*Science, Service, Stewardship*

# 2022 5-Year Review:
# Summary & Evaluation of
# **Eulachon, Southern DPS**

National Marine Fisheries Service
West Coast Region

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# 5-Year Review: Southern Distinct Population Segment of Eulachon

| Species Reviewed | Distinct Population Segment |
|---|---|
| **Eulachon**<br>(*Thaleichthys pacificus*) | *Eulachon* |

## Table of Contents

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# 1 General Information

## 1.1 Introduction

On March 18, 2010, the National Marine Fisheries Service (NMFS) published a final rule in the Federal Register (75 FR 13012) to list the southern distinct population segment (DPS) of eulachon, hereafter, eulachon; (*Thaleichthys pacificus*) as threatened under the United States (U.S.) Endangered Species Act (ESA). This listing encompassed all 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 (Figure 1). The Biological Review Team (BRT) categorized climate change impacts on ocean conditions (all subpopulations[1]), and eulachon bycatch in offshore shrimp fisheries (Columbia River and British Columbia subpopulations) as the most serious threats to the persistence of eulachon (Gustafson et al. 2010). These threats, together with large declines in abundance, indicated to the BRT that eulachon were at moderate risk of extinction throughout all of its range (Gustafson et al. 2010). These factors collectively led NMFS to list eulachon as a threatened species under the ESA.

The ESA, under section 4(c)(2), directs the Secretary of Commerce to review the listing classification of threatened and endangered species at least once every 5 years. After completing this review, the Secretary must determine if any species should be: (1) removed from the list; (2) have its status changed from threatened to endangered; or (3) have its status changed from endangered to threatened. The most recent 5-year review for eulachon occurred in 2016. This document constitutes the agency's 5-year review of eulachon for the succeeding 5-year period.

## 1.2 Methodology Used to Complete the Review

On March 5, 2020 (85 FR 12905), we announced the initiation of a 5-year review for eulachon. We requested that the public submit new information on this species that has become available since the last 5-year review in 2016. In response to our request, we received one comment letter.

As part of this review, scientists from our Northwest Fisheries Science Center (NWFSC) collected and analyzed updated information related to the DPS (Gustafson et al. 2022).

In preparing this report, we considered the best available scientific information, including: the NWFSC report (Gustafson et al. 2022), the 2016 5-year review (NMFS 2016), the eulachon recovery plan (NMFS 2017), the listing record (including designation of critical habitat), and recent biological opinions issued for eulachon. The present report describes the agency's findings based on all of the information considered.

[1] The BRT used the "subpopulation" concept as a way to geographically subdivide the DPS and evaluate the threat scores, since threats had different levels of severity in different parts of the DPS. Therefore, the "subpopulation" concept used by the BRT is a geographical construct and is not synonymous with the population biology concept of demographically independent populations.

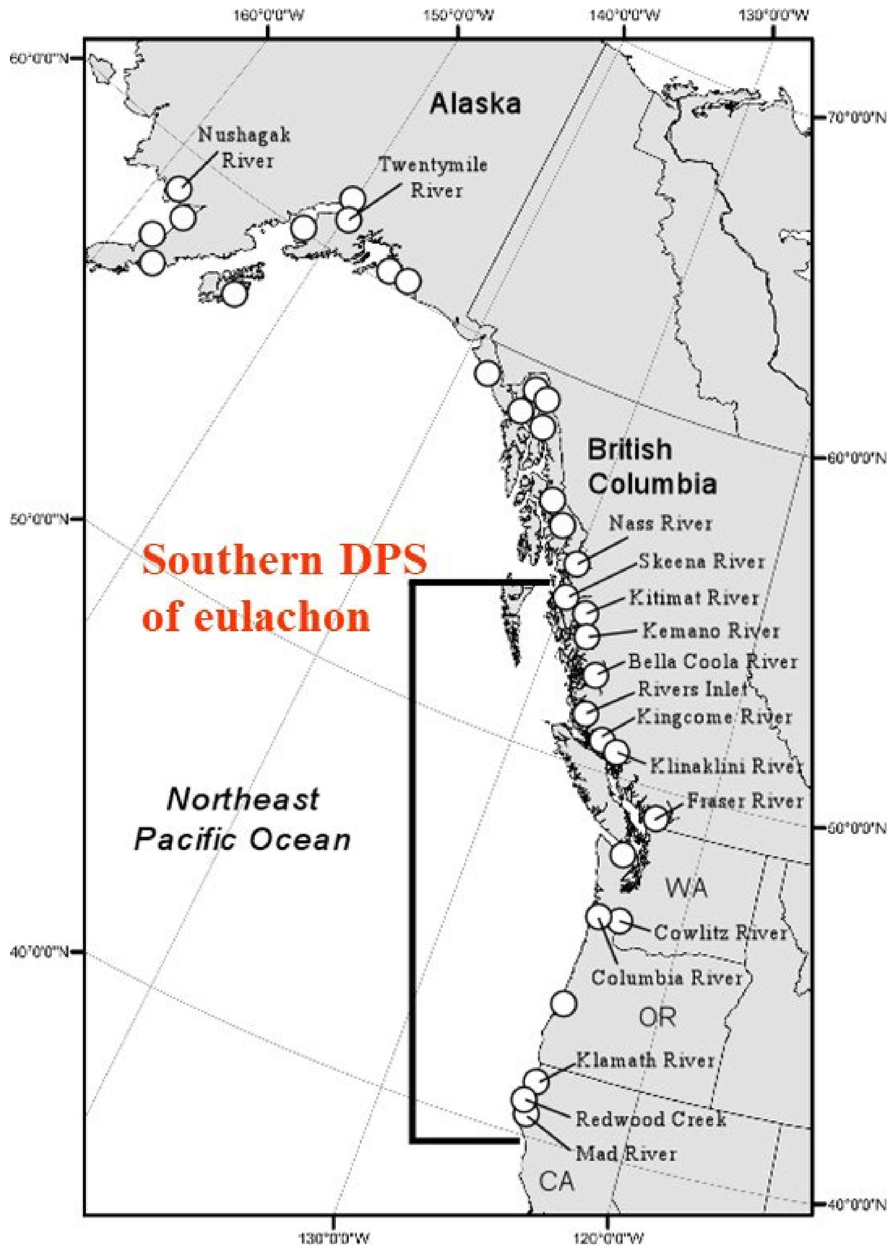


**Figure 1. Distribution of the southern district population segment of eulachon.**

## 1.3 Background – Summary of Previous Reviews, Statutory and Regulatory Actions, and Recovery Planning

### 1.3.1 Federal Register Notice announcing initiation of this review

85 FR 12905; March 5, 2020.

### 1.3.2 Listing history

In 2010, NMFS listed eulachon under the ESA and classified it as a threatened species (Table 1).

**Table 1. Summary of the listing history under the Endangered Species Act for Eulachon.**

| Species | DPS Name | Original Listing |
|---|---|---|
| **Eulachon**<br>(*Thaleichthys pacificus*) | Eulachon | **FR Notice:** 75 FR 13012<br>**Date:** 3/18/2010<br>**Classification:** Threatened |

### 1.3.3 Associated rulemakings

**Critical Habitat:** 76 FR 65324, October 20, 2011. Endangered and Threatened Species; Designation of Critical Habitat for the Southern Distinct Population Segment of eulachon.

### 1.3.4 Review History

Gustafson, R. G., M. J. Ford, D. Teel, and J. S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-105, 360 p.

National Marine Fisheries Service, West Coast Region. 2016. 5-Year status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California.

### 1.3.5 Recovery Priority Number at Start of 5-year Review Process

On April 30, 2019, NMFS issued new guidelines (84 FR 18243) for assigning listing and recovery priorities. For determining a recovery priority for recovery plan development and implementation, we assess demographic risk (based on the listing status and species' condition in terms of its productivity, spatial distribution, diversity, abundance, and trends) and recovery potential (major threats understood, U.S. has jurisdiction, authority or influence to implement management or protective actions to abate major threats, and certainty that management actions will be effective) to assign a Recovery Priority number from 1 (high) to 11 (low). Additionally, if the listed species is in conflict with construction or other development projects or other forms of economic activity, then they are assigned a 'C' and are given a higher priority over those species that are not in conflict.

Table 2 lists the current recovery priority number for the subject species, as reported in NMFS 2019. In January 2022, NMFS issued a new report with updated recovery priority numbers (NMFS 2022). The number for eulachon remained unchanged.

### 1.3.6 Recovery Plan

**Table 2. Recovery Priority Number and Endangered Species Act Recovery Plans for Eulachon.**

| Species | DPS Name | Recovery Priority Number | Recovery Plans |
|---|---|---|---|
| **Eulachon** (*Thaleichthys pacificus*) | Eulachon | 9C | **Title: Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*)**<br><br>Available at: https://www.fisheries.noaa.gov/resource/document/recovery-plan-southern-distinct-population-segment-eulachon-thaleichthys<br><br>**Date:** 9/6/2017 |

### 1.3.7 Eulachon Recovery Team

Priority Action number one of the *Recovery Plan for the Southern Distinct Population Segment of Eulachon (Thaleichthys pacificus)* (Eulachon Recovery Plan) called for establishment of a eulachon technical recovery and implementation team to develop an overall framework for funding, prioritization, implementation, and reporting of recovery actions (NMFS 2017). NMFS has formed a team of interested stakeholders, the Eulachon Recovery Plan and Implementation Team (ETRIT). To date, the ETRIT is composed of the following members:

- Cowlitz Indian Tribe
- Lower Elwha Klallam Tribe
- Jamestown S'Klallam Tribe
- Yakama Nation
- Confederated Tribes of Warm Springs
- Quileute Nation
- Yurok Tribe
- Haisla Fisheries Commission
- California Department of Fish and Wildlife
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife
- Department of Fisheries and Oceans Canada
- National Marine Fisheries Service

# 2 Review Analysis

In this section we review new information to determine whether the eulachon delineation remains appropriate.

## 2.1 Delineation of species under the Endangered Species Act

**Is the species under review a vertebrate?**

| DPS Name | YES | NO |
|---|---|---|
| Eulachon | X | |

**Is the species under review listed as a DPS?**

| DPS Name | YES | NO |
|---|---|---|
| Eulachon | X | |

**Was the DPS listed prior to 1996?**

| DPS Name | YES | NO | Date Listed if Prior to 1996 |
|---|---|---|---|
| Eulachon | | X | |

**Prior to this 5-year review, was the DPS classification reviewed to ensure it meets the 1996 DPS policy standards?**

In 1991, NMFS issued a policy on how the agency would apply the definition of "species" in evaluating populations for listing consideration under the ESA (56 FR 58612). Under this policy, a group of populations is considered a "species" if it represents an "evolutionarily significant unit" (ESU) that meets two criteria of: (1) being substantially reproductively isolated from other populations of the same taxonomic species, and (2) representing an important component in the evolutionary legacy of the biological species. In 1996, the joint NMFS and U.S. Fish and Wildlife Service DPS policy (61 FR 4722) affirmed that a stock (or stocks) of species is considered a DPS if it represents an ESU of a taxonomically recognized species. Accordingly, in listing the southern DPS of eulachon in 2010, we used the joint DPS policy to delineate the DPS under the ESA and conclude that it was threatened (75 FR 13012).

### 2.1.1 Summary of relevant new information regarding the eulachon DPS

This section provides a summary of relevant new information since the last 5-year review in 2016. For additional details see: *Gustafson 2022 et al. Information in Support of a Five-Year Status Review of Eulachon (Thaleichthys pacificus) Listed under the Endangered Species Act: Southern Distinct Population Segment.*

*Otolith Microchemistry*

Benson et al. (2019) attempted to detect population differences in eulachon using otolith ratios of various elements; Sr:Ca, Ba:Ca, Zn:Ca, and Mg:Ca. Eulachon otoliths from Oregon, Southeast Alaska, and the Bering Sea were correctly classified to region with an overall accuracy of about 79%. The results were similar to those of Benson et al. (2019), which indicated that there were differences in the elemental composition of eulachon otoliths over a broad geographic range, but that otolith microchemistry was not useful in distinguishing between closely adjacent river populations.

*Estuary Spawning*

Spangler (2020) recently completed a study of "how salinity affects fertilization and hatching success of Eulachon" in laboratory experiments on eulachon eggs and sperm obtained from ripe pre-spawn adults from the Twentymile River in south-central Alaska. Gametes were obtained from 10 female and 10 male eulachon and placed in glass trays previously filled with seawater diluted to test static salinities of 0, 6, 12, 18, 25, and 30 Practical Salinity Units (PSU). The experiment was replicated three times at each salinity. Percent fertilization success after 24 hours was recorded and "fertilized eggs were identified by their light gray appearance whereas unfertilized eggs turned an opaque white color" Spangler (2020, p. 17). Mean percent fertilization success of the three replicates was 98.6% at 0 and 6 PSU, 98.9% at 12 and 18 PSU, 95.6% at 24 PSU, and 0% at 30 PSU.

*Genetics*

Sutherland et al. (2021) developed an improved genetic baseline of 521 variant single nucleotide polymorphism (SNP) loci, genotyped in 1,989 individuals from 14 populations ranging from south-central Alaska (Twentymile River) to northern California (Klamath River). A number of locations with 35 or fewer individual samples (including the Elwha River, Washington and Kitimat River, British Columbia) were removed from the baseline, since the low sample sizes resulted in a lack of resolving power shown by these locations being consistently outside of the main clusters in dendrograms. Three main groupings were evident: southern rivers (Klamath, Columbia, Cowlitz, Sandy, and Fraser), northern rivers (Kingcome, Klinaklini, Wannock, Bella Coola, Kemano, Skeena, Nass, and Unuk), and the Gulf of Alaska (Twentymile River). These results were similar to those of Candy et al. (2015), and "the general trend of the data was similar between the SNP and microsatellite results, with a large divide between the populations to the south of the Fraser River, inclusive, and the populations to the north of the Fraser River, with Twentymile River as an outgroup" (Sutherland et al. 2021, p. 84–85). Although there appears to be significant isolation by distance (IBD) across the entire range of locations, as evidenced by a pairwise comparison of physical distance (km) and Fst (a measure of genetic differentiation) between locations (R2 = 0.708), there is no IBD evident within regions. Separation of the southern rivers group from northern rivers "had high bootstrap support (>99.99%)" in dendrograms (Sutherland et al. 2021, p. 82).

Within the southern grouping, there was some clustering of Columbia River populations together, but the Cowlitz River population grouped into a cluster with Klamath River, and more broadly with the Fraser River rather than with the other Columbia River populations (Columbia River, Sandy River). Cowlitz River and Klamath River are grouped closely together, and in 87% of trees Cowlitz and Klamath rivers group together without the Fraser River. In general these populations were very similar (e.g., Fraser River versus Columbia River: Fst = 0.0079 Fraser River versus Klamath River: FST = 0.0021, and Klamath River versus Columbia River: Fst = 0.0091 [Sutherland et al. 2021, p. 82].

