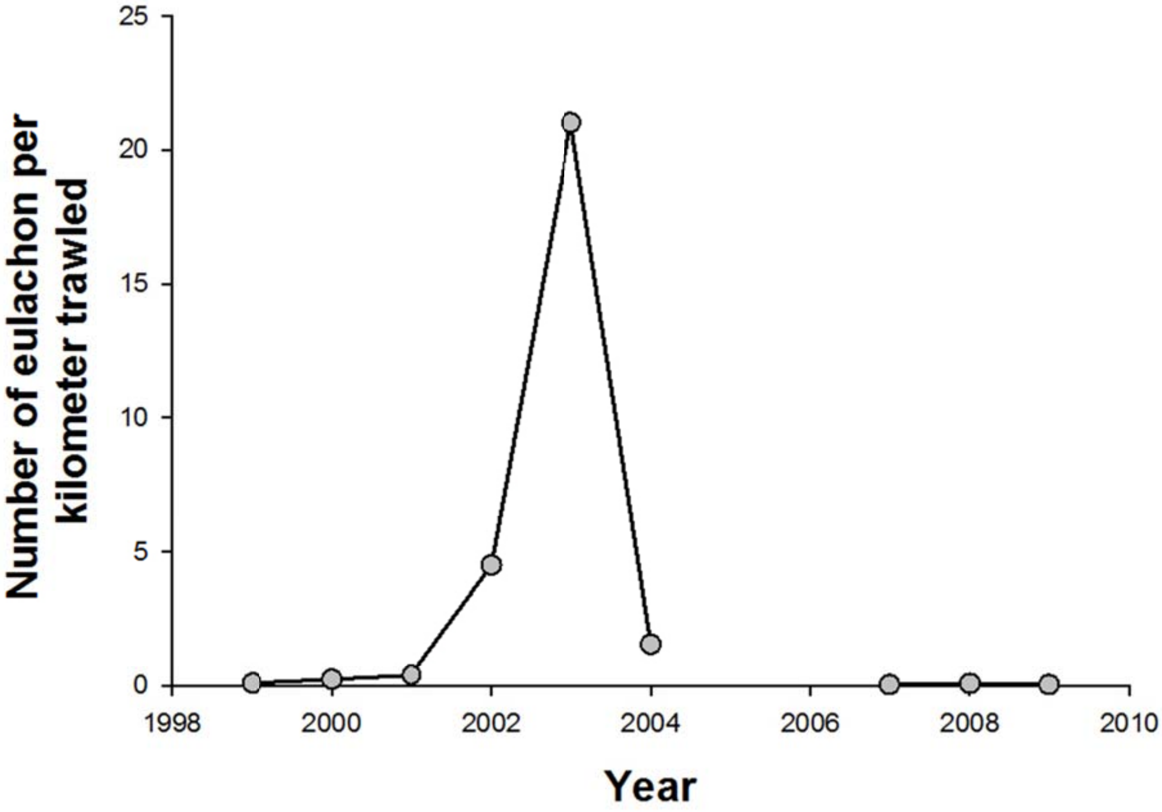

Figure 9. Annual mean catch of eulachon (number of eulachon per kilometer trawled) in night-time surface trawls from 1999–2009 in the Columbia River plume (Litz et al. 2013). Data derived from 1080 surface tows conducted every 10 days from May to July in all 11 years and additional tows in August (2002, 2004–2009) and April (1999–2005) (Litz et al. 2013).

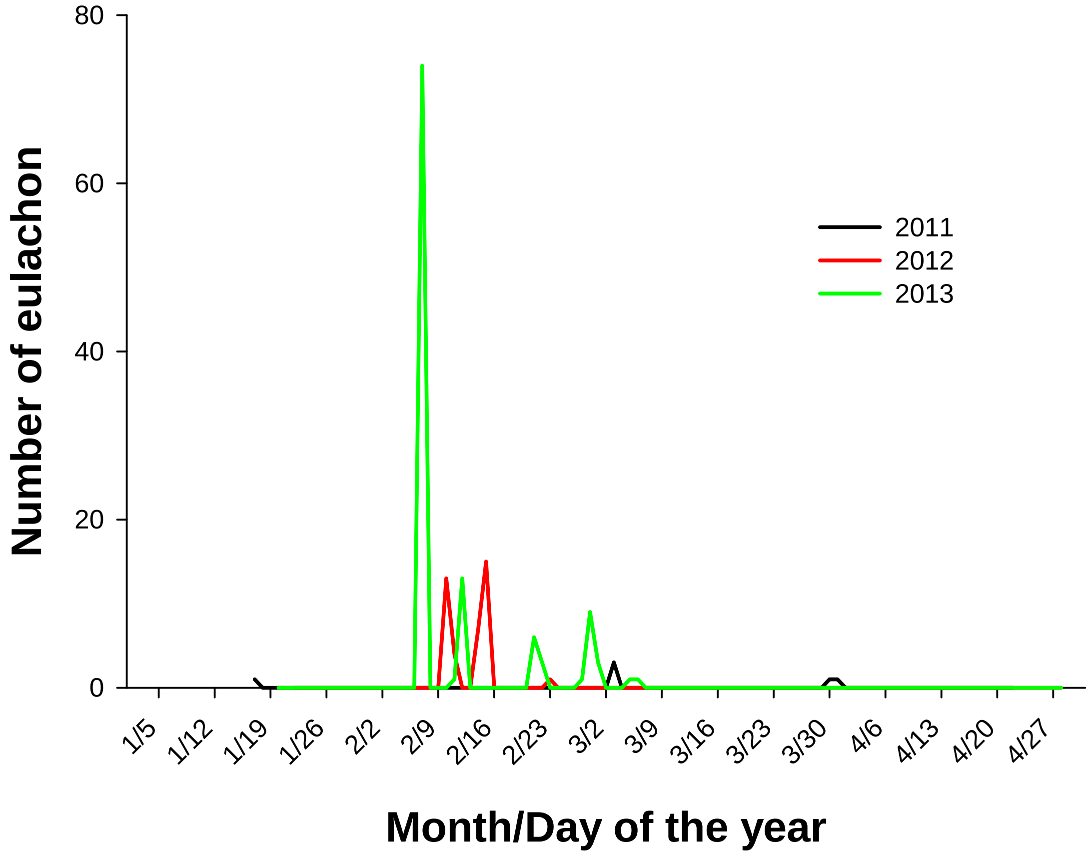

Figure 10. Date of capture and number of eulachon captured during eulachon dip net sampling by Yurok Indian Tribe biologists near the mouth of the Klamath River in 2011, 2012, and 2013. Data from McCovey (2011, 2012) and McCovey and Walker (2013).