Within the northern grouping, the Kingcome, Klinaklini, and Bella Coola Rivers "had high genetic similarity with each other (mean Fst = 0.0021)," as did the Kemano and Wannock Rivers (Fst = 0.0043) (Sutherland et al. 2021, p. 82). The Skeena and Nass Rivers "were nearly indistinguishable Fst = 0.0009" and the "Unuk River clustered outside of the north coast and central coast groupings, but still within the larger northern grouping" (Sutherland et al. 2021, p. 82).

Some rivers (Klamath, Fraser, Kingcome, Bella Coola, and Skeena) were sampled in multiple years above the 35-sample threshold, and for these rivers, "there was often close clustering of the different collection years, but not always" (Sutherland et al. 2021, p. 82). For example, Fraser River 2018 and 2019 clustered closely, but not with Fraser 2014; the largest difference was between collections taken in 2014 and 2018 (pairwise Fst = 0.0106). Similarly, there was close clustering, between Skeena River 2010 and 2013 (but not 2001) and "Bella Coola River 1998 and 2017 (but not 2013 or 2018)" (Sutherland et al. 2021, p. 82). On the other hand, Fst values for "Bella Coola River 1998 and 2017 collections, Klamath River 2013 and 2014 collections, and Skeena River 2001 versus 2010 and 2013 were not significantly different from zero" (Sutherland et al. 2021, p. 83). Sutherland et al. (2021, p. 87) noted that some of this variance across sampling years in the same river may be influenced by occurrence of multiple runs in some rivers with variable spawning times "if there is only a single sampling event per year." In the future, this improved genetic baseline will be applied to mixed stock analysis of at-sea sampled eulachon to improve estimates of where eulachon from specific rivers are distributed and which rivers are most impacted from at-sea bycatch risk (Sutherland et al. 2021).

*Bycatch*

Total fleetwide bycatch in U.S. West Coast groundfish fisheries increased from an estimated 56 total eulachon in 2016 and 68 total eulachon in 2017, to an estimated 782 total eulachon in 2018 and 3,121 total eulachon in 2019 (Gustafson et al. 2022). Assuming codend mesh sizes have remained relatively unchanged since restrictions on mesh sizes were removed, it is likely that most eulachon would continue to readily pass through the mesh openings of groundfish trawl nets and it is difficult to envision how eulachon are retained in groundfish trawl nets unless the codend becomes plugged. Thus the 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. However, we currently 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.

Coastwide eulachon bycatch in the combined Washington, Oregon, and California ocean shrimp trawl fisheries declined from 60 million in 2015 to about 4.4 million fish in 2016 and then 649,600 fish in 2017 (Gustafson et al. 2022). Coastwide eulachon bycatch was 3.2 million fish in 2018 and 19.8 million fish in 2019. These increases in coastwide bycatch were mostly due to increased bycatch in both Washington and Oregon. Eulachon bycatch and bycatch ratios declined from 2015–17. However, declines in bycatch and bycatch ratios were most dramatic in Oregon and California over this time period. In 2017 comparative bycatch ratios as number of eulachon per metric ton of shrimp were 145.4 for Washington, 19.9 for Oregon, and nearly zero for California. The bycatch ratio remained at a very low level during 2018 and 2019 in California; however, the ratio increased in Washington from 367 eulachon per mt of shrimp in 2018 to 1,570 eulachon per mt of shrimp in 2019. In Oregon the ratio increased from 111 eulachon per mt of shrimp in 2018 to 1,088 eulachon per mt of shrimp in 2019. Sorting grid bycatch reduction devices are mandated in ocean shrimp trawl fisheries. Washington and Oregon also mandated the use of LED lights on the footrope of each trawl net in 2018, and similar regulations took effect in British Columbia for the 2021/2022 season.

*Ocean Conditions*

From late 2013 to mid-2017 the California Current Ecosystem (CCE) experienced both a severe marine heat wave (MHW) in the form of the "Blob" (2013–16) and a strong El Niño event (2015–16). The impact of the "Blob" on eulachon abundance is likely reflected in the 2018 Columbia River SSB estimate of slightly more than four million fish, the lowest since 2010. Eulachon returning to the Columbia River in 2018 were mostly from the broodyears 2015 or 2016, which would have entered the CCE in spring to summer of those years, when both the "Blob" and the strong El Niño of 2015–16 were active. In 2015 and 2016, the biological spring transition never occurred, as northern copepods were absent from surveys along the Newport Hydrographic Line during both years. Euphausiids (commonly called krill), the primary prey of juvenile/adult eulachon, experienced very low densities during 2015–2016, which likely had negative impacts on eulachon growth and survival. Additional MHWs developed in May 2019, and again in 2020 and 2021, although the latter two MHWs mostly stayed offshore and had low impact on the CCE.

La Niña conditions prevailed from August 2020–May 2021, and redeveloped in October 2021 and are predicted to strengthen and last through spring of 2022. Both La Niña conditions and a negative Pacific Decadal Oscillation (PDO - which has prevailed since mid-2020), are associated with high productivity in the CCE, which should provide eulachon with positive growth conditions. Other indications of the presence of good ocean conditions for eulachon are the northern copepod biomass anomalies, which were mostly positive in 2020. Early and strong upwelling in 2020 and 2021 fueled very productive conditions in the CCE. However, this high level of primary production has likely led to the widespread near-bottom hypoxia on the continental shelf off Washington and Oregon in 2021. How eulachon respond to these hypoxic water events is unknown.

The near-term outlook for eulachon productivity in the CCE is positive, based on the presence of good ocean conditions. The current abundance of northern copepods and depressed numbers of southern copepods in the CCE would be expected to result in increased eulachon survival. The return of good ocean conditions and the likelihood that these conditions will persist into the near future suggests that population stabilization or increases may be widespread in the upcoming return years. The productivity potential as indicated by life history characteristics such as low age-at-maturity, small body size, planktonic larvae, and perhaps their high fecundity, confers eulachon with some resilience to environmental perturbations, as they retain the ability to quickly respond to favorable ocean conditions.

*Ocean Ecosystem Indicators*

Montgomery (2020) used a multivariate analyses to look at ocean ecosystem indicators in years when ocean residency is correlated with eulachon abundance in the Columbia River. Large-scale and bottom-up indicators such as the status of the PDO and prey abundance describe much of the variation in eulachon abundance. The time series analysis also indicates eulachon abundance correlates strongly with ocean conditions in the 2 and three 3 years prior to their return, suggesting dominant life histories of 2- and 3-year ocean types. These results suggest that the ocean ecosystem indicators developed for salmon are a reasonable starting point for a more fine-tuned model for predicting eulachon abundance in the Columbia River and potentially the DPS.

## 2.2 Recovery Criteria

The ESA requires NMFS to develop recovery plans for each listed species. Recovery plans must contain, to the maximum extent practicable, objective measurable criteria for delisting the species, site-specific management actions necessary to recover the species, and time and cost estimates for implementing the recovery plan.

### 2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

| DPS Name | YES | NO |
|---|---|---|
| Eulachon | X | |

### 2.2.2 Adequacy of recovery criteria

**Based on new information considered during this review, are the recovery criteria still appropriate?**

| DPS Name | YES | NO |
|---|---|---|
| Eulachon | X | |

**Are all of the listing factors that are relevant to the species addressed in the recovery criteria?**

| DPS Name | YES | NO |
|---|---|---|
| Eulachon | X | |

## 2.3 Updated Information and Current Species' Status

### 2.3.1 Demographic Recovery Criteria

The BRT used the "subpopulation" concept as a way to geographically subdivide the DPS and evaluate the threat scores, since threats had different levels of severity in different parts of the DPS. Therefore, the "subpopulation" concept used by the BRT for eulachon is a geographical construct and is not synonymous with the population biology concept of demographically independent populations.

To assess the status of eulachon, and evaluate if the threats (Table 3) that led to the listing of eulachon have been alleviated, the following demographic recovery criteria (Table 4) have been developed[2] for a subset of rivers in representative watersheds for each subpopulation. The demographic recovery criteria are comprised of two criterion. The first criterion is an abundance target (number of adult spawners), and the second criterion is a presence/absence metric.

[2] Eulachon Recovery Plan, Recovery Action 3.8.1 – develop abundance and productivity criteria for each subpopulation of eulachon.

**Criterion 1** – the abundance targets[3] are divided into two categories: HIGH and LOW. The recovery scenario calls for meeting both targets within each subpopulation within a 30-year timeframe.

For the Columbia River subpopulation, the abundance targets are:

> **HIGH** – a minimum of 229,500,000 spawners for 24 out of 30 years.
> **LOW** – a minimum of 66,500,000 spawners for 6 out of 30 years.

For the Fraser River subpopulation, the abundance metrics are:

> **HIGH** – a minimum of 17,500,000 spawners for 24 out of 30 years.
> **LOW** – a minimum of 5,200,000 spawners for 6 out of 30 years.

**Criterion 2** – Except for the Fraser River subpopulation, we also developed a presence/absence metric (Table 4) in a subset of rivers for each subpopulation to assess eulachon presence, spatial distribution, and frequency of occurrence in representative watersheds where eulachon historically spawned at a moderate to high frequency.

**Table 3. Eulachon Threats and Level of Threat Severity in each Subpopulation.**

| | **Subpopulation** | | | |
|---|---|---|---|---|
| **Threats** | **Klamath** | **Columbia** | **Fraser** | **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 |
| Commercial harvest | very low | low | low | very low |
| Scientific monitoring | very low | very low | very low | very low |
| Dredging | very low | moderate | low | very low |

[3] The abundance targets are based on the eulachon spawning stock biomass monitoring programs in the Columbia and Fraser Rivers. The abundance targets are based on the mean values of the respective spawning stock biomass calculations.

**Table 4. Demographic Recovery Criteria for Eulachon**

| Demographic Recovery Criteria for the Columbia River Subpopulation |
|---|
| 229,500,000 spawners 24 out of 30 years, and 66,500,000 spawners for 6 out of 30 years |
| PLUS – presence/absence surveys in the Cowlitz River with presence 27 out of 30 years |
| PLUS - presence/absence surveys in the Grays River with presence 21 out of 30 years |
| PLUS - presence/absence surveys in the Sandy River with presence 10 out of 30 years |
| PLUS - presence/absence surveys in the Lewis River with presence 15 out of 30 years |
| **Demographic Recovery Criteria for the Fraser River Subpopulation** |
| 17,500,000 spawners 24 out of 30 years, and 5,200,000 spawners for 6 out of 30 years |
| **Demographic Recovery Criteria for the BC Subpopulation** |
| Klinaklini River - presence/absence surveys with presence 24 out of 30 years |
| Kingcome River presence/absence surveys with presence 27 out of 30 years |
| Bella Coola River - presence/absence surveys with presence 27 out of 30 years |
| Kemano River - presence/absence surveys with presence 24 out of 30 years |
| Kitimat River - presence/absence surveys with presence 24 out of 30 years |
| Skeena River - presence/absence surveys with presence 27 out of 30 years |
| Kilbella River - presence/absence surveys with presence 21 out of 30 years |
| Wannock River - presence/absence surveys with presence 24 out of 30 years |
| **Demographic Recovery Criteria for the Klamath Subpopulation** |
| Klamath River - Presence/absence surveys with presence 24 out of 30 years |

### 2.3.2 Updated Risk Summary

#### Spawning Stock Biomass Estimations

*California*

Although the Yurok Tribal Fisheries Program has not conducted any official eulachon surveys since 2014, eulachon have been observed in small numbers (no more than two per night) at the mouth of the Klamath River every year since then (Gustafson et al. 2022).

*Oregon/Washington*

Since the 2016 5-year status review, annual monitoring of eulachon spawning stock biomass (SSB) has continued in the Columbia (2011–2021) River; and expanded to the Grays (2011–2013, 2015–2016), Cowlitz (2015–2018), Naselle (2015–2017), and Chehalis (2015–2018) Rivers (Gustafson et al. 2022). In 2018, eulachon were 2.4 times more abundant in the Fraser River than in the Columbia River. Although the cause of the decline in Columbia River SSB in 2017–2018 is unknown, it is possibly related to the 2013–2016 MHW, known as the “Blob,” that reduced productivity of northern copepods and euphausiids, critical prey for eulachon in the CCE.

The Lower Elwha S’klallam Tribe has sampled eulachon adults and/or larvae in the Elwha, Dungeness, and Lyre Rivers on the Olympic Peninsula of Washington.

**Columbia River Basin** – In the Columbia River, eulachon abundance decreased markedly since the 2016 status review (Tables 5 and 6). The decrease in abundance reflects both changes in biological status and changes in ocean conditions. For the years 2011 through 2015, the 5-year SSB mean was 97.9 million spawners. For the years 2016 through 2021[4], the 6-year SSB mean was 40.2 million spawners. However, the 2021 estimate (96.4 million spawners) was nearly equivalent to the 2011-2015 mean.

**Table 5. Eulachon Spawning Stock Biomass Estimations in the Columbia River for the years 2011 through 2015 (JCRMS 2017, Gustafson et al. 2022).**

| Eulachon Spawning Stock Biomass Estimations | | | |
|---|---|---|---|
| | **MAX** | **MEAN** | **MIN** |
| 2011 | 69,661,800 | 36,775,900 | 17,860,400 |
| 2012 | 61,437,400 | 35,722,100 | 20,008,600 |
| 2013 | 197,943,400 | 107,794,900 | 45,546,700 |
| 2014 | 323,778,300 | 185,965,200 | 84,243,100 |
| 2015 | 207,570,500 | 123,582,000 | 57,525,700 |

[4] Due to the COVID-19 pandemic field sampling restrictions, the 2020 estimate for biomass and number of spawning eulachon is based on the sampling estimate of 1,900,000 pounds (JCRMS 2021, p. 23–24), which was based on 10 days of truncated larval sampling.

**Table 6. Eulachon Spawning Stock Biomass Estimations in the Columbia River for the years 2016 through 2021 (JCRMS 2021, Gustafson et al. 2022).**

| Eulachon Spawning Stock Biomass Estimations | | | |
|---|---|---|---|
| | **MAX** | **MEAN** | **MIN** |
| 2016 | 111,991,000 | 54,556,500 | 21,654,800 |
| 2017 | 34,071,100 | 18,307,100 | 8,148,600 |
| 2018 | 9,200,000 | 4,100,000 | 1,300,000 |
| 2019 | 89,137,289 | 46,684,765 | 19,285,087 |
| 2020 | 40,644,800 | 21,280,000 | 8,724,800 |
| 2021 | 184,115,810 | 96,395,712 | 39,522,242 |

*Canada*

No new information on the status of Klinaklini River eulachon has been located since the 2016 status review (Gustafson et al. 2022); however, there were anecdotal reports that large numbers of eulachon were observed in Kingcome River during 2015–17. Wuikinuxv Nation conducts an annual eulachon monitoring survey on the Wannock, Kilbella and Chckwalla Rivers in Rivers Inlet; however, results have not been released. Anecdotal information indicates that eulachon began to return to the Bella Coola River in 2012 and the run has been slowly building in numbers, such that multiple schools of eulachon were observed in 2018; however, the run was not large enough to support a fishery.

The Haisla Fisheries Commission has estimated abundance of adult eulachon in the Kemano River from 2008–2021. Abundance has ranged from 589,298 fish to 3,754,031 fish since 2016, with no apparent run in 2020. Mosty recently, an estimated 785,723 fish returned to the Kemano River in 2021. The Haisla Fisheries Commission eulachon monitoring program detected eulachon in the Kitimat and Kildala Rivers in 2018. Haisla Fisheries Commission surveyed for eulachon eDNA in 12 rivers in Haisla territory (Kitimat, Anderson, Wahtl, Moore, Kildala, Dala, Gilloteyse, Foch, Kemano, Wahoo, Kitlope, and Kawasas) in 2020 and 2021. Nine out of these 12 systems were positive for eulachon presence in 2020 and results for the 2021 run year are expected later this year.

The North Coast Skeena First Nations Stewardship Society coordinates a Skeena River eulachon catch monitoring survey of the eulachon food fishery. An estimated 856,000 eulachon and 373,000 eulachon were harvested from the Skeena River in 2019 and 2020, respectively.

**Fraser River** – In the Fraser River, eulachon abundance increased markedly since the 2016 5-year review (Tables 7 and 8). The increases in abundance in the Fraser River, reflects both changes in biological status and changes in ocean conditions. For the years 2011 through 2015, the 5-year SSB mean, was 2.8 million spawners. For the years 2016 through 2021, the 6-year SSB mean (standard 7-week survey period) was 4.9 million spawners; however, the increase is largely associated with strong returns in 2018 and 2020. If the three large returns during the 2011-2021 period are removed, the SSB means for the two periods are comparable (2011-2015: 1.7 million spawners, and 2016-2022: 1.8 million spawners).

**Table 7. Eulachon Spawning Stock Biomass Estimations[5] in the Fraser River for the years 2011 through 2015 (DFO 2021a, Gustafson et al. 2022).**

| Eulachon Spawning Stock Biomass Estimations | |
|---|---|
| 2011 | 676,596 |
| 2012 | 2,619,095 |
| 2013 | 2,182,574 |
| 2014 | 1,440,500 |
| 2015 | 6,918,764 |

**Table 8. Eulachon Spawning Stock Biomass Estimations in the Fraser River for the years 2016 through 2021 (DFO 2021a, b, DFO 2022, Gustafson et al. 2022).**

| Eulachon Spawning Stock Biomass Estimations | |
|---|---|
| 2016 | 960,330 |
| 2017 | 763,902 |
| 2018 | 8,904,912 |
| 2019 | 2,357,180 |
| 2020 | 13,619,277 |
| 2021 | 3,077,433 |

*Summary* – During the years 2016 through 2021, eulachon mean SSB estimates did not meet any of the HIGH demographic recovery criteria for either the Columbia River subpopulation or the Fraser River subpopulation. Although the mean SSB estimate for 2020 on the Fraser River was only 380,000 fish of the HIGH criterion. For the Columbia River subpopulation, the LOW demographic recovery criterion was met in 2020, and for the Fraser River subpopulation, the LOW demographic recovery criterion was met in 2018 and 2020.

### 2.3.3 Five-Factor Analysis

Section 4(a)(1) of the ESA directs us to determine whether any species is threatened or endangered because of any of the following factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or man-made factors affecting its continued existence. Section

[5] Converted from metric tons to fish at 9.9 fish/pound.

4(b)(1)(A) requires us to make listing determinations after conducting a review of the status of the species and taking into account efforts to protect such species.

Limited new information has become available regarding the threats (Table 3) to eulachon since the 2016 5-year review. Below we provide a summary of relevant new information relating to each of the five factors, where available. For additional details regarding relevant new information, see *Gustafson 2022 et al. Information in Support of a Five-Year Status Review of Eulachon (Thaleichthys pacificus) Listed under the Endangered Species Act: Southern Distinct Population Segment.*

**Listing Factor A: Present or threatened destruction, modification or curtailment of its habitat or range**

**Habitat Cross-Over Analysis**—while not specific to eulachon, significant habitat restoration and protection actions at the federal, state, tribal, and local levels have been implemented to improve degraded habitat conditions for Pacific salmon and steelhead stocks in the Pacific Northwest and California. While these efforts have been substantial and are expected to improve freshwater and estuarine habitat conditions for the targeted species, we do not yet have evidence demonstrating that these improvements in habitat conditions will yield similar benefits for eulachon. Nonetheless, these habitat restoration actions likely have yielded indirect benefits to eulachon, especially habitat restoration actions in estuarine habitats that provide material influx that support food web processes that may contribute to improvements in eulachon fitness and survival in estuarine and nearshore environments.

### 2.3.4 Environmental Factors

This section provides an overview, with a particular emphasis on recent changes, and predicted future changes, in environmental factors that are important to eulachon productivity and survival in marine and freshwater environments.

#### 2.3.4.1 Observed and Predicted Future Marine Conditions

*El Niño-Southern Oscillation*

Under normal weather conditions in the equatorial tropical Pacific Ocean, warm surface water along the coast of South America is carried offshore to the west along the equator by trade winds. This warm water is replaced by cold, upwelled-water, that provides nutrients to the Humboldt Current System. These normal conditions are often interrupted by the opposing hot and cold climate patterns in the tropical Pacific termed El Niño and La Niña, respectively. These cyclic equatorial sea surface temperatures (SST) phenomena have been termed the El Niño-Southern Oscillation (ENSO) cycle. The ENSO can be described by the Oceanic Niño Index (ONI), which is based on three-month running-mean SST anomalies in the Niño 3.4 region (between 5°N and 5°S latitude and 120–170°W longitude). El Niño is characterized by a positive ONI greater than or equal to +0.5ºC and La Niña is characterized by a negative ONI less than or equal to -0.5ºC. These threshold SST anomalies in the Niño 3.4 region must also last for at least five consecutive overlapping three-month periods in order to be classified as either a full-fledged El Niño or La Niña. Warmer, less productive conditions off the Pacific Northwest are associated with the El Niño phase of ENSO, which occurs on average every two to seven years and may last from six to 18 months.

During the period of 2015-2021, there have been two El Niño events and three La Niña events. A very strong El Niño occurred from November 2015–April 2016 followed by two weak La Niña conditions (August–December 2016 and October 2017–April 2018). A weak El Niño then occurred from October 2018–June 2019 returning to La Niña conditions from August 2020–May 2021. As of 13 December 2021, we are experiencing another La Niña event with equatorial SSTs below average across the central and east-central Pacific Ocean. La Niña conditions are expected to continue through the Northern Hemisphere winter 2021-2022 (~95% chance) until spring 2022 (~60% chance during April-June).

*Pacific Decadal Oscillation*

The PDO index is an indicator of the ocean-atmosphere variation for the North Pacific whose opposite regimes, characterized by a positive and negative PDO, typically last for 20–30 years (Mantua et al. 1997, Mantua and Hare 2002). The main driver of the PDO index is variability in anomalies of monthly SST in the North Pacific (poleward of 20°N) (Mantua et al. 1997). Negative PDO values are associated with relatively cool ocean temperatures in the northern CCE, and positive values are associated with warmer, less productive conditions. Changes in regional patterns of the PDO have been associated with variation in the abundance of numerous species in the ocean off the Pacific Northwest: including copepods (Fisher et al. 2015), forage fish (Lindegren et al. 2013), Pacific salmon (Mantua et al. 1997), and Pacific hake (McFarlane et al. 2000).

The PDO was mostly positive from January 2014 to fall of 2019, indicative of poor upwelling conditions in the northern CCE. However, the PDO has been steadily decreasing since 2016 (Harvey et al. 2021a) and has been mostly negative since January 2020. A similar string of consecutive negative PDO values (15 months to date) has not occurred since before the beginning of the 2013–2016 MHW (see "Marine Heat Waves" section below). This string of negative PDO values indicates that greater upwelling of nutrient-rich deep waters to the surface occurred in the northern CCE than in the previous several years (Di Lorenzo et al. 2008) (Weber et al. 2021, p. 5).

*North Pacific Gyre Oscillation*

The North Pacific Gyre Oscillation (NPGO) is a basin-scale climate index representing the second leading mode in sea surface height anomalies in the northeast Pacific Ocean as driven by variations in the circulation of the North Pacific Subtropical Gyre and Alaskan Gyre (Di Lorenzo et al. 2008).

Positive NPGO values usually indicate increased equatorward flow in the California Current, and are associated with increased nutrients, chlorophyll-*a*, and surface salinities (Harvey et al. 2020, Weber et al. 2021). Negative NPGOs are associated with decreased nutrients, chlorophyll-*a*, and surface salinities implying less subarctic source water and generally lower productivity (Harvey et al. 2020, p. 8). The NPGO has been negative since December 2016, which historically would indicate a decrease in equatorward flow in the CCE (Weber et al. 2021).

*Marine Heat Waves*

A marine heatwave (MHW) is defined as: "a prolonged discrete anomalously warm water event that can be described by its duration, intensity, rate of evolution, and spatial extent" (Hobday et al. 2016, p. 227), or more simply, a discrete period of prolonged anomalously warm [sea] water at a particular location (Oliver et al. 2021, p. 314). In the North Pacific, major MHWs are classified when daily interpolated standardized sea-surface temperature anomalies (SSTa), are greater than 1.29 times the standard deviation from normal and the minimum areal extent of the heatwave is at least 400,000 $km^2$.

One of the largest MHWs ever recorded began in late 2013 in the northeast Pacific Ocean off Alaska during the boreal winter of 2013–2014 and lasted into 2016. Because of its size and persistence this patch of anomalously warm water came to be nicknamed "the Blob" (Bond et al. 2015, Di Lorenzo and Mantua 2016, Jacox et al. 2018a, Thompson et al. 2019). Peak SST anomalies were greater than 2.5°C by February 2014 in the main blob patch (Bond et al. 2015, Di Lorenzo and Mantua 2016). During 2014, the blob continued to grow in size to the south and reached Baja California in the southern CCE by late 2014 (Bond et al. 2015, Di Lorenzo and Mantua 2016, Gentemann et al. 2017, Jacox et al. 2018a). Some warm-water patches of the blob were greater than 4.5 million $km^2$ in area and persisted for over six months. According to Peterson et al. (2017, p. 7267):

> At least 14 species of copepods occurred which had never been observed in shelf/slope waters off Oregon, some of which are known to have NP Gyre affinities, indicating that the source waters of the coastal ''Blob'' were likely of both offshore (from the west) and subtropical/tropical origin. … Impacts to the lower trophic levels were unprecedented and include a novel plankton community composition resulting from increased copepod, diatom, and dinoflagellate species richness and increased abundance of dinoflagellates. Additionally, the multiyear warm anomalies were associated with reduced biomass of copepods and euphausiids, high abundance of larvaceans and doliolids (indictors of oligotrophic ocean conditions), and a toxic diatom bloom (*Pseudo-nitzschia*) throughout the California Current in 2015, thereby changing the composition of the food web that is relied upon by many commercially and ecologically important species.

Besides copepods, many other groups experienced dramatic shifts in both distribution and abundance in response to the anomalously warm waters from 2014–2016, including other members of the plankton community, pelagic red crabs, pelagic fish, forage fish, seabirds, and marine mammals (Cavole et al. 2016, Peterson et al. 2017). In addition, an extensive and long-lasting harmful algal bloom of the toxic diatom *Pseudo-nitzschia* coincided with the coastal MHW that began nearly synchronously along the entire coast in late spring/early summer (April–June), with the onset of seasonal upwelling, and endured through the end of 2015 (Bates et al. 2018, p. 16).

A new MHW (known as NEP19 or Blob 2.0) began in mid-May 2019 in the Gulf of Alaska, and by late August 2019 had extended to the CCE off Washington to central California (Amaya et al. 2020, Chen et al. 2021). Amaya et al. (2020, p. 6) stated:

> … the 2019 Blob 2.0 primarily resulted from a weakened North Pacific High, which reduced the strength of the surface winds, resulting in reduced evaporative cooling and wind-driven upper ocean mixing in the Northeast Pacific. Consequently, strong downward surface heat fluxes were mixed over a record minimum mixed layer depth, producing surface warming in excess of 2.5°C above normal.
>
> At its greatest extent, NEP19 covered about 8.5 million km$^2$ and lasted for 239 days. By January 2020, NEP19 had shrunk to an area less than 100,000 km$^2$ and receded to a region far offshore in the Gulf of Alaska, with SST in the region mostly falling below the threshold for classification as a heatwave (Harvey et al. 2021b, p. S-11). A new MHW formed in February 2020 (NEP20a) and covered 4.6 million km$^2$ at its peak in April. By June 2020, NEP20a had weakened and since this heatwave remained >1500 km from the coast … [it] likely had little impact on the CCE (Harvey et al. 2021b, p. S-11).

A new MHW (NEP20b) formed in May–June 2020 (Harvey et al. 2021a) and expanded to its maximum size of 9.1 million km$^2$ by late September 2020. Moderate to strong upwelling apparently kept NEP20b from impacting the CCE until late September, although during this peak period, the second 2020 heatwave covered over 50% of the CCE … particularly in waters off central and northern California, Oregon, and Washington (Harvey et al. 2021b, p. S-11). By 4 April 2021, NEP20b had shrunk to less than 400,000 km$^2$ (the area threshold for a large MHW) after lasting for 309 days.

*Upwelling Indices*

Three major indices of upwelling strength in the CCE are available: 1) the Bakun Index, 2) the Coastal Upwelling Transport Index (CUTI), and 3) the Biologically Effective Upwelling Transport Index (BEUTI) (Jacox et al. 2018b). Various versions of the Bakun Index are available beginning in 1946 (Bakun 1973, Schwing et al. 1996); however, from 1988 onward the CUTI and BEUTI are the preferred indices for the U.S. West Coast from 31–47°N. The CUTI provides estimates of the physical vertical transport of either upwelled or downwelled water, whereas the BEUTI estimates the vertical flux of nitrate that is either upwelled or downwelled and is more relevant when analyzing biological systems (Jacox et al. 2018b). Strong winter upwelling occurred in 2020, which preceded the start of an average to above-average upwelling season (Harvey et al. 2021a, p. 5). Harvey et al. (2021a, p. 5) noted that in 2020 frequent upwelling events occurred at: 45°N, with peaks ≥1 s.d. above the mean, which were usually followed by relaxation events. When upwelling events are followed by relaxation, as occurred in 2020, the upwelled nutrients may be more likely to be retained and spur coastal production (Harvey et al. 2021a, p. 5). Daily values of the CUTI at 45°N for each year from 2016–21 show periodic strong early upwelling in February through April in 2020 and 2021, in contrast to a more typical upwelling year such as 2016.