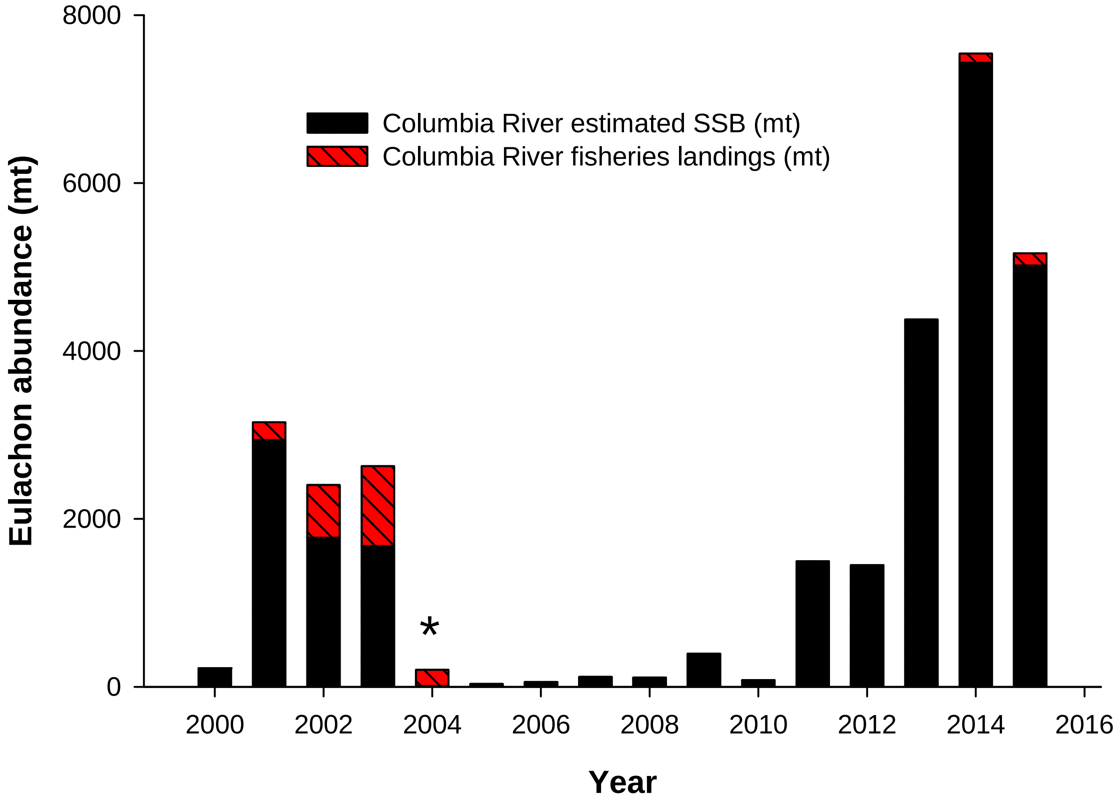

Figure 11. Estimated Columbia River eulachon spawning stock biomass and fisheries landings from 2000–2015. Pre-2011 adjusted SSB estimates are based on historical Columbia River water discharge rates and expansions of historical larval densities adjusted for the shorter duration of the pre-2011 surveys (B. James and O. Langness, WDFW, pers. commun.). Asterisk indicates that a survey was conducted in 2004; however, detailed daily larval density data for that year are unavailable and only harvest data for that year is displayed.

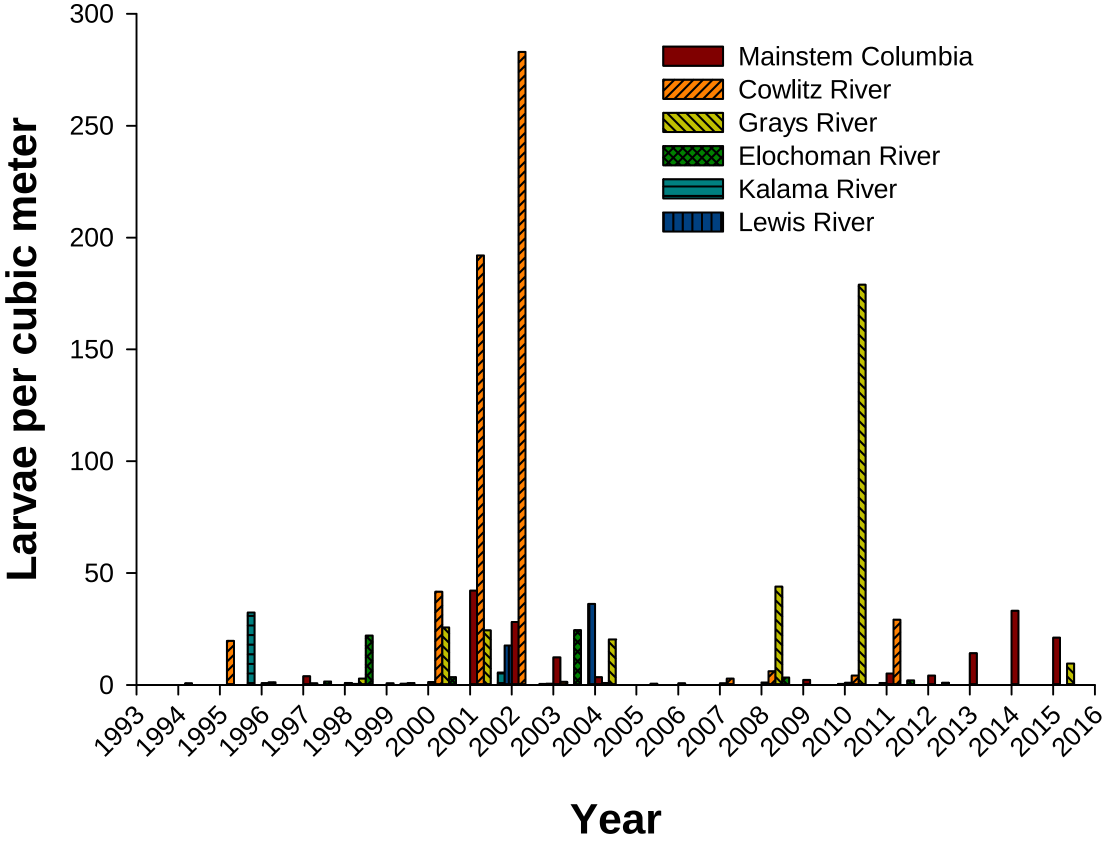

Figure 12. Average eulachon larval density (larvae per cubic meter) in mainstem Columbia River and tributaries. Interannual comparisons are problematic due to inconsistent effort and methods from year to year. Individual tributaries are not sampled in every year. Larvae were encountered in the Sandy River in 1998–2000, 2003, and 2011; however, values are too small (0.1 to a trace per cubic meter) to be evident on the graph. Data from JCRMS (2014, its table 19; 2015, its table 18).