*Copepod Anomalies*

Larval and juvenile eulachon are planktivorous and commonly feed upon copepods during the critical transition period between these two life stages (Gustafson et al. 2010). Osgood et al. (2016) examined historical stomach content records from the 1960s in the Strait of Georgia and found that calanoid copepods accounted for 73% of individual larval and juvenile eulachon stomach contents. There are two main suites or assemblages of copepod species over the continental shelf off the West Coast of North America: a lipid-rich boreal shelf assemblage (e.g., *Calanus marshallae*, *Pseudocalanus mimus*, and *Acartia longiremis*), that normally occurs from central Oregon to the Bering Sea and a southern assemblage (e.g., *Paracalanus parvus*, *Mesocalanus tenuicornis*, *Clausocalanus* spp., and *Ctenocalanus vanus*), that are lower in nutritional quality and usually most abundant along the California coast (Mackas et al. 2001, 2007, Fisher et al. 2015). Northern copepods are normally the dominant species off Newport, Oregon at 45ºN in summertime, whereas in winter, southern copepod species dominate.

Changes in the relative abundance and distribution of these copepod assemblages covary with oceanographic conditions (Roemmich and McGowan 1995, Mackas et al. 2001, 2007, Peterson and Keister 2003, Zamon and Welch 2005, Hooff and Peterson 2006, Fisher et al. 2015). When warm conditions prevail, as during an El Niño year or when the PDO is positive, the distribution of zooplankton communities shift to the north and the southern assemblage of copepods become dominant in the northern CCE (Mackas et al. 2007, Fisher et al. 2015). The presence of these southern copepod species indicates onshore or poleward transport of water from the subtropics, whereas the presence of northern lipid-rich copepods indicates that subarctic waters are flowing equatorward (Fisher et al. 2015).

Variations in the normal seasonal cycles of northern and southern copepods are illustrated via anomalies in the abundance of northern copepods. Harvey et al. (2021a, p. 9) noted:
In 2020, northern copepods continued an overall increasing trend since the extreme lows during the 2014–2016 heatwave. They were >1 standard deviation above the mean in spring/summer 2020 before their regular seasonal decline in the fall, and the spring-summer anomaly was among the

highest of the time series. Southern copepods were below-average for much of 2020, continuing a decline since the heatwave. These values suggest above-average feeding conditions for pelagic fishes off central Oregon in 2020, with late-spring/summer copepod ratios the most favorable observed since before the 2014–2016 heatwave, and in nearly a decade.

The current abundance of northern copepods and depressed numbers of southern copepods in the CCE would be expected to result in increased eulachon survival, and suggest that eulachon returns to the Columbia River may remain relatively elevated, at least in the near term.

*Hypoxia*

Although hypoxia (defined here as dissolved oxygen ≤1.4 ml/l) occurs off the CCE in an Oxygen Minimum Zone on the continental slope below about 600 m, hypoxia in inner continental shelf waters of the CCE (in depths less than 50 m) was unknown until 2002 (Chan et al. 2008, 2019). Since reports of crab mortality in 2002 in the Dungeness crab fishery, severe hypoxic water conditions (defined here as dissolved oxygen ≤0.5 ml/l) on the continental shelf have become a recurring phenomenon despite the absence of such low values in the previous five decades of observations in the system (Chan et al. 2019, p. 64). These low dissolved oxygen (DO) levels in shelf waters are likely to negatively impact many near-bottom species of invertebrates and fishes, such as eulachon. Shelf hypoxia in the CCE is driven by upwelling, which brings nutrient-rich water of low dissolved oxygen content and low pH to the surface. This nutrient-rich water fuels blooms of plankton, which provide food for many organisms. However, when these plankton blooms die and sink to the ocean bottom, their decomposition consumes oxygen, often leading to hypoxia of near-bottom waters. The link is strong between the start of upwelling and emergence of hypoxic conditions over the continental shelf (Chan et al. 2019). Hypoxia in shelf portions of the CCE is most apparent in late summer and early fall (Feely et al. 2016), until the fall transition causes mixing of shelf waters.

Hypoxia now occurs regularly in the CCE over the continental shelf in summer and fall months (Chan et al. 2019, Adams et al. 2013, Peterson et al. 2013). Along the Newport Hydrographic Line near 45°N in summer 2020, DO levels were above the hypoxia threshold at each station, though the seasonal mean at Station NH25 (approximately 25 nautical miles west of Newport, Oregon) was close to the threshold and was at the threshold in July (Harvey et al. 2021b, p. S-13). Hypoxic waters do not usually impact the nearshore waters of the CCE until mid-June to July; however, in 2021, the early onset of the spring transition in March (see “Upwelling Indices” section) led to hypoxic conditions over the continental shelf as early as April.

*Ocean Acidification*

Global increases in atmospheric $CO_2$ have caused an increase in the amount of $CO_2$ absorbed by the oceans. As Canadell et al. (2021, p. 5-48) stated:

> Once dissolved in seawater, $CO_2$ reacts with water and forms carbonic acid. In turn carbonic acid dissociates, leading to a decrease in the concentration of carbonate ($CO_3^{-2}$) ions, and increasing both bicarbonate ($HCO_3^-$) and hydrogen (H+) ion concentration, which … [causes] a shift in the carbonate chemistry towards a less basic state, commonly referred to as ocean acidification.

According to the SROCC (Bindoff et al. 2019, p. 450):

> Multiple datasets and models show that the rate of ocean uptake of atmospheric $CO_2$ has continued to strengthen in the recent two decades in response to the increasing concentration of $CO_2$ in the atmosphere. The *very likely* range for ocean uptake is between 20–30% of total anthropogenic emissions in the recent two decades.
>
> The ocean is continuing to acidify in response to ongoing ocean carbon uptake. The open ocean surface water pH is observed to be declining (*virtually certain*) by a *very likely* range of 0.017−0.027 pH units per decade since the late 1980s across individual time series observations longer than 15 years. … These changes in pH have reduced the stability of mineral forms of calcium carbonate due to a lowering of carbonate ion concentrations … [(Bindoff et al. 2019, p. 450)]

Feely et al. (2016) emphasized the linkage between hypoxia and ocean acidification (OA) in the CCE. Much of the nutrient-rich, low-oxygen upwelled water that fuels productivity in the CCE also is relatively low in pH. Aragonite is a form of calcium carbonate that is a measure of OA. An aragonite saturation state of less than 1.0 … indicates corrosive conditions that have been shown to be stressful for many CCE species, including oysters, crabs, and pteropods (Harvey et al. 2021c, p. 19). Since upwelled water is hypoxic and acidified relative to surface waters … aragonite saturation levels tend to be lowest during and following upwelling in the spring and summer, and highest during the winter (Harvey et al. 2021c, p. 19).

Aragonite saturation is measured at Stations NH05 (approximately 5 nautical miles off Newport, Oregon) and NH25 along the Newport Line, and Harvey et al. (2021c, p. 19) stated:

> Generally, at NH05, the waters from about 15 m to the bottom become corrosive [aragonite saturation <1.0] in summer and fall, and the entire water column is above the saturation value in winter and into spring. Offshore, at NH25, waters below about 140 m remain corrosive year-round, and the annual variability is between ~50–140 m.

*Predicted Changes in the California Current Ecosystem*

Many of the climate modelling studies in the following section refer to two climate change scenarios, RCP 2.6 and RCP 8.5. RCP stands for representative concentration pathways that characterize greenhouse gas concentration trajectories used by the Intergovernmental Panel on Climate Change (IPCC) in their fifth Assessment Report in 2015. RCP 2.6 represents a very stringent scenario in which greenhouse gases peak in the mid-20th century and then decline over time, and RCP 8.5 represents a scenario where greenhouse gases continue to steadily increase through the end of the century (aka, "business as usual," but actually, a worst-case emissions outcome). In the future, the CCE is predicted to experience more frequent and intense MHWs, regional increases in wind-forced upwelling, and worsening acidification and hypoxia, which are all forecast to increase with anthropogenic climate change (Rykaczewski and Dunne 2010, Somero et al. 2016, Feely et al. 2016, Joh and DiLorenzo 2017, Brady et al. 2017, Xiu et al. 2018, Frölicher et al. 2018, Buil et al. 2021, Siedlecki et al. 2021).

In regards to MHWs, model projections of future conditions out to the year 2100 under the IPCC climate warming scenario RCP 8.5, indicate that there will be more prolonged multiyear warm events (>1°C) with larger spatial coverage (~18%) and higher maximum amplitude (~0.5°C for events >2°C) over the Northeast Pacific (Joh and DiLorenzo 2017). Additional model simulations by Frölicher et al. (2018, p. 360) indicate that the number of MHW days … is projected to further increase on average by a factor of 16 for global warming of 1.5°C relative to preindustrial levels and by a factor of 23 for global warming of 2.0°C. … models project an average increase in the probability of MHWs by a factor of 41. … However, current national policies for the reduction of global carbon emissions are [by the end of the twenty-first century, for global warming of 3.5°C]. … At this level of warming, MHWs have an average spatial extent that is 21 times bigger than in preindustrial times, last on average 112 days and reach maximum sea surface temperature anomaly intensities of 2.5°C.

Bakun (1990, p. 198) stated that coastal, upwelling-favorable winds are generated by the:

> …pressure gradient between a thermal low-pressure cell that develops over the heated land mass and the higher barometric pressure over the cooler ocean. Bakun (1990) hypothesized that climate warming will intensify these thermal land-sea differences, since land areas are predicted to warm twice as fast as the oceans, and should lead to more intense coastal upwelling in the CCE. Numerous studies (García-Reyes et al. 2013, Sydeman et al. 2014, Brady et al. 2017, Xiu et al. 2018, Howard et al. 2020, Quilfen et al. 2021, Siedlecki et al. 2021) have attempted to test the Bakun hypothesis by examining changes in coastal winds and upwelling intensity.

Most analyses of historical observations suggest that winds have intensified in the CCE (García-Reyes and Largier 2010, Sydeman et al. 2014, Quilfen et al. 2021); however, the mechanism behind this intensification is debatable, and therefore the Bakun "hypothesis has increasingly been challenged" (Fox-Kemper et al. 2021, p. 9-39). In regards to regional changes in upwelling intensity, Fox-Kemper et al. (2021, p. 9-39) stated that of the four eastern boundary upwelling systems only the CCE has experienced large-scale upwelling-favorable wind intensification over the period 1982–2010 albeit with regional differences (García-Reyes and Largier, 2010, Seo et al., 2012). An early global simulation (Rykaczewski and Dunne 2010) using an earth system model (ESM) projected decreases in DO and increases in nutrients, productivity, and acidification in the CCE during the 21st century.

More recently, Brady et al. (2017) used a climate model ensemble to simulate changes in upwelling from 1920 to 2100 in the CCE and projected that CCE upwelling will become more intense in the spring and less intense in the summer as a result of anthropogenic climate change. However, these changes will only begin to: "emerge primarily in the second half of the [21st] century. Brady et al. (2017) argued that earlier studies (e.g., García-Reyes and Largier 2010, Sydeman et al. 2014) that attributed: "observed historical trends in CCE upwelling … [to] anthropogenic climate change, were unlikely to be able to distinguish natural climate variability from anthropogenic forcing.

Xiu et al. (2018) applied a high-resolution coupled physical–biological model to the CCE from 1970 to 2049 under the RPC 8.5 greenhouse gas scenario. The results indicated an *increased upwelling intensity associated with stronger alongshore winds in the coastal region*, accompanied by increased nutrient transport and a likely decrease in DO and increase in future hypoxic events (Xiu et al. 2018, p. 1). However, these impacts are predicted to vary across the CCE, with an increase in upwelling in the north and a decrease in the south.

Howard et al. (2020) utilized five dynamically downscaled earth system models to project future CCE physical and biogeochemical variables out to 2100. Results showed that global and downscaled models agreed: "on significant increases in temperature and decreases in oxygen in the coastal Northeast Pacific" (Howard et al. 2020, p. 12). However, changes in upwelling, primary productivity, and nutrients were less certain. Howard et al. (2020, p. 13) concluded that basin-scale processes were more important than the local wind changes in driving the climate response, and that despite the substantial body of research focused on testing the Bakun hypothesis and evaluating changes in winds, shifting winds are likely not the dominant or decisive factor controlling changes in the key biogeochemical variables in the coastal CCE that have long motivated study of the sensitivity of wind-driven upwelling to climate change.

Buil et al. (2021) produced climate projections for the CCE under the high emission scenario (RCP 8.5) by application of a regional ocean circulation model together with a biogeochemical model to downscale global earth system models. Buil et al. (2021, p. 1) found that all models agree in the direction of the future change in offshore waters: an intensification of upwelling favorable winds in the northern CCE, an overall surface warming, and an enrichment of nitrate and corresponding decrease in dissolved oxygen below the surface mixed layer. Siedlecki et al. (2021) also utilized multiple models downscaled to the CCE to project future trajectories of temperature, $O_2$, pH, $CO_2$, and carbonate saturation state. Siedlecki et al. (2021, p. 2871) found that projected changes for the

CCE are consistent with the directional trends indicated by the global model for scenario RCP8.5 – warmer, more acidified, higher carbon content, and lower oxygen concentration. These changes are expected to be most intense in the northern CCE (Siedlecki et al. 2021), similar to the findings of Xiu et al. (2018).

Recently, Quilfen et al. (2021) examined estimated trends in upwelling winds using satellite wind analyses and atmospheric model re-analyses in the CCE for 1996–2018. The start and end years were chosen because they are not influenced by particular positive or negative phases of the ENSO, PDO, or NPGO. Results show a 25% increase in winter and spring upwelling-favorable winds within the central CCE (Cape Blanco to Point Conception), which: "is associated with a local increase of more than 25% in the seasonal upwelling transport index, as found with satellite products" (Quilfen et al. 2021, p. 14).