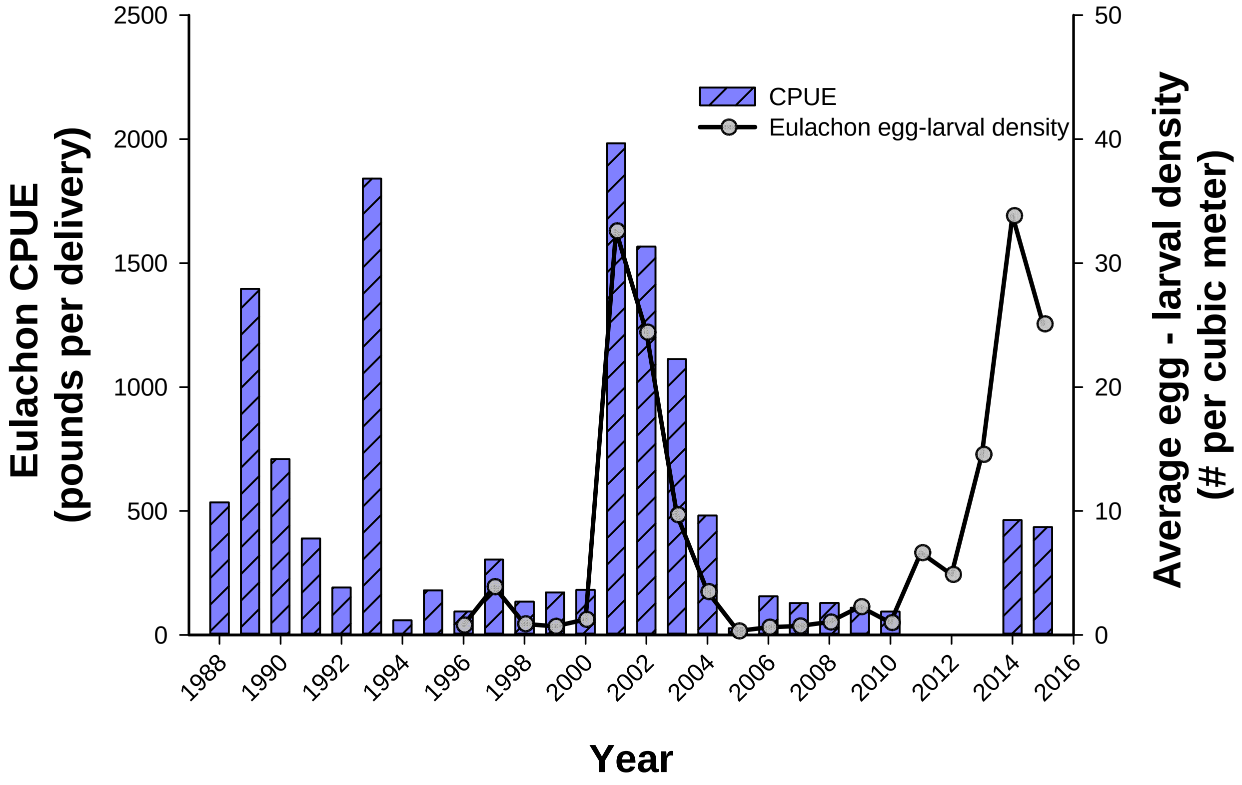

Figure 13. Historical trends in CPUE (pounds per delivery) and average larval density in the mainstem Columbia River (1996–2015). CPUE is lacking for 2011–2013 due to closure of the commercial fishery. Adjusted density in the mainstem Columbia River from 2011–2014 represents average density during February-April for consistency with previous years. Data from JCRMS (2014, tables 18 and 19; 2015, tables 17 and 18). Figure modified from JCRMS (2014, p. 17, fig. 1).

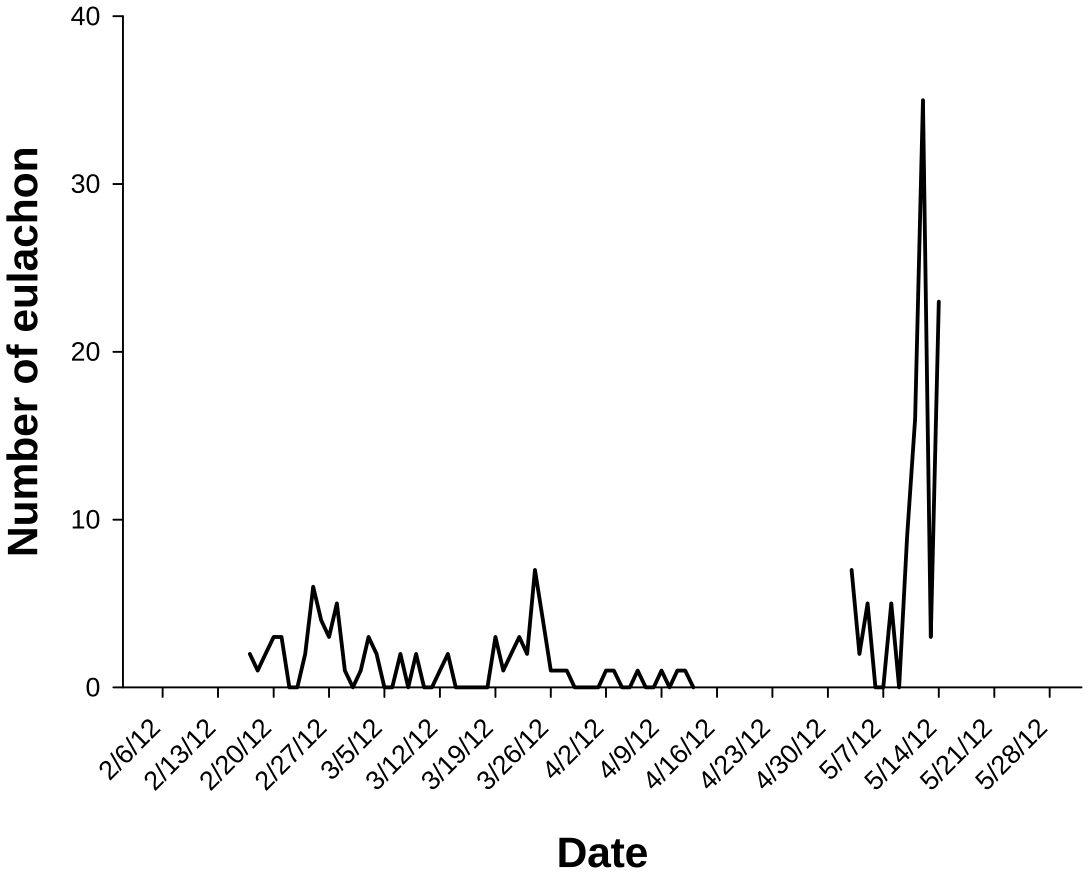

Figure 14. Date of capture and number of eulachon captured during salmonid smolt outmigration surveys in the Elwha River during 2012. Data courtesy of Mike McHenry, Lower Elwha Klallam Tribe, Port Angeles, WA, e-mail to R. Gustafson, NMFS. Pers. commun. 23 January 2015.