*Summary - Marine Conditions*

Weatherdon et al. (2016) employed a dynamic bioclimate envelope model to predict changes in abundance, distribution, and catch potential of species of commercial and cultural importance to coastal British Columbia First Nations under both the lower (RCP 2.6) and higher (RCP 8.5) greenhouse gas emission scenarios. For eulachon, changes in relative abundance from 2000–2050 were projected to decline by 26.4% and 35.7% under the lower (RCP 2.6) and upper (RCP 8.5) scenarios of climate change, respectively (Weatherdon et al. 2016). Projected poleward range shifts for eulachon from 2000–2050 on the British Columbia coast were estimated at 32.9 km/decade under RCP 2.6 and 39.5 km/decade under RCP 8.5 (Weatherdon et al. 2016). Change in catch potential for eulachon from 2000–2050 declined by 22.7% and 37.1% under climate change scenarios RCP 2.6 and 8.5, respectively (Weatherdon et al. 2016). Although two other models, AquaMaps and Maxent, corroborated eulachon catch declines, these models gave significantly more conservative estimates of 5.0% and 6.8% declines, respectively (Weatherdon et al. 2016).

From late 2013 to mid-2017 the CCE experienced both a severe MHW in the form of the "Blob" (2013–2016) and a strong El Niño event (2015–2016). The period from 2014–16 was the warmest 3-year period on record, with mean SSTa of 1.3°C, 3.1 … [standard deviations] above the mean of all 3-year periods from 1920–2016 (Jacox et al. 2018a). The impact of the "Blob" on eulachon abundance is likely reflected in the 2018 Columbia River SSB estimate of slightly more than four million fish, the lowest since 2010. Eulachon returning to the Columbia River in 2018 were mostly from the broodyears 2015 or 2016, which would have entered the CCE in spring or summer of those years, when both the "Blob" and the strong El Niño of 2015–16 were active. The Estuarine and Ocean Ecology Program at the NWFSC describes the biological spring transition as the date the copepod community switches from a winter (warm water) community to a summer (cold water) community. In 2015 and 2016, the biological spring transition never occurred, as northern copepods were absent from surveys along the Newport Hydrographic Line during both years. In addition, Brodeur et al. (2019, p. 1) stated:

> The community of taxa in both 2015 and 2016 was significantly different from the previously sampled years. Crustacean plankton densities (especially Euphausiidae) were extremely low in both of these years, and the invertebrate composition became dominated mostly by gelatinous zooplankton.

Since euphausiids are the primary prey of juvenile/adult eulachon in the CCE these low densities of euphusiids during the "Blob" likely had long-lasting negative impacts on eulachon growth and survival.

Another MHW developed in May 2019 that was as large and intense as the "Blob," but did not extend as deep into the water column and diminished in the fall. This MHW came ashore along Washington to central California by late August, but little data are available to assess its ecological impact on the northern CCE (Harvey et al. 2020). Nevertheless, Harvey et al. (2021c, p. 29) noted biological and ecological survey data suggest average to above-average feeding conditions in 2020 in much of the CCE, although … [these data] should be interpreted with care: survey effort was reduced in 2020 due to COVID-19, and many samples have yet to be processed.

Two additional MHWs were observed in the North Pacific in 2020 and 2021, but mostly stayed offshore. Although a weak El Niño event occurred from late 2018 into 2019, it had minimal impact on the CCE. ENSO-neutral conditions prevailed for the second half of 2020 and first half of 2021. La Niña conditions prevailed from August 2020–May 2021, and, as of October 2021, La Niña conditions have redeveloped and are predicted to strengthen and last through spring of 2022.

From 2014 to late 2019, the PDO index was mostly positive, while the NPGO index was mostly negative, both of which are indicative of warm, low productivity conditions in the CCE. The PDO switched to a negative state in 2020 and remained negative through November 2021. Paradoxically, the NPGO index did not similarly switch states in 2020 and has remained in a negative state since 2014.

Both a negative PDO and La Niña conditions are associated with high productivity in the CCE, which should provide eulachon with positive growth conditions. Other indications of the presence of good ocean conditions for eulachon are the northern copepod biomass anomalies, which were mostly positive in 2020; however, this index turned negative in September 2020, near the end of the 2019 MHW, and more recent data are unavailable. Early and strong upwelling in 2020 and 2021 fueled very productive conditions in the CCE. However, this high level of primary production likely led to the widespread near-bottom hypoxia on the continental shelf off Washington and Oregon in 2021. How eulachon respond to these hypoxic water events is unknown.

The near-term outlook for eulachon productivity in the CCE is positive, based on the presence of good ocean conditions. The productivity potential as indicated by life history characteristics such as low age-at-maturity, small body size, planktonic larvae, and perhaps their high fecundity, confers eulachon with some resilience to environmental perturbations, as they retain the ability to rapidly respond to favorable ocean conditions.

#### 2.4.3.2 Observed and Predicted Future Freshwater Conditions

*Predicted Changes for Columbia River Eulachon*

Sharma et al. (2017, p. 114–118) modelled historic conditions and future climate change scenarios for monthly runoff in the lower Columbia River and its major eulachon spawning tributaries. Sharma et al. (2017, p. 118–120) also modelled historic and future climate change scenarios for mean monthly (January, February, March) water temperatures in the lower Columbia River below Bonneville Dam. Results (Sharma et al. 2017, p. 114) of the modelled monthly flow under several climate change scenarios indicated:

> The March freshet was projected to increase or remain steady in all hydrologic units, as overall increases in winter precipitation in future climate change scenarios compensates for a smaller snowpack. Notably, early and mid-winter flows are significantly higher for hydrologic units with headwaters in snow-dominant areas, presumably because more precipitation in future climate change scenarios falls as rain and less as snow, leading to earlier runoff. In the Cowlitz River Basin … December-February combined runoff is projected to increase 26% from the baseline historic period to the 2040s, and 44% from the baseline historic period to the 2080s. Similar, but less dramatic increases are projected to occur in the Sandy and Lewis basins … The lower basins (Skamokawa, Elochoman, Kalama and Grays …) experience only small increases in early-mid winter runoff, because they are historically rain-dominant. These projections suggest that a reduction in the March freshet, which would likely be detrimental to the outmigration of future eulachon runs, may not be a concern in the lower Columbia tributaries, but a shift to earlier peak flows may change run timing (or protract the outmigration period).

Although management of dams and reservoirs act to control and smooth out flows in the Columbia River increasing rainfall and less snowfall in the Upper Columbia River Basin is projected to cause the peak in available discharge to occur earlier in the spring, and likely increase the overall water supply during the winter months while decreasing it during the late spring and summer months (Sharma et al. 2017, p. 117).

Since water temperatures and water temperature models for the winter months are not available for the lower Columbia River, Sharma et al. (2017, p. 119) projected:

> "air temperature increases (January-March) from the ensemble climate change scenarios onto the historical water temperature record of the Columbia River at Bonneville. In order

> to do this, it was necessary to convert air temperature increases to water temperature increases Morrill, et al. (2005) examined the historic water temperature of a group of disparate streams and rivers, and found an average ratio of increase of +0.7°C water temperature for each increase of +1.0° C air temperature. We applied this 0.7:1.0 ratio increase to projected air temperature increases for future climate change scenarios to the historical water temperature record. As part of this process, it was also necessary to adjust for the difference between the climate change scenarios baseline period (1916–2006) and the period of the Columbia River temperature data (1965–2014). To do this, we used the Pacific Northwest Index. We then summarized the mean water temperature in the Lower Columbia River by month for the historic and future scenarios."

Smith and Saalfeld (1955) reported that eulachon are present in the Columbia River when water temperatures are between 2°C and 10°C and delay migration into spawning tributaries until temperatures at the Bonneville Dam forebay are above 4.4°C (WDFW and ODFW 2001).

However, Sharma et al. (2017, p. 120) stated:

> … under all future climate change scenarios, a 4.4° C water temperature threshold appears irrelevant, as winter water temperatures will rarely dip below this mark, if at all. For in-migrating eulachon adults, it may mean that this will allow earlier migration into the system, as warmer water temperatures may be hospitable throughout the winter for spawning. This effect could potentially be beneficial to eulachon, in that it could allow for a longer spawning period, and different life cycle strategies to take advantage of this. However, higher water temperatures in coldwater fish during rearing causes a faster development but smaller size at hatch. Without adequate food sources, these fish are disadvantaged in their growth and development. There is also a potential for ill effects on out-migrating larvae, if they leave their natal rivers earlier in the winter, and their arrival in the ocean is mismatched with spring upwelling periods off of Oregon and Washington, which usually don't begin until April, and usually peaks in early summer.

*Vulnerability of Eulachon to Climate Change*

Moyle et al. (2013) evaluated potential climate change effects on 164 freshwater fish species in California, including eulachon, through application of expert knowledge by four scientists to score each fish species across ten metrics for vulnerability to impacts of future climate change. Each of the ten ecological, physiological, or behavioral characteristics of each species were given scores of one through three or one through four, with lower scores indicating that the characteristic gave the species a greater vulnerability to climate change. Species were classified into five categories based on their climate change vulnerability (Vc) scores (in parenthesis): critically vulnerable (<17), highly vulnerable (18–22), less vulnerable (23–27), least vulnerable (28–32), and likely to benefit from climate change (>32). Total climate change vulnerability (Vc) scores could potentially range from 10 for critically vulnerable to 35 for likely to benefit from climate change (Moyle et al. 2013, p. 2). The mean Vc score for eulachon in this exercise was 18.8 with a range of 15–20, indicating that eulachon in California are highly vulnerable to climate change and the species is on the path towards extinction as the result of climate change (Moyle et al. 2013).

Moyle et al. (2013) classified fully 83% of native freshwater fishes in California as either critically or highly vulnerable to climate change using their expert knowledge framework. According to Moyle et al. (2013, p. 10):

> Predicted climate change effects on freshwater environments in California will dramatically change the fish fauna. Principally, most native fishes will become more restricted in their distributions and many will ultimately be driven to extinction if present trends continue.

McClure et al. (in preparation) have initiated a California Current Fish Stock Climate Vulnerability Assessment following the methodology developed by NMFS and described in Morrison et al. (2015) and Hare et al. (2016). Crucial steps in this vulnerability assessment include expert scoring for: 1) climate exposure variables impact on each species (e.g., mean SST, phenology of upwelling, etc.), 2) biological and ecological sensitivity attributes of each species (e.g., habitat specificity, population growth rate, etc.), 3) the quality of data used in the assessment, and 4) the directional effect of climate change for each species (whether negative, neutral, or positive on the species). Experts scored each climate exposure variable and sensitivity attribute as low, moderate, high, and very high using a five-tally scoring system, where each expert had five points or tallies to distribute across four bins (e.g., low, moderate, high, very high) depending on their level of certainty. To score the anticipated directional effect of climate change on a species, experts had four tallies to distribute across three bins (negative, neutral, or positive direction). Further methodological details are in Morrison et al. (2015) and Hare et al. (2016).

A summary of results of the climate vulnerability assessment for eulachon including numerical scores for each sensitivity attribute and climate exposure variable, as well as, overall vulnerability ranking, biological sensitivity, and climate exposure scores are given in McClure et al. (in preparation). Eulachon had an overall climate vulnerability ranking of Moderate, with a 79% certainty from bootstrap analysis (McClure et al. in preparation). Eulachon had a High overall climate exposure score. Primary drivers of the climate exposure score included ocean acidification (mean score of 3.8) and mean sea surface temperature (mean score of 3.2). The primary drivers of eulachon's overall biological sensitivity score of Moderate were complexity in reproductive strategy (mean score of 3.1), spawning cycle (mean score of 2.9), other stressors (mean score of 2.6), and early life history survival and settlement requirements (mean score of 2.5). It was noted that eulachon spawn-timing is temperature dependent and thus sensitive to climate change. Eulachon larval use of estuarine environments and post-larval dependence on the presence of preferred prey organisms at the time of ocean entry also highlight eulachon's sensitivity to climate change. McClure et al. (in preparation) noted that estuarine environments and upwelling conditions are especially susceptible to environmental change. These analyzes indicate that climate change is likely to have a negative effect on eulachon. McClure et al. (in preparation) noted:

> Significant changes have already been observed in eulachon spawning distribution in the southern portion of the range with decadal gaps in spawning occurrence and/or very low spawner abundance in northern California and southern Oregon rivers that historically supported eulachon spawning. These changes may result in an extirpation or a shift in the spawning distribution of a population and may be linked to warming temperatures.

**<u>Recommended Future Actions</u>**

- Ensure there are adequate monitoring programs in place to detect significant changes in eulachon habitat due to climate change (by monitoring changes in marine and freshwater survival at all life stages), and evaluate ocean survival for eulachon for each year in order to signal the need for enhanced conservation measures when survival is poor.

- To assess the effects of natural climate variability on the inter-annual variability of eulachon abundance and distribution in the marine environment, develop a research and monitoring plan to collect and analyze data on large-scale oceanographic conditions in the California Current Ecosystem.

- Develop a plume-nearshore oceanographic model to assess the relationship and significance of plume and nearshore ocean environments on eulachon survival, especially larval eulachon, during the freshwater-ocean transition period.

- Develop an oceanographic survival indicator model to determine the relationship between eulachon and short-term and long-term variability in ocean conditions in the California Current.

- Develop a research and monitoring plan to analyze how shifts in water temperature and flow from climate change will potentially affect spawn timing, location, and success.

- Conduct a cross-evaluation of habitat restoration projects in Washington, Oregon, and California to assess how they might contribute to the recovery of eulachon.

- Develop a research and monitoring plan to monitor and evaluate the causal mechanisms, e.g., shifts in the timing, magnitude, and duration of the hydrograph of the Columbia River caused by the hydropower system, and their effects on the migration and behavioral characteristics and effects on larval eulachon during their first weeks in the plume-ocean environment.

**Listing Factor A Conclusion**

We conclude that the risk to the species' persistence remains **unchanged** since the last 5-year review.

## Listing Factor B: Overutilization for commercial, recreational, scientific, or educational purposes

### Commercial, Recreational, and Tribal Fishery

#### Oregon/Washington

*Fishery Landings*

Commercial fishery landings of eulachon in the Columbia River Basin were first recorded by state and federal fisheries agencies in 1888, although newspaper records show that commercial fisheries for eulachon were in operation by 1866. Since the listing of eulachon in March 2010, NMFS, WDFW, and ODFW have worked to implement a limited-opportunity eulachon fisheries in the Columbia River Basin.

**Columbia River—**A commercial gill-net fishery opening occurred in the mainstem Columbia River on Mondays and Thursdays for seven hours each day from 1–25 February in 2016, and from 2–27 February in 2017, for a total opening each year of 56 hours (JCRMS 2017, 2018, 2019, 2020, 2021; ODFW 2016).