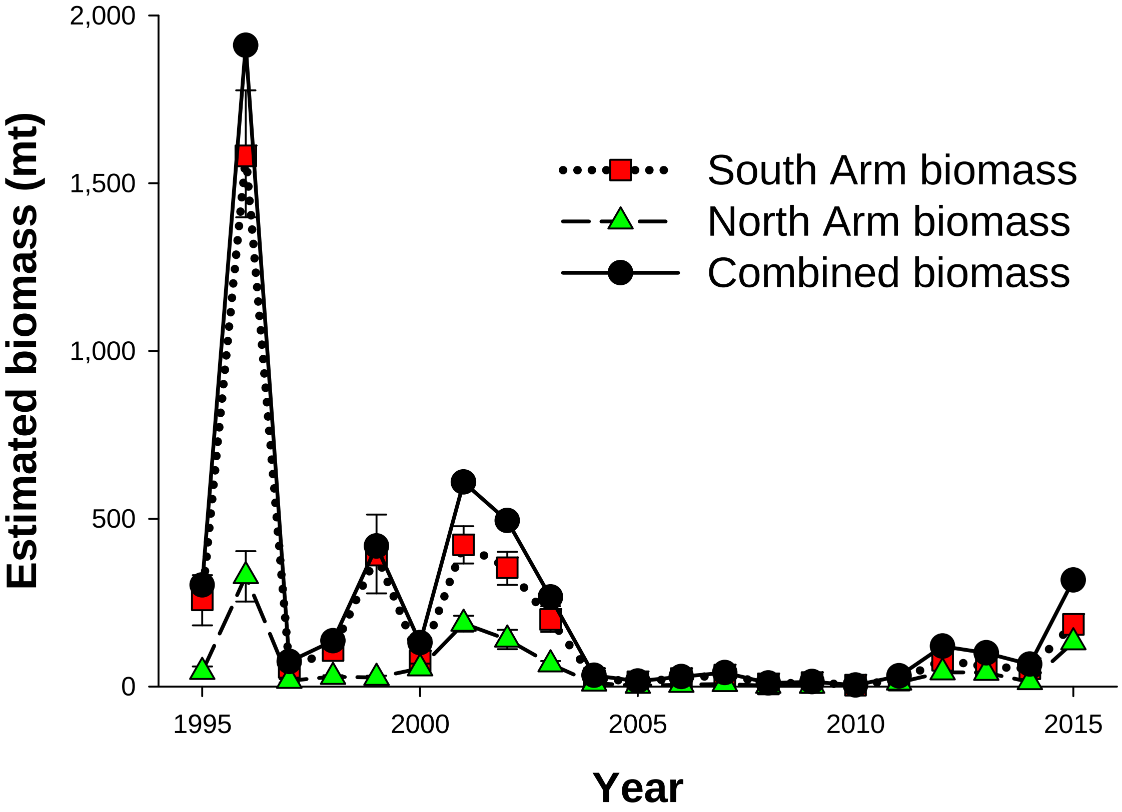

Figure 15. Fraser River eulachon spawning stock biomass from 1995–2015 (estimated from egg and larval surveys). Data from Table 7 and online at: http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/river1-eng.html.

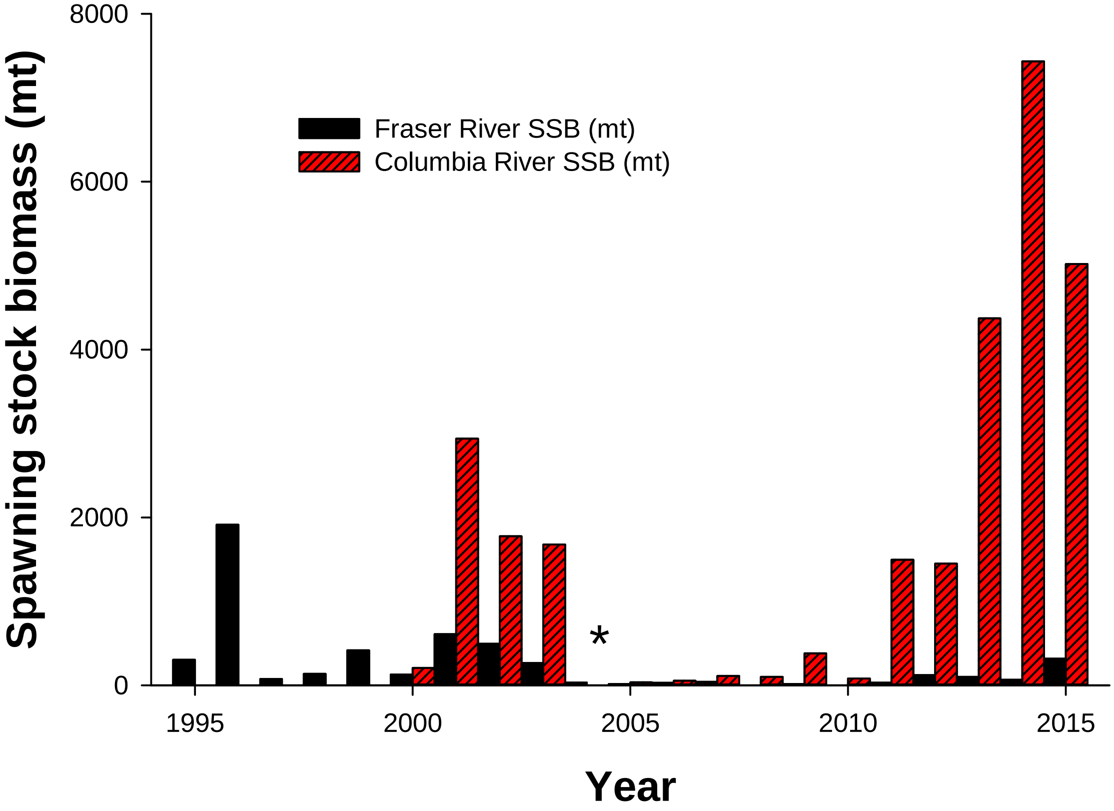

Figure 16. Comparison of Columbia River and Fraser River eulachon spawning stock biomass (SSB) estimates. Columbia River data for 2011–2013 from James et al. (2014) and for 2014–2015 from B. James and O. Langness (WDFW, pers. commun.). Columbia River pre-2011 SSB estimates are based on historical water discharge rates and expansions of historical larval densities adjusted for the shorter duration of the pre-2011 surveys (B. James and O. Langness, WDFW, pers. commun.). Fraser River data from Table 7 and online at: http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/river1-eng.html. Asterisk indicates that a 2004 SSB estimate for the Columbia River is unavailable.

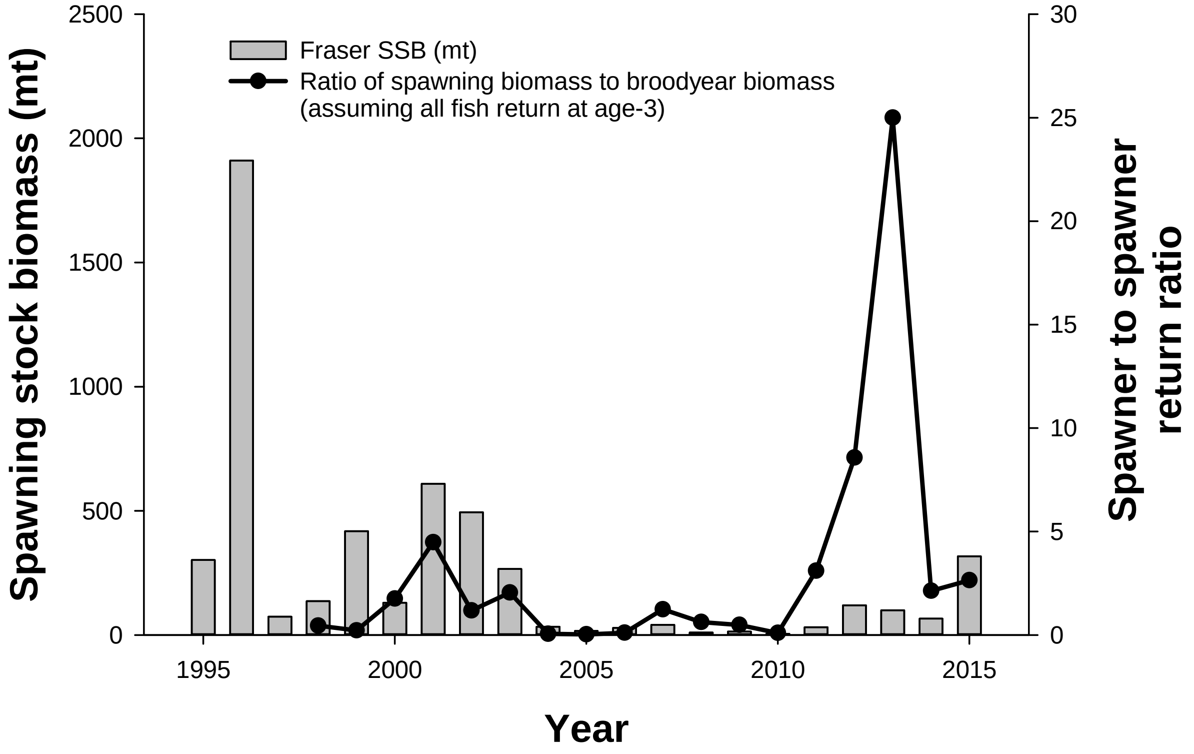

Figure 17. Fraser River estimated number of adult spawning eulachon (based on SSB estimates in Table 7 and average weight of 40.6 g per fish), and estimated spawner to spawner return ratio, assuming only a single year class of 3-year old spawners (Clarke et al. 2007, COSEWIC 2011, McAllister 2012).