Approximately 53,984 and 57,008 eulachon were commercially harvested in 2016 and 2017, respectively (ODFW 2014, 2015, 2016, 2017). Commercial harvest was again open for 8 days in 2018 on Mondays and Thursdays for 7 hours per day for a total of 56 hours, but only 1,232 eulachon were landed (JCRMS 2019). No commercial eulachon fishery occurred in 2019 due to a prediction of low returns, similar to 2018; however, returns were better than expected (JCRMS 2020). In 2020, a Columbia River mainstem commercial eulachon fishery occurred on Mondays and Thursdays for 12 hours each day from 3–27 February for a total of eight days or 96 hours. Approximately 114,856 eulachon were landed in 2020 (JCRMS 2021). In 2021, approximately 123,166 eulachon were caught by commercial mainstem fishers, again fishing on Mondays and Thursdays for 12 hours per day, from 28 January to 11 March for a total of 13 days and 156 hours.

Recreational harvest was estimated at approximately 1,579,760 eulachon in the single day opening of the recreational fishery on the Cowlitz River in 2016. Eulachon did not enter the Sandy River from 2016–2021 in sufficient numbers to allow a sport fishery opening. A one-day 5-hour recreational fishery opening occurred on 25 February 2017 in the Cowlitz River; however, eulachon were scarce and only an estimated 6,048 eulachon were harvested (JCRMS 2018). No recreational fisheries were opened in either 2018 or 2019 on the Cowlitz River due to low commercial catch in 2018 and predicted low returns in 2019 (JCRMS 2019, 2020). In 2020, recreational fishers on the Cowlitz River harvested approximately 392,448 eulachon during two separate 5-hour fishery openings (14 and 26 February) (JCRMS 2021). In 2021, approximately

1,016,400 eulachon were harvested by over 10,000 recreational fishers on the Cowlitz River during a single 5-hour opening on 2 March.

Tribal subsistence and ceremonial fishery landings for the years 2016, 2017, 2019, 2020, and 2021 (no tribal fishery occurred in 2018) were 93,296; 21,280; 264,992; 267,680, and 626,528 fish; respectively.

**British Columbia—**In regards to eulachon fishing opportunities on the Fraser River, DFO Integrated Fisheries Management Plans (IFMP) (DFO 2013–20, 2021a) indicate that there were no recreational or commercial fisheries for eulachon on the Fraser River in 2005–20. From 1995 to 2005 (with the exception of 1999), a test fishery for eulachon on the Fraser River operated in the vicinity of New Westminster; however, this fishery has not operated since 2006 (DFO 2013, 2021a).

In regards to Indigenous Fisheries, the IFMP for Fraser River eulachon (DFO 2020, p. 55) stated:

> Indigenous peoples' access to eulachon for food, social and ceremonial (FSC) purposes was managed through communal Aboriginal fishing licenses on the Fraser River. In 2017, 2018, 2019, and 2020 the total eulachon Indigenous Fisheries was 28,859 54,262, 77,685 102,287 eulachon, respectively, were harvested (DFO 2021a, p. 59).

**<u>Recommended Future Actions</u>**

- Minimize impacts on eulachon productivity related to a directed fishery by developing and implementing an abundance-based/stock-recruitment-based fishery management plan linked to subpopulation-specific demographic recovery criteria for the Columbia River subpopulation.
- To assess the impacts of directed fisheries on eulachon, maintain annual in-river spawning stock biomass surveys in the mainstem of the Columbia and Fraser Rivers.

**<u>Listing Factor B Conclusion</u>**

*Summary* - Commercial and recreational harvest rates of eulachon for the Columbia River subpopulation for the years 2016 through 2021 were similar to rates in 2011 through 2015 of 0.01 percent to 3 percent (there were no commercial or recreational fisheries in 2011 and 2012) at 0.03 percent to 3 percent of the mean SSB estimates.

Tribal subsistence and ceremonial harvest rates of eulachon for the Columbia River subpopulation for the years 2013 through 2015 (there were no tribal fisheries in 2011 and 2012) of 83,664, 78,064, 116,480 fish, respectively, tribal subsistence and ceremonial fisheries have increased, but still only represent 0.08, 0.04, and 0.17 percent of the mean SSB estimates for the respective years.

Therefore, while tribal subsistence and ceremonial fisheries has increased incrementally since the previous 5-year review, the impact on eulachon productivity was minor.

In Canada (Fraser River subpopulation) the Indigenous Fisheries harvest regime for the years 2017 through 2020 of 28,000 fish to 102,000 fish was similar to the 2012 through 2016 harvest regime.

We conclude that the risk to the species' persistence remains **unchanged** since the last 5-year review.

## Listing Factor C: Disease or Predation

### Disease

There is no new information available on diseases affecting eulachon since the previous 5-year review.

### Predation

#### Pinniped Predation

With the passing of the Marine Mammal Protection Act (MMPA) in 1972, pinniped (seals and sea lions) stocks along the West Coast of the United States have steadily increased in abundance, expanded their geographical range, and had a negative impact on ESA-listed fish species, including eulachon. This section describes the status of three species of pinnipeds; management actions taken to address pinniped predation; and recommended future actions to reduce the risks of pinniped predation on ESA-listed fish species.

### Status of Pinniped Stocks in Washington, Oregon and California

#### California Sea Lion (United States Stock)[6]

The current population size of California sea lions (CSL) is 257,606 (Carretta et al. 2019). The stock is estimated to be approximately 40% above its maximum net productivity level[7] (183,481 animals), and it is therefore considered within the range of its optimum sustainable population (OSP) [8] size (Carretta et al. 2019).

Puget Sound—estimates (number of seasonal animals) of CSL in Puget Sound typically ranges from 600 to 700 animals annually (WDFW 2018).

[6] For a complete description of stock status, definition and geographic range see Carretta et al. (2019).
[7] Maximum net productivity level (MNPL) has been expressed as a range of values (between .50 and .70 of K) (K = carrying capacity) determined on a theoretical basis by estimating what stock size, in relation to the original stock size, will produce the maximum net increase in population.
[8] OSP is a population size that is at or greater than its MNPL, which is the population size that produces the maximum net productivity (e.g., greatest net change in the population). OSP = a population size ≥ MNPL (>K*.60).

Columbia River Basin—estimates (number of seasonal animals) of CSL in the Columbia River Basin, based on surveys in the East Mooring Basin, Astoria, Oregon, over the past 5 years was 3,834 animals in 2016, 2,345 animals in 2017, 1,030 animals in 2018, 805 animals in 2019, and 952 in 2020[9].

California—the current population size of CSL (California rookery sites) is 257,606 (Carretta et al. 2019). There are no qualitative or quantitative estimates (number of seasonal animals) of CSL in California estuaries/rivers.[10]

**Steller Sea Lion (Eastern United States Stock)[11]**

The current population size of Steller sea lions (SSL) is 71,562 (52,139 non-pups and 19,423 pups) (Muto et al. 2019). Muto et al. (2017) conclude that the eastern stock of SSL is likely within its OSP range; however, NMFS has made no determination of its status relative to OSP.

Columbia River Basin—the number of SSL at Bonneville Dam has more than doubled compared to the 10-year average, with a minimum estimate of 54 SSL.

Puget Sound—estimates (number of seasonal animals) of SSL in Puget Sound typically ranges from 500 to 700 animals annually (WDFW 2018).

California—the current population size of SSL (California rookery sites) is 3,120 non-pups, and 936 pups (Muto et al. 2019). There are no qualitative or quantitative estimates (number of seasonal animals) of SSL in California estuaries/rivers[12].

**Harbor Seals (Oregon and Washington Coast Stock, Washington Inland Waters Stock, and the California Stock)[13]**

Washington Coast and Columbia River—the current population size of the Oregon and Washington Coast stock of harbor seals (HS) is 15,533 (Pearson and Jeffries 2018). This stock's status relative to OSP is unknown.

Puget Sound—the current population size of the Washington Inland Waters stock (Hood Canal, Puget Sound, San Juan Islands, Eastern Bays) is 18,883 (Pearson and Jeffries 2018). This stock's status relative to OSP is unknown.

California—the current population size of the California stock of HS (HS mainland and

[9] E-mail to Robert Anderson, NMFS, from Bryan Wright, ODFW, November 17, 2020.
[10] E-mail to Robert Anderson, NMFS, from Justin Garwood, California Department of Fish and Wildlife (CDFW), December 15, 2020, and Michelle Gilroy, CDFW, December 18, 2020.
[11] For a complete stock status, definition and geographic range see Muto et al. (2019).
[12] E-mail to Robert Anderson, NMFS, from Justin Garwood, California Department of Fish and Wildlife (CDFW), December 15, 2020, and Michelle Gilroy, CDFW, December 18, 2020.
[13] For a complete stock status, definition and geographic range see Carretta et al. (2019).

offshore islands haul out sites) is 30,968 (Carretta et al 2019), with a minimum population size estimated at 27,348 (Carretta et al 2019). This stock's status relative to OSP is unknown.

**Pinniped Predation Impacts to Eulachon**

Pinnipeds, especially HS, may be present in the lower river year-round, and CSL and SSL are typically present August through June. A study by Riemer (2018) identified eulachon in scat samples collected at the East Mooring Basin in Astoria, Oregon, and noted that eulachon were commonly found in the diet of pinnipeds in January and February. Riemer (2018) identified 43 prey types, and eulachon were found in all sample years (2003, 2004, 2004, 2016, 2017, and 2018). The scat data were summarized as frequency of occurrence (FO) by month and minimum number of individual (MNI) by month. Riemer (2018) noted that "it is possible that species such as eulachon, that exhibit a strong schooling behavior, may be more impacted by pinnipeds even when fish numbers are low as pinnipeds will focus on the schools and ignore other solitary prey … [for example] In 2017 when the total run size of eulachon was a tenth the size of 2015, sea lions still focused primarily on eulachon in January and February (Figure 2)."

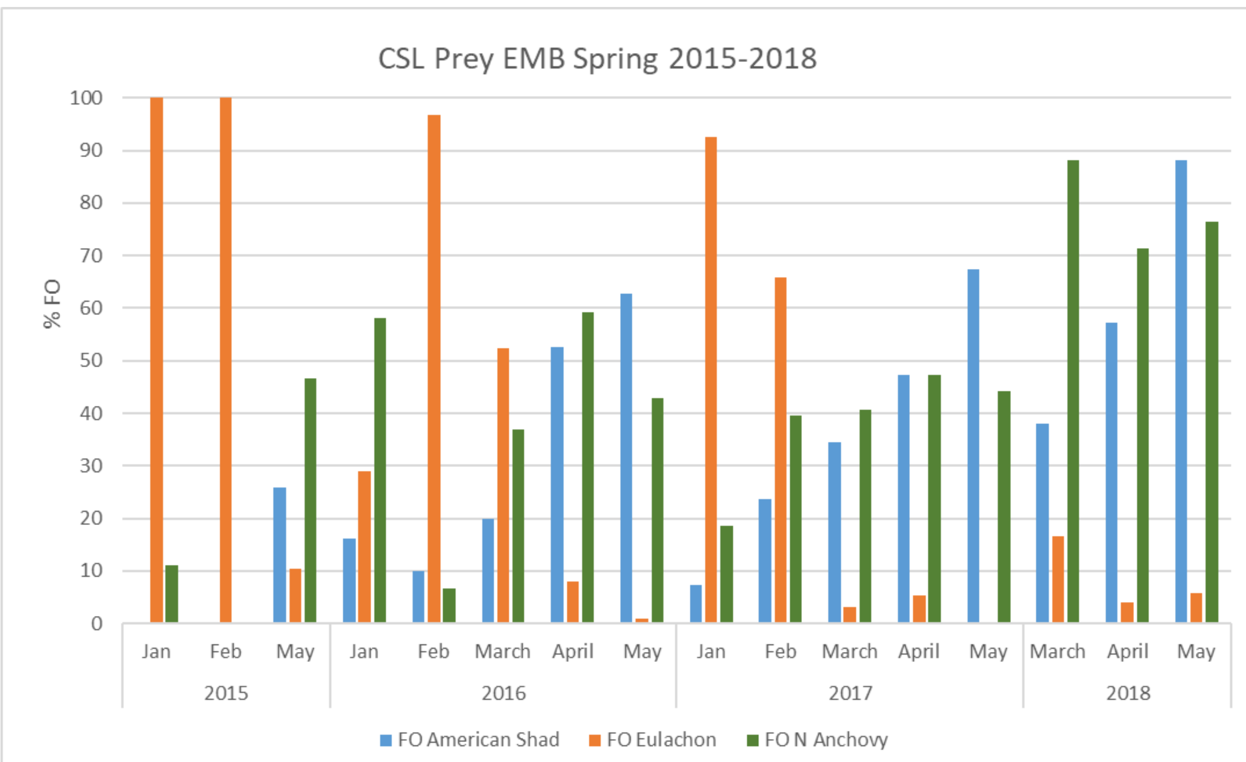


**Figure 2. Comparison by year and month of three primary prey items recovered in California sea lion scat collected at the East Mooring Basin, Astoria, Oregon during spring (Jan – May) 2015 – 2018.**

To estimate the potential impact of pinniped predation on eulachon in the Columbia River, we used two different methods depending on species. For CSL and SSL, we calculated the single-day average number of fish[14] needed to meet daily resting metabolic requirements[15] using a bioenergetics model developed by ODFW et al. (2019) (Table 9). For HS we used a 2015 WDFW[16] HS-eulachon consumption estimate, based on a biomass reconstruction for eulachon consumption per day in the Columbia River estuary, and the Columbia River HS population estimates in Pearson and Jeffries (2018).

While the diet of pinnipeds adapt to fluctuations in prey on a daily basis, their impact on eulachon, especially in years of low abundance such as in 2018, may have a significant impact on eulachon productivity.

**Table 9. Daily metabolic requirements, pinniped per day consumption potential, and SSB estimates for corresponding years.**

| Daily Metabolic Requirement | | | Pinniped Abundance (# pinnipeds) | | | Total Consumption per Day (# eulachon) | | | Eulachon SSB Estimate |
|---|---|---|---|---|---|---|---|---|---|
| Pinniped Species | # Eulachon Required per Pinniped | Year | CSL | SSL | HS | CSL | SSL | HS | # Eulachon |
| CSL | 202 | **2016** | 3,834 | 54 | 5000 | 774,468 | 18,306 | 2,700,000 | 54,556,500 |
| SSL | 339 | **2017** | 2,345 | 63 | 3050 | 473,690 | 21,357 | 1,647,000 | 18,307,100 |
| HS | 540 | **2018** | 1,030 | 66 | 1342 | 208,060 | 22,374 | 724,680 | 4,100,000 |
| | | **2019** | 805 | 50 | 523 | 162,610 | 16,950 | 282,420 | 46,684,765 |
| | | **2020** | 952 | 45 | 523 | 192,304 | 15,255 | 282,420 | 21,280,000 |

## Recommended Future Actions

- Consistent with the Congressional intent of the Endangered Salmon Predation Prevention Act,[17] the MMPA section 120(f) permit Eligible Entities[18] are encouraged to develop and implement a long-term management strategy to deter the future recruitment of sea lions into the MMPA 120(f) geographic area.[19]

[14] Mean (constant) = 0.09 lbs (11.1 fish/lb). Energy density: mean = 9.97 kJ/g, Standard Deviation = 1.1 kJ/g (Sigler et al. 2004) in Wright, 2019.
[15] The model assumes that the primary prey contributed 90% of the energetic density to the overall daily metabolic requirements.
[16] E-mail (forwarded) to Robert Anderson, NMFS, from Brent Norberg, NMFS, on February 19, 2015, from Steven Jefferies, WDFW, regarding sea lion counts in Astoria, Oregon.
[17] Public Law 115-329, the Endangered Salmon Predation Prevention Act.
[18] Eligible Entities: Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, the Idaho Department of Fish and Game, on behalf of their respective states; the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Nation; and the Willamette Committee.
[19] MMPA 120(f) geographic area is defined by statute as the main stem of the Columbia River between river mile 112 (I-205 Bridge) and river mile 292 (McNary Dam), or in any tributary to the Columbia River that includes spawning habitat of threatened or endangered salmon or steelhead.

- Regional recovery partners[20] are encouraged to develop and implement a long-term management strategy to reduce pinniped predation on ESA-listed species in the Columbia River Basin and Puget Sound by removing, reducing, and-or minimizing the use of manmade haul outs used by pinnipeds in select areas, e.g., river mouths/migratory pinch points.
- Regional recovery partners[21] are encouraged to expand, develop, and implement monitoring efforts in the Columbia River Basin, Puget Sound, and California to identify pinniped predation interactions in select areas, e.g., river mouths/migratory pinch points, and quantitatively assess predation impacts by pinnipeds on ESA-listed species.

**Listing Factor C Conclusions**

**Disease**—we conclude that the risk to the species' persistence remains **unchanged** since the last 5-year review.

**Predation**—as eulachon runs, particularly for the Columbia River subpopulation, are markedly less since the previous 5-year review, the overall daily consumption of eulachon by sea lions is likely to be markedly less, but likely proportional to run size; therefore we conclude that the risk to the species' persistence remains **unchanged** since the last 5-year review.

### Listing Factor D: Inadequacy of Regulatory Mechanisms

For this review, we focus our analysis on regulatory mechanisms for habitat, especially climate change impacts on ocean conditions, as this was the overarching threat identified by the BRT. We reviewed summaries of national and international regulations and agreements governing greenhouse gas emissions, which indicate that while the number and efficacy of such mechanisms have increased in recent years there has not yet been a substantial deviation in global emissions from the past trend, and upscaling and acceleration of far-reaching, multilevel, and cross-sectoral climate mitigation will be needed to reduce future climate-related risks (IPCC 2014, 2018). These findings suggest that current regulatory mechanisms, both in U.S. and internationally, are not currently adequate to address the rate at which climate change is negatively impacting habitat conditions for eulachon.

**Listing Factor D Conclusion**

We conclude that the risk to the species' persistence remains **unchanged** since the last 5-year review.

[20] Federal and state agencies, tribes, landowners, watershed councils, private organizations, etc.
[21] Federal and state agencies, tribes, landowners, watershed councils, private organizations, etc.

## Listing Factor E: Other Natural or Manmade Factors Affecting its Continued Existence

**Eulachon Bycatch**—for additional information on bycatch see *Gustafson 2022 et al. Information in Support of a Five-Year Status Review of Eulachon (Thaleichthys pacificus) Listed under the Endangered Species Act: Southern Distinct Population Segment.*

### Eulachon Bycatch in U.S. West Coast Groundfish Fisheries 2002–2019

Gustafson et al. (2021) reported bycatch ratios for eulachon as weight (kg) and as number of individual fish caught per metric ton (mt) of total groundfish or Pacific hake/rockfish retained per haul. These ratios were then used to estimate eulachon bycatch in the fleet sectors where only portions of the total hauls were observed. Data sources and bycatch estimation methods for eulachon bycatch in West Coast groundfish fisheries in 2002–19 are provided in Gustafson et al. (2021).

*Catch shares: non-hake bottom and midwater trawl IFQ fishery bycatch*

From 2011–2019, 439 individual eulachon were estimated as fleet-wide bycatch in the Washington IFQ non-hake bottom and midwater trawl fisheries. However, no eulachon were observed or estimated as bycatch in the Washington sector from 2015–2019. Between 2011 and 2019, the Oregon IFQ non-hake bottom and midwater trawl fisheries had an estimated eulachon bycatch of 5,127 individual fish with 49% (2,510 individuals) of this total occurring in 2014. Eulachon bycatch in the Oregon sector declined from a high in 2014 to an estimated 11 fish during 2017; however, this trend reversed in 2018 and 2019, with estimated bycatch increasing to 334 fish and 760 fish, respectively. Two eulachon were recorded as bycatch in the California IFQ bottom and midwater trawl fisheries in 2015; however, no eulachon occurred as bycatch in this sector from 2011–2014 or from 2016–2019. Rarely, entire hauls may not be sampled due to unforeseen circumstances (e.g., sickness of observers). Bycatch estimation methods for these rare events were detailed in Gustafson et al. (2021).

*At-sea Pacific hake fishery bycatch*

The eulachon bycatch in the at-sea Pacific hake fishery was reported by year and by two sub-sectors: catcher-processors (CP) and mothership-catcher vessels (MSCV). Gustafson et al. (2021) reported combined non-tribal and tribal MSCV data and the current report does likewise. All vessels fishing in the at-sea Pacific hake fishery carry two At-Sea Hake Observer Program observers for every fishing day (i.e., 100% coverage). Rarely, entire hauls may not be sampled due to unforeseen circumstances (e.g., observer illness). Bycatch estimation methods for these rare events were detailed in Gustafson et al. (2021).

Eulachon are encountered sporadically in the at-sea Pacific hake fishery as bycatch. The at-sea CP sector of the Pacific hake fishery has caught more eulachon than other at-sea Pacific hake sectors

(Gustafson et al. 2021). However, no eulachon bycatch was observed in the CP sector from 2002–05, or in 2010. Between 2002 and 2019 eulachon bycatch in the at-sea CP Pacific hake fishery exceeded an estimated 50 fish in 2006 (147 fish), 2011 (1,268 fish), 2014 (242 fish), 2015 (56 fish), 2018 (259 fish), and 2019 (889 fish). In all other years, fewer than 40 individual eulachon were observed in the CP Pacific hake sector. The bycatch estimate in 2011 of 1,268 fish amounted to 42% of the total estimate of 3,009 fish from 2002–2019. In the most recent years of 2018 and 2019, a total of 259 and 889 eulachon were estimated as bycatch in the at-sea Pacific hake CP sector, respectively. These bycatch levels represent 9% (2018) and 30% (2019) of the 2002–2019 total bycatch, and are in contrast to the relatively low bycatch in 2016 of 2 fish and in 2017 of 18 fish.

The combined non-tribal and tribal MSCV Pacific hake sector had a total estimated eulachon bycatch of 816 individual fish from 2002–2019, with 34% of this bycatch occurring in 2013 (277 fish) and 24% in 2019 (199 fish). The tribal mothership fishery has not operated since 2012. No eulachon bycatch occurred in 2002–2006 or in 2010 or 2015, and fewer than 10 individual fish were caught in 2007, 2008, 2012 or 2016 in this sector. In the most recent years of 2018 and 2019, 26 and 199 eulachon were estimated as bycatch in the at-sea Pacific hake MSCV sector, respectively.

*Catch shares: IFQ shoreside midwater Pacific hake trawl and rockfish trawl bycatch*

Prior to 2015, this sector was defined as either the shoreside hake or IFQ non-hake midwater trawl fishery. Since 2015, the shoreside midwater sector of the IFQ fishery has been redefined and is now reported separately as the Pacific hake midwater trawl sector and the rockfish midwater trawl sector The Pacific hake fishery consists of trips fishing midwater trawl gear landing more than 50% Pacific hake by weight on a landing day. The rockfish fishery consists of trips fishing midwater trawl gear landing less than 50% Pacific hake by weight on a landing day. All non- electronic monitoring (EM) IFQ vessels carry an observer on every fishing trip. The shoreside midwater trawl fishery functions as a full-retention fishery, so only at-sea discards are observed by West Coast Observer Program (WCGOP). Bycatch in these fisheries is sampled at nearly 100% after being landed and a catch monitor weighs bycatch. Therefore, numbers of bycaught eulachon were estimated using a linear weight-count regression based on data from all other catch share eulachon observations. Non-EM and EM eulachon bycatch data for these two sectors have been combined; however, when confidentiality rules allowed, non-EM data and EM data were reported independently in Gustafson et al. (2021).

No recorded eulachon bycatch occurred in either the midwater hake or the midwater rockfish sectors in 2015 or 2016. In 2017, 0.5 kg of eulachon bycatch was recorded in the midwater rockfish sector, equivalent to 8 individual eulachon, and 0.9 kg of eulachon bycatch was recorded in the midwater Pacific hake fishery, equivalent to 15 individual eulachon. No eulachon bycatch occurred during 2018 in the midwater Pacific hake fishery; however, an estimated 163 eulachon were incidentally caught in the 2018 midwater rockfish fishery. Bycatch increased in 2019 to an estimated 788 and 485 eulachon in the midwater Pacific hake and the midwater rockfish sectors, respectively.

### Eulachon Bycatch in Groundfish Trawl Fisheries in Canada

The most recent Integrated Fisheries Management Plan (IFMP) for Fraser River eulachon (DFO 2021a) indicated that bycatch of eulachon in the groundfish trawl fishery is typically low, based on data from a mandatory observer program that has covered 100% of all groundfish fishing activities since 1996. The IFMP (DFO 2021a, p. 33) stated:

> Since 2007, Eulachon bycatch was estimated to be typically 0.7 tonnes or less, with the exception of four years: 2012 (1.8 tonnes), 2013 (1.8 tonnes), 2014 (4.2 tonnes), and 2019 (4.7 tonnes). Bycatch of Fraser River–bound Eulachon in the fishery was estimated to be 0.6 tonnes or less since 2007, with the exception of 2012 (1.2 tonnes), 2013 (0.8 tonnes), and 2014 (2.6 tonnes).

### Eulachon Bycatch in Ocean Shrimp Trawl Fisheries

Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur off the West Coast of North America from Queen Charlotte Sound (QCS) and the west coast of Vancouver Island (WCVI) to Cape Mendocino, California (Hannah and Jones 2007, DFO 2021b). *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). Previous 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, Gustafson et al. 2015, 2017, 2019, 2021, Rutherford et al. 2013).

#### *Estimated Eulachon Bycatch in U.S. West Coast Ocean Shrimp Fisheries 2004–19*

Gustafson et al. (2021) reported observed and estimated bycatch of eulachon in ocean shrimp trawl fisheries for the years 2004, 2005, and 2007–2019. The observed tows were in waters shallower than 250 m and deeper than 80 m. Data sources and bycatch estimation methods for eulachon bycatch in West Coast ocean shrimp fisheries in 2004–2019 are detailed in Gustafson et al. (2021). The following bycatch summary for U.S. West Coast Ocean shrimp fisheries is based on data from Gustafson et al. (2021), which contains additional detailed bycatch information. Bycatch in this report is presented as number of eulachon, and bycatch ratios are presented as number of eulachon caught per mt of shrimp (Gustafson et al. 2021).

The Washington sector bycatch ratio, measured as number of eulachon per metric ton of retained ocean shrimp observed, was highest during 2012 (3,369 eulachon/mt shrimp) and 2013 (2,777 eulachon/mt shrimp) and lowest in 2010 (16 eulachon/mt shrimp) and 2011 (29 eulachon/mt shrimp). The high bycatch ratios of 2012–2015 had been declining to 234 eulachon/mt shrimp in 2016, and 145 eulachon/mt shrimp in 2017; however, this ratio has risen in the last 2 available years to 367 and 1,570 eulachon/mt shrimp in 2018 and 2019, respectively. Washington bycatch ratios measured as kg of eulachon per metric ton of retained ocean shrimp observed are available in Gustafson et al. (2021). Since 2010, the percentage of total shrimp landings observed in Washington have fluctuated from about 7–19.5%.

Eulachon bycatch in the Oregon ocean shrimp trawl sector reached over 59.3 million fish in 2014 and over 35.4 million fish in 2015. Eulachon bycatch numbers were down in the subsequent 2 years to about 2.8 million fish in 2016, and about 208,000 fish in 2017. These declines in bycatch from 2015–2017 did not continue into 2018 and 2019. Eulachon bycatch numbers increased to about 1.8 million fish in 2016, and over 13.2 million fish in 2019.

As in the Washington sector, bycatch ratios in the Oregon sector, (measured as numbers of eulachon/mt of retained ocean shrimp observed) also increased dramatically from 2011 to 2012, remained high in 2013–2015, declined through 2017, but then began increasing again in 2018 through 2019. Observed bycatch ratios were at their highest in 2014 (2,517 eulachon/mt shrimp) and declined to 1,460 eulachon/mt shrimp in 2015. Further declines in bycatch ratios continued in 2016 and 2017, reaching 178 eulachon/mt shrimp in 2016 and 20 eulachon/mt shrimp in 2017. From the low point of 2017, eulachon bycatch ratios have increased by an order of magnitude in both 2018 and 2019 to 111 and 1,088 eulachon/mt shrimp, respectively. Oregon bycatch ratios measured as kg of eulachon per metric ton of retained ocean shrimp observed are available in Gustafson et al. (2021). The percentage of total shrimp landings observed in Oregon fluctuated from 6–15% from 2004–2019.

Eulachon bycatch in the California ocean shrimp fishery followed a very different trajectory from that observed in Washington and Oregon during 2011–2013 and again from 2016–2019. California ocean shrimp fishery eulachon bycatch and bycatch ratios in 2016, and especially in 2017, were down to levels not seen since prior to 2010. California fleetwide bycatch was over 51,000 fish with a bycatch ratio of nearly 38 eulachon/mt of shrimp in 2016, and further declined in 2017 to only 31 fish and a bycatch ratio of 0.02 eulachon/mt of shrimp. Eulachon bycatch and bycatch ratios in California rose moderately to 3,503 fish and 1.5 eulachon per mt of shrimp in 2018, and declined in 2019 to 938 fish and 0.8 eulachon per mt of shrimp in 2019. The tonnage of observed ocean shrimp and of fleet-wide ocean shrimp landings were relatively stable from 2011–2019, 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.