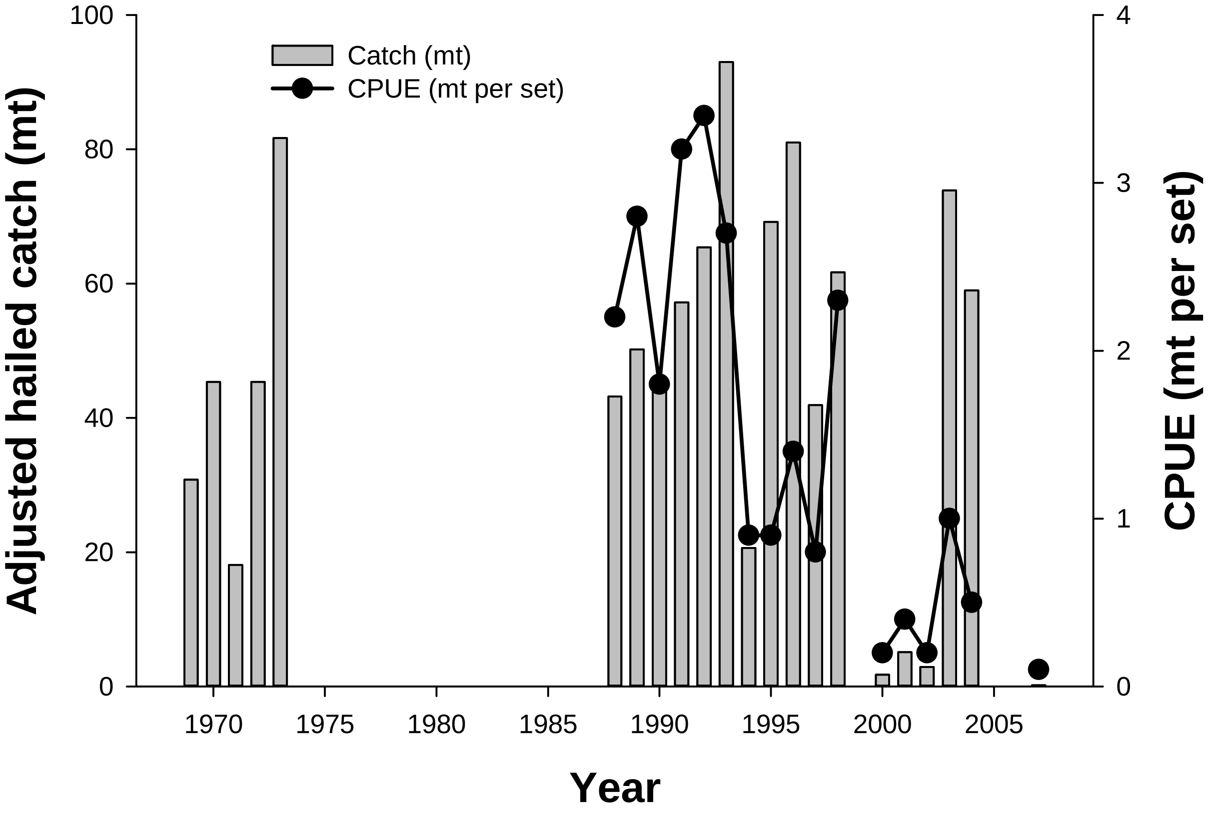

Figure 18. First Nations fishery catch and CPUE of eulachon on the Kemano River, British Columbia (data from COSEWIC, 2011 and sources cited therein).

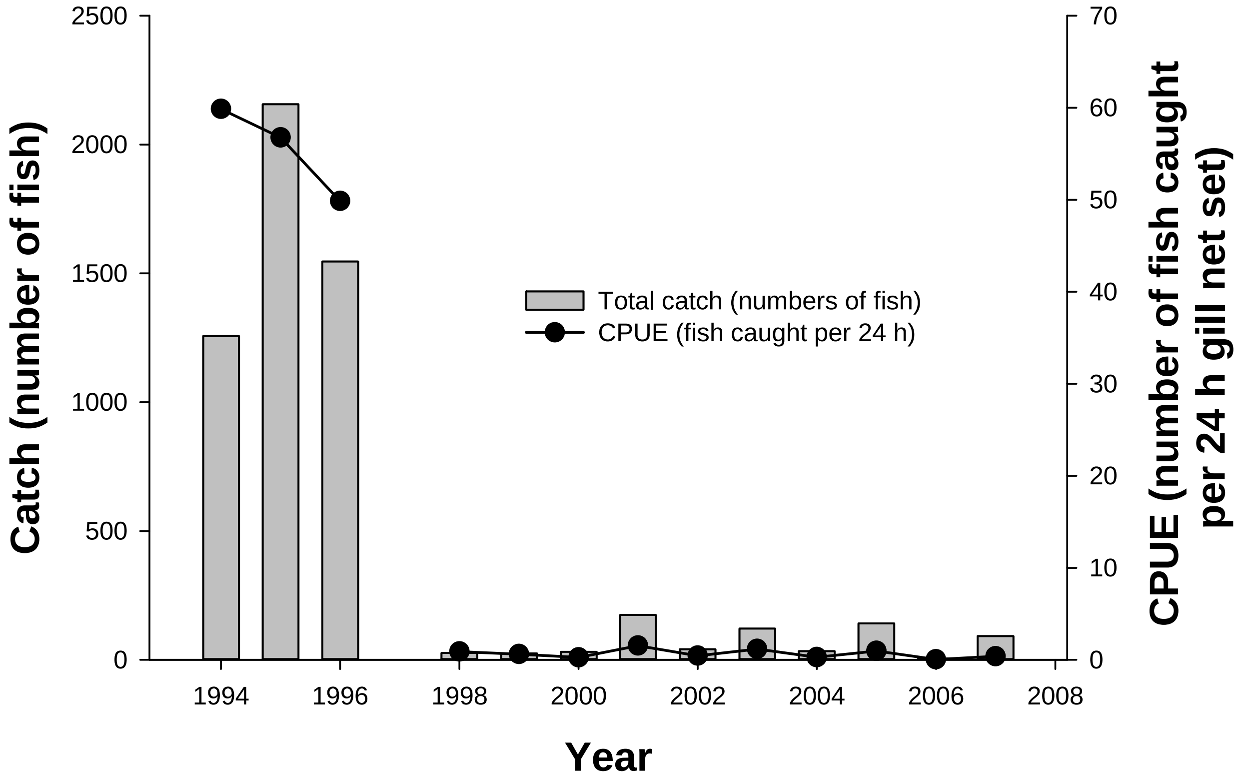

Figure 19. First Nations fishery catch (numbers of fish) and CPUE (number of fish per 24 h gill net set) of eulachon on the Kitimat River, British Columbia (data from COSEWIC, 2011 and sources cited therein).

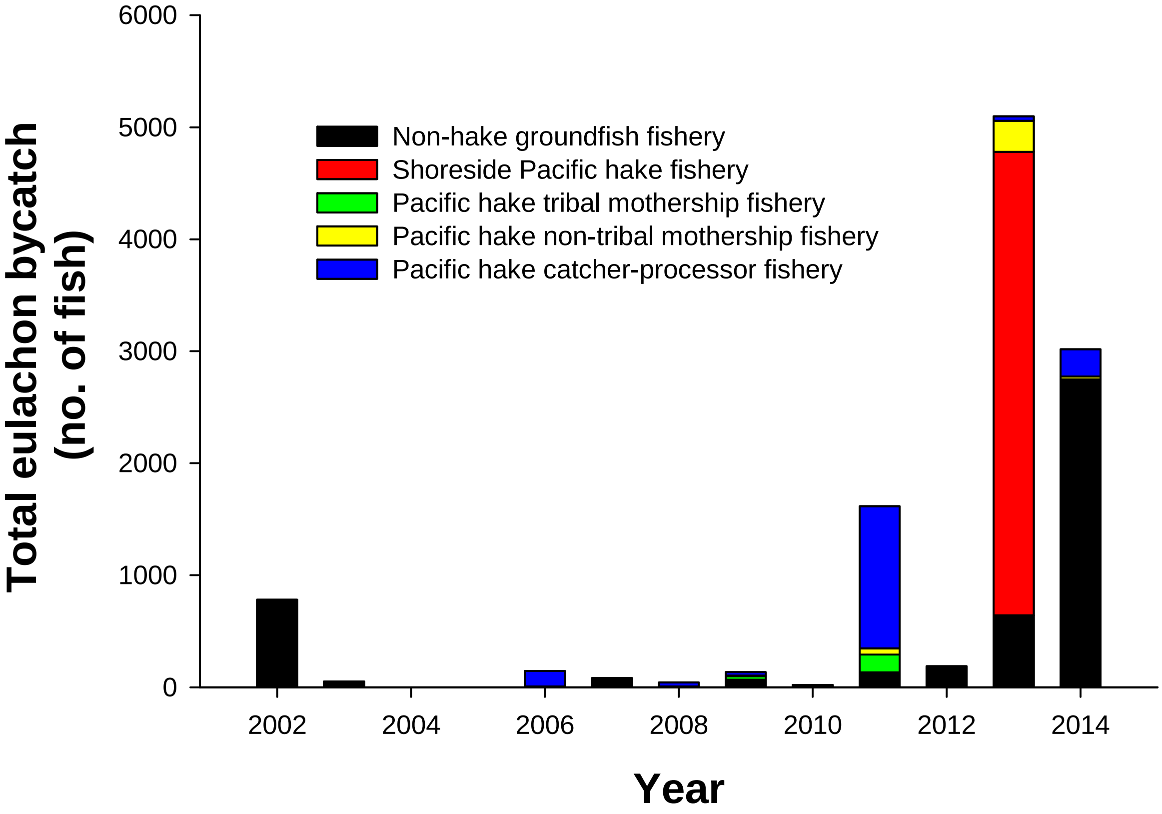

Figure 20. Estimated bycatch of eulachon in U.S. west coast groundfish fisheries 2002–2014. Data from Tables 14-16.

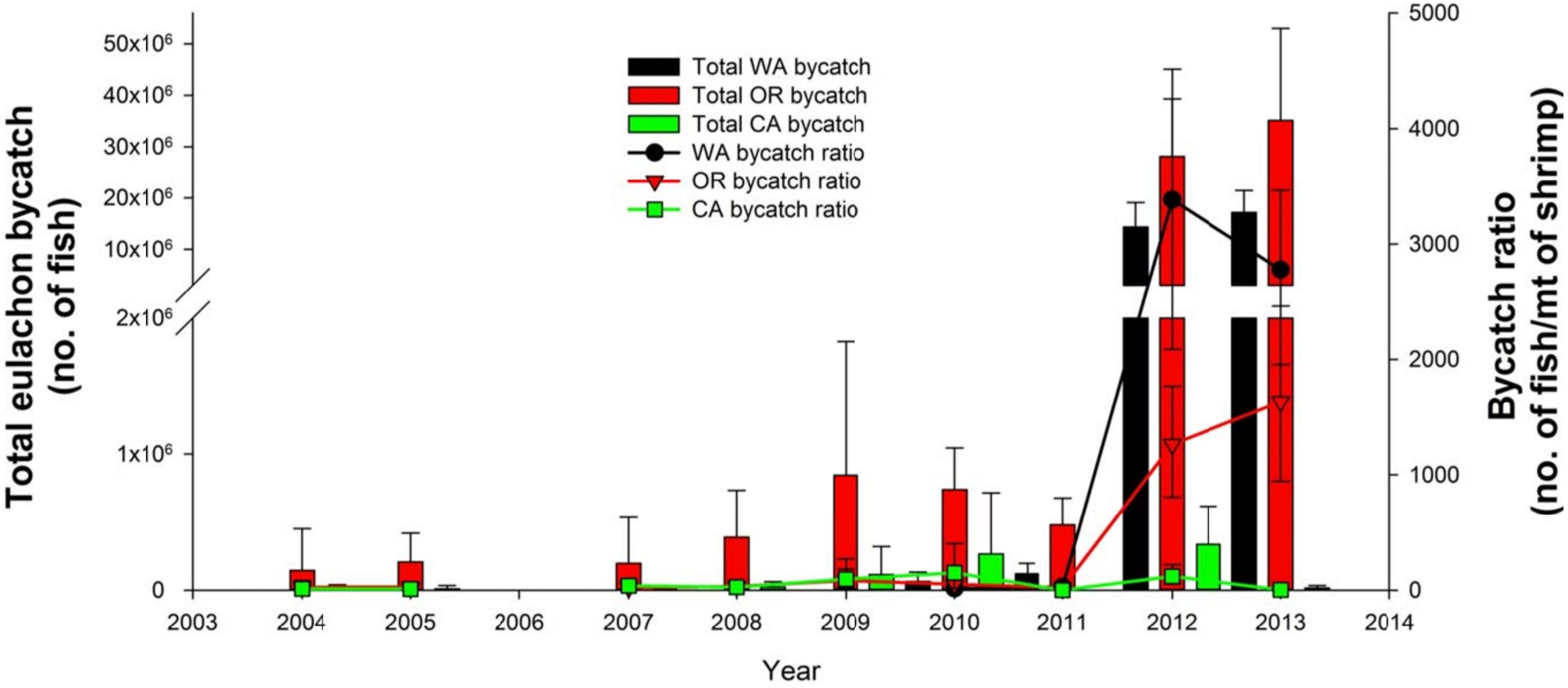

Figure 21. Estimated total bycatch and bycatch ratios of eulachon in the California, Oregon (2004–2013), and Washington (2010–2013) ocean shrimp trawl fisheries. Ocean shrimp fisheries were not observed in 2006.

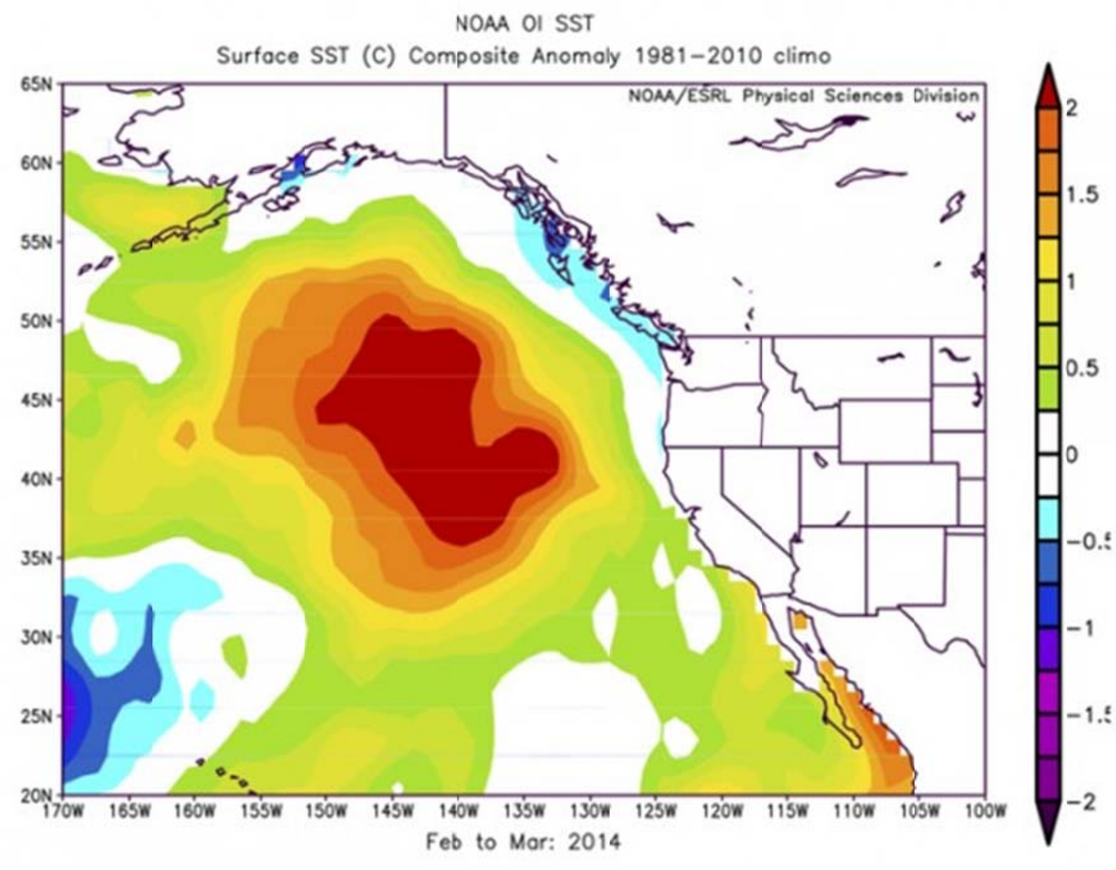

Figure 22. Mean sea surface temperature anomalies in the Northeast Pacific Ocean during February and March 2014 showing the warm water associated with the warm blob.

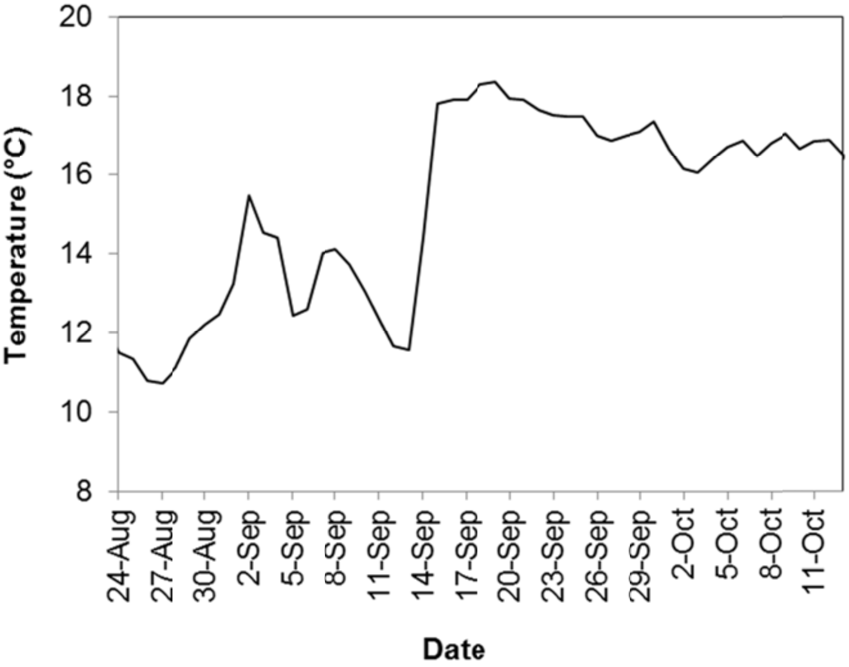

Figure 23. Sea surface temperatures recorded at Stonewall Bank (NOAA Buoy 46050; 44°39'22" N 124°31'33" W) on 24 August -12 October 2014, showing the rapid rise in temperature on 13-14 September 2014 as the 'warm blob' moved on shore.

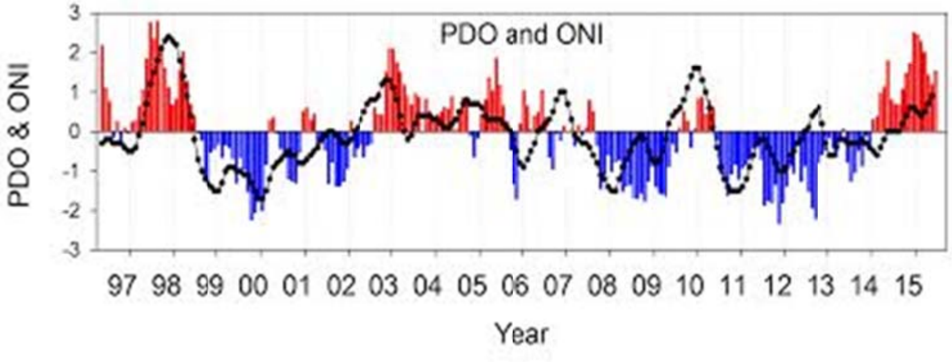

Figure 24. Time series of the Pacific Decadal Oscillation (PDO; red and blue vertical bars) and Oceanic El Niño Index (ONI; black line) during 1996–2015. The PDO shifts between positive (warm) to negative (cold) values at roughly decadal scales and has been positive since January 2014, while the ONI has a higher frequency. Figure from Bill Peterson (NWFSC).

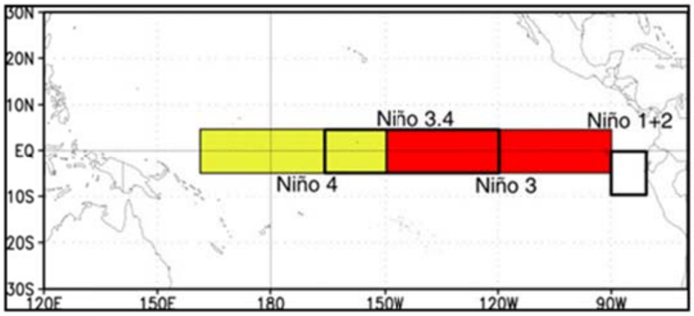

Figure 25. Location of the Niño 3.4 area along the equator. Figure from online source at: http://www.elnino.noaa.gov/.

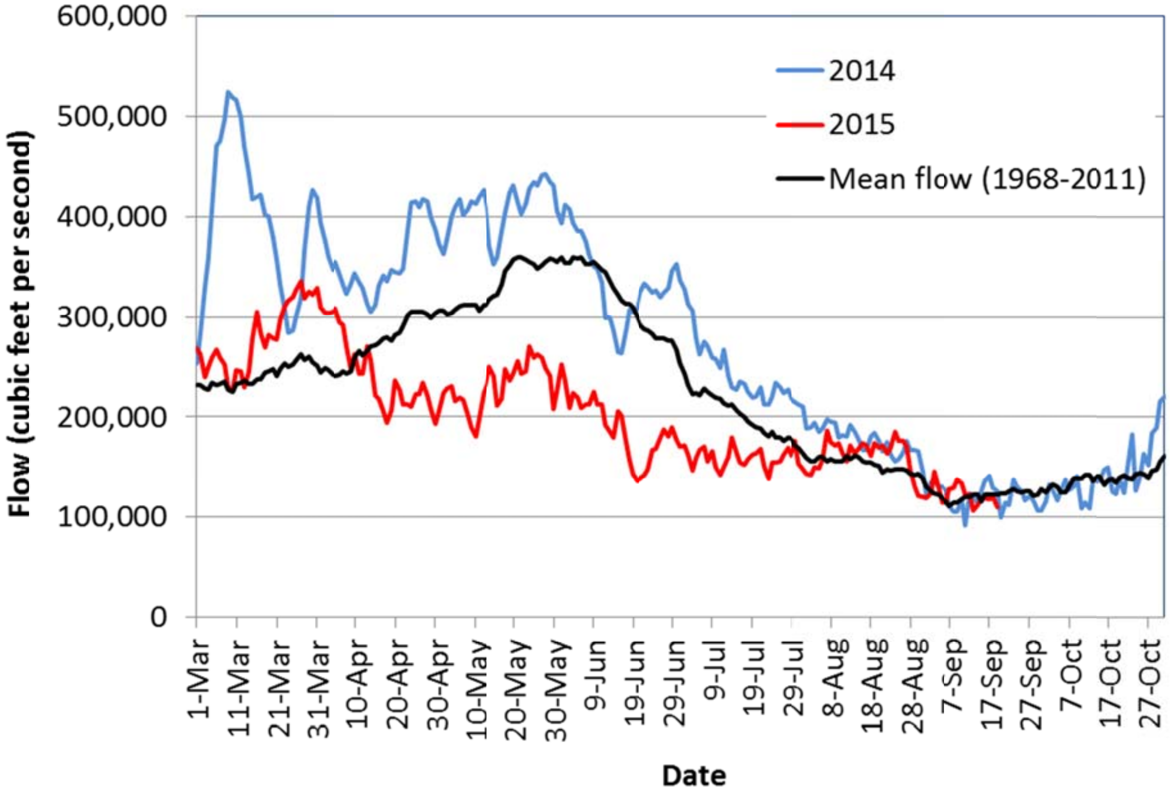

Figure 26. Columbia River flow measured near Quincy, WA (USGS Station 14246900) during 2014 and 2015, compared to the long term mean (1968–2011). Data available online at: http://waterdata.usgs.gov/nwis/dv/?site_no=14246900&agency_cd=USGS&amp;referred_module=sw.

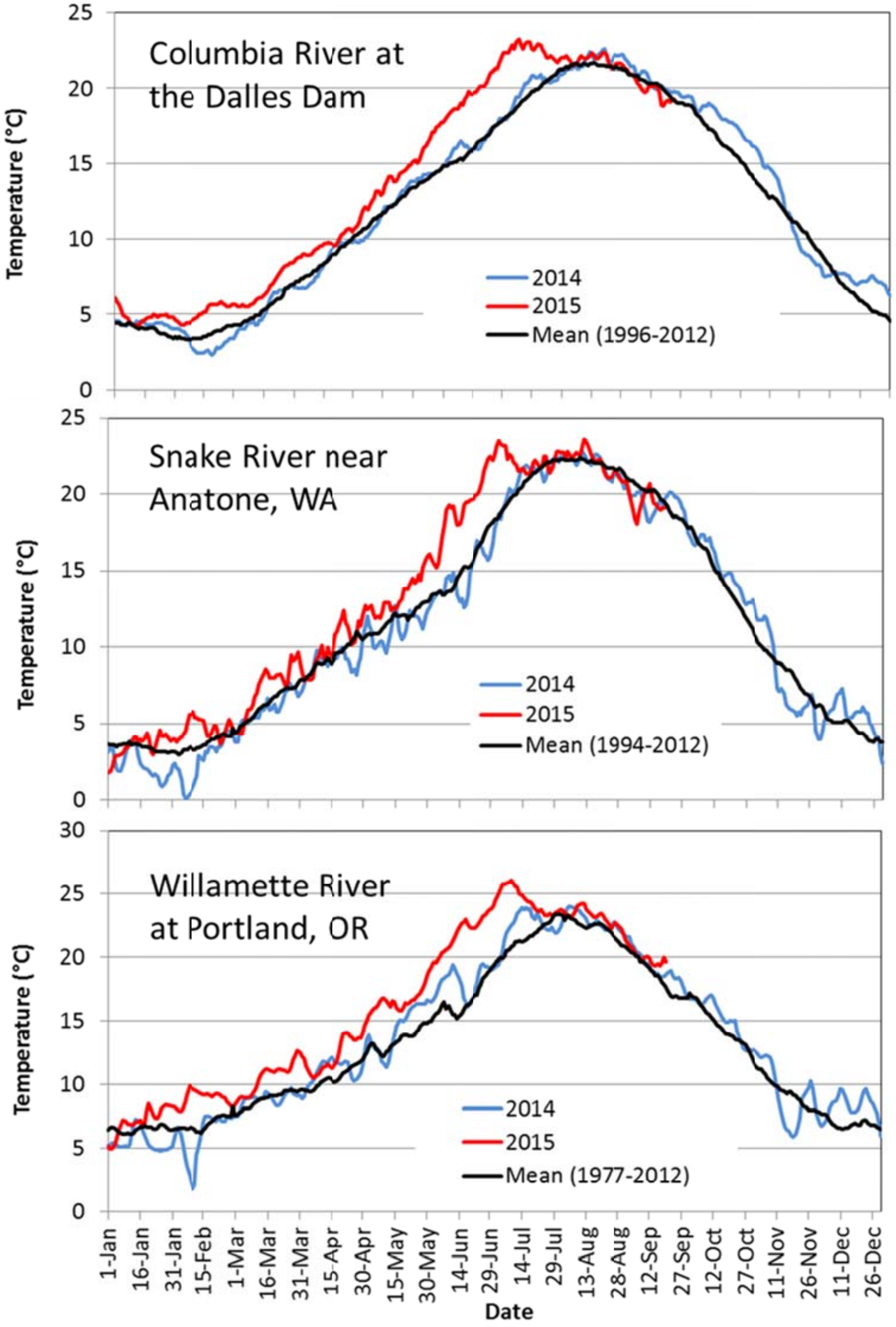

Figure 27. Water temperature measured in the Columbia River at the Dalles Dam (USGS Station 14105700; top), Snake River near Anatone, WA (USGS Station13334300; middle) and Willamette River in Portland, OR (USGS Station 14211720; bottom) during 2014 and 2015, compared to the long term mean. Data from USGS National Water Information System (Available online at: http://waterdata.usgs.gov/).