Estimated coastwide bycatch in 2015 amounted to nearly 60 million fish. Coastwide eulachon bycatch in ocean shrimp trawl fisheries declined by two orders of magnitude from 2015–2017, from 60 million in 2015 to about 4.4 million fish in 2016 and 649,600 fish in 2017. Coastwide eulachon bycatch in ocean shrimp trawl fisheries increased by an order of magnitude from 2017 to 2018, and another order of magnitude to 2019. Coastwide bycatch was 3.2 million fish in 2018 and 19.8 million fish in 2019. These increases in coastwide bycatch were mostly due to increased bycatch in both Washington and Oregon.

Eulachon bycatch and bycatch ratios declined in all three state ocean shrimp fisheries from 2015–2017. However, declines in bycatch and bycatch ratios were most dramatic in Oregon and California over this time period. In 2017, comparative bycatch ratios as number of eulachon per metric ton of shrimp were 145.4 for Washington, 19.9 for Oregon, and nearly zero for California. The bycatch ratio remained at very low levels during 2018 and 2019 in California; however, the ratio increased in Washington from 367 eulachon per mt of shrimp in 2018 to 1,570 eulachon per mt of shrimp in 2019 and in Oregon from 111 eulachon per mt of shrimp in 2018 to 1,088 eulachon per mt of shrimp in 2019. Bycatch ratios in Washington and Oregon, reported as number of eulachon per mt of observed shrimp, have followed similar trajectories from 2010–2019; starting at relatively low levels in 2010–2011 (less than 30), increasing dramatically in 2012–2015 (thousands of fish), falling to moderate levels during 2016–17 (tens to low hundreds of fish), and increasing by 2019 to a 1,000 fish in Oregon and 1,500 fish in Washington. Bycatch ratios for the Washington, Oregon, and California ocean shrimp sectors measured as kg of eulachon per metric ton of observed ocean shrimp are available in Gustafson et al. (2021).

The fluctuating relative abundance of eulachon likely influenced high eulachon bycatch from 2012–2015, the subsequent decrease in bycatch in 2016 and 2017, and increased bycatch observed in 2018 and 2019 in West Coast ocean shrimp trawl fisheries, as reported in (Gustafson et al. 2021). Bycatch ratios, particularly in Washington and Oregon, also appear to wax and wane in concert with increases and decreases in eulachon abundance. These patterns are also likely influenced by the orientation and degree to which artificial LED lighting has been used since 2015 to illuminate portions of trawl nets in different sectors of these fisheries. LED lighting of ocean shrimp trawl footropes became mandatory in both Oregon and Washington during the 2018 and 2019 seasons (Wargo and Ayres 2018, 2019, Groth et al. 2018). The potential impact of lighted trawl net footropes on bycatch ratios and overall bycatch is an active area of research and is further discussed below.

*Comparison of bycatch and bycatch ratios by state sector*

Although the Washington state sector of the ocean shrimp fishery accounted for only 20%, 17%, and 24% of total coastwide shrimp landings in 2017, 2018, and 2019, respectively, it disproportionately accounted for 68%, 44%, and 33% of total coastwide eulachon bycatch in the same respective 3 years. This is also reflected in the bycatch ratios—as eulachon per metric ton of shrimp landed—which averaged 694, 406, and 1 in Washington, Oregon, and California for the three years 2017–2019, respectively. Eulachon bycatch ratios in the Oregon sector show a similar pattern to the Washington sector, increasing in each of the last 2 years, from a low point of about

20 eulachon per metric ton of shrimp in 2017, to about 111 and 1,088 eulachon per metric ton of shrimp in 2018 and 2019, respectively. The bycatch ratio in the Washington sector was about 145 eulachon per metric ton of shrimp in 2017, increasing to about 367 and 1,570 eulachon per metric ton of shrimp in 2018 and 2019, respectively. Although an average of about 9% of total shrimp landings from 2017–2019 occurred in the California sector, only an estimated total of 4,472 eulachon were caught in this sector during this entire 3-year period (less than 0.02% of the coastwide total). The scarcity of eulachon in the California sector over this period is also reflected in the relatively low bycatch ratios of 0.02, 1.53, and 0.83 eulachon caught per metric ton of shrimp landed in California in 2017, 2018, and 2019, respectively.

*Summary of eulachon bycatch in the U.S. West Coast Groundfish Fisheries*

Across 18 years of observation (2002–19), a total of 13,305[22] individual eulachon were estimated to have been caught as bycatch in all groundfish sectors of the U.S. West Coast groundfish fishery (Gustafson et al. 2021). About 60% of this bycatch occurred during the 5-year period from 2011–2015, when efforts to identify eulachon in the bycatch of these fisheries became a priority and when other indices of eulachon abundance were highly positive. Total fleetwide bycatch in U.S. West Coast groundfish fisheries has increased from an estimated 56 total eulachon in 2016 and 68 total eulachon in 2017, to an estimated 782 total eulachon in 2018 and 3,121 total eulachon in 2019 (Gustafson et al. 2021).

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 … 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, “unaccounted fishing mortality” (Chopin and Arimoto 1995, Suuronen 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) 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

[22] Eulachon bycatch count and weight estimates were updated in Gustafson et al. (2021) and may not always match estimates previously published in Gustafson et al. (2015, 2017, 2019).

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).

*Summary of eulachon bycatch in the Ocean Shrimp Trawl Fisheries*

Eulachon bycatch and bycatch ratios declined markedly after 2015, only to rise again in 2018 and 2019. Estimated eulachon bycatch numbers in both 2016 and 2017 in this sector were each about an order of magnitude lower than they had been in the previous year. The state fleetwide bycatch count estimate of eulachon in the Washington ocean shrimp fishery declined to about 1.5 million fish in 2016 and to 442,000 fish in 2017. However, bycatch increased in 2018 and 2019 to over 1.4 million and 6.5 million fish, respectively.

**Recommended Future Actions**

- Develop and implement a biologically-based analysis on the long-term effects of bycatch from the ocean shrimp fishery on eulachon recruitment.
- Develop and implement a research and monitoring plan to better understand the relationship between habitat types shared between eulachon and pink shrimp in the California Current.
- Develop and implement a monitoring plan to help quantify the benefits of by-catch reduction methods.

**Listing Factor E Conclusion**

We conclude that the risk to the species' persistence has **slightly decreased** since the last 5-year review.

### 2.3.5 Efforts Being Made to Protect the Species

*California*

The current California Code of Regulations for fishing in inland waters states that "Candlefish or eulachon may not be taken or possessed."

*Bycatch Regulations in U.S. West Coast Ocean Shrimp Fisheries*

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 deflecting grid BRDs is to reduce bycatch of groundfish species, and more recently, protected species such as eulachon. BRDs became mandatory in California in 2002 (Frimodig 2008, Frimodig et al. 2009) and in Washington and Oregon in 2003. Current 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[23] and for Oregon[24] can be found online.

In California, approved deflecting grid BRDs for use in the ocean shrimp fishery 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 larger than 6 inches; and 3) fisheye excluders, which have a forward facing escape opening that is maintained by a rigid frame (see the 2020 California Commercial Fishing Regulations Digest[25]).

As of 2018, Washington and Oregon also mandated the use of LED lights on the footrope of each trawl net. Washington regulations as stated in Wargo and Ayres (2018, p. 11) are as follows:

> Washington Administrative Code 220-340-500 Commercial ocean pink shrimp trawl fishery—Coastal waters.
>
> (7) It is unlawful to fish with trawl gear for pink shrimp for commercial purposes unless footrope lighting devices that have been approved by the department are used in each net. A list of approved footrope lighting devices is available from the department.
>
> Footrope lighting devices must meet the following criteria:
>
> (a) Lighting devices must be operational;
>
>> (b) Lighting devices must be securely attached within six inches of the forward leading edge of the bottom panel of trawl netting; and

[23] https://apps.leg.wa.gov/wac/default.aspx?cite=220-340-500
[24] https://www.dfw.state.or.us/fish/commercial/docs/2020_Commercial_Synopsis.pdf
[25] https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=175639&inline

(c) Each trawl net must have a minimum of five lighting devices, spaced four feet apart in the central sixteen feet of each net.

(8) It is unlawful to modify footrope lighting devices or device placement on the footrope in any way inconsistent with subsection (7)(c) of this section, except as provided by special gear permit as described in subsection (9) of this section.

(9) Testing of footrope lighting devices or placement on the footrope is allowed by special gear permit only, consistent with the terms and conditions of the permit.

Three lighting devices are approved for use in 2018:

1. Lindgren-Pitman "LP Electrolume Light" – Green

2. Catch All Tackle "Deep Drop LED Fishing Light" – Green

3. Rock-engineering "LED Rope Light" – Green

Groth et al. (2021, p. 10) reported: "FishTek Marine 'netlight' is now an Oregon legal LED fishing light." Oregon regulations on footrope lights, as stated in Groth et al. (2018, p. 2), are as follows:

Oregon Administrative Rule 635-005-0630;

3) It is unlawful to fish with trawl gear for pink shrimp for commercial purposes unless footrope lighting devices that have been approved by the Department are used in each net. A list of approved footrope lighting devices is available from the Department. Footrope lighting devices must meet the following criteria:

(a) Lighting devices must be operational;

(b) Lighting devices must be securely attached within 6 inches of the forward leading edge of the bottom panel of trawl netting; and

(c) Each trawl net must have a minimum of five lighting devices, spaced 4 feet apart in the central 16 feet of each net.

As part of an ESA Section 6 grant from NOAA to ODFW, WDFW, and CDFW, a year's supply of LED lights were distributed to all fishers in the state–regulated ocean shrimp trawl fisheries on the U.S. West Coast (Groth 2020). In addition, six laminated informational sheets relating to species identification of shrimp trawl bycatch and species life history were produced and distributed to fishers (Groth 2020). These informational sheets are available on the ODFW Marine Resources website.[26] One of these informational sheets illustrates identifying characteristics of typical roundfishes, including eulachon, which may occur as bycatch in the ocean shrimp trawl fisheries

[26] https://www.dfw.state.or.us/MRP/shellfish/commercial/shrimp/news_publications.asp

(Bancroft and Groth 2019). Another of these informational sheets describes and illustrates the chronological development of bycatch reduction devices in U.S. West Coast ocean shrimp trawl fisheries (Groth and Bancroft 2019).

*Bycatch Regulations in 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 2021b). 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 WCVI. Bycatch reduction gear has been mandatory since 2000.

The most recent DFO Shrimp Trawl Integrated Fisheries Management Plan for 2021–22 (DFO 2021b, p. 19) stated:

> 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. Various First Nations organizations in the North Coast, Central Coast, and Fraser River 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 the EAL [Eulachon Action Level] … with an at-sea observer program were implemented to monitor Eulachon bycatch in WCVI. Bycatch reduction devices (including rigid grates, and footrope lighting devices) are mandatory coast wide.

DFO (2021b, appendix 1, p. 42) also stated that these BRDs consist of:

> … 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 31.75 mm (1.25 inches) on the rigid grate has been implemented as a Condition of Licence for all fishing areas other than 21OFF, 23OFF, 124OFF, 125OFF, and 27OFF. Within SMA [Shrimp Management Area] 21OFF, 23OFF, 124OFF, 125OFF, and 27OFF the maximum spacing is 19 mm. The netting directly above the grate shall have a triangular opening (escape hole) the full width of the grate.

DFO (2021b, appendix 1, p. 15) stated:

> Specific management measures for Eulachon bycatch have been developed for WCVI SMAs [West Coast Vancouver Island Shrimp Management Areas]. An at-sea

> observer program 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 EAL is set annually for WCVI … to encourage active shrimp trawl harvesters to adjust their gear to minimize Eulachon bycatch. The 2021/22 EAL for the WCVI will be 4 t [2.0 t in SMAs 124OFF and 125OFF and 2.0 t in 23OFF & 21OFF and 23IN]. There will be no in-season adjustment to the EAL based on the WCVI surveys as in previous years. Eulachon bycatch cannot be retained

Furthermore, DFO (2021b) stated: "In the event the estimate of Eulachon bycatch in a given WCVI area reaches the EAL the commercial fishery will likely close in that area." New management changes and highlights for 2021/2022 relevant to eulachon bycatch issues in the DFO shrimp trawl fisheries management plan (DFO 2021b) include the following:

- Mandatory Use of LED Lights

> Vessels fishing for shrimp by trawl must use footrope lighting devices (LEDs) on their trawl nets in all shrimp trawl management areas of the coast.

- Eulachon Action Level for West Coast Vancouver Island (WCVI)

> The Eulachon Action Level (EAL) for the WCVI remains set at 4 tonnes (t). The WCVI EAL is further divided into two (2) portions, with an EAL of 2 t set for SMAs 124OFF and 125OFF combined, and 2 t set for SMAs 23OFF & 21OFF and 23IN combined.

- Individual Vessel Eulachon Bycatch Limit

> An individual vessel Eulachon bycatch limit pilot program for SMAs 124OFF and 125OFF will be in place for the 2021/22 season. A maximum of 250 lb. of Eulachon bycatch will be authorized under this pilot for each 'S' and 'FS' vessel fishing within SMAs 124OFF and 125OFF during the licence year. Each vessel's eulachon bycatch will be monitored by an independent at-sea observer for 100% of fishing effort.

- Individual Vessel Eulachon Bycatch Limit Overage Adjustment

> An individual vessel Eulachon bycatch overage adjustment provision for SMAs 124OFF and 125OFF will be in place for the 2021/22 licence year. Individual

vessels fishing within SMAs 124OFF and 125OFF that exceed their individual vessel Eulachon bycatch limit for the 2021/22 season will have the overage amount deducted from their 2022/23 individual vessel bycatch limit. SMAs 124OFF and 125OFF will close effective 23:59 hours on February 28, 2022 even if these SMAs have remaining shrimp quota available. This closure is to allow the Department time prior to licence renewal to calculate any individual vessel Eulachon overages, and prepare unique individual vessel licence conditions for the following season.

- At-Sea Observer Coverage

At-Sea Observer coverage will be required on all fishing trips for SMA 124OFF and 125OFF during the 2021/22 season (100% observer coverage). Within SMAs 23OFF & 21OFF and 23IN coverage will be required at a rate of 25% of each vessels fishing days in these areas during the season.

- Skeena River Estuary Area Seasonal Closure

A new seasonal closure in Pacific Fisheries Management Area 4-12 and 4-15. Those waters that include Area 4-15 and that portion of Area 4-12 in that lies south of a boundary formed by two submarine cables that cross Inverness Passage about 0.8 miles South East of Hicks Point, and then beginning 2 miles north of Hazel Point on Smith island and following the line of the two submarine cables that cross Marcus Passage and Malacca Passage, to the North end of Lawyer Island and the Ashore to Porcher Island one mile south of Hunter Point, will be closed February 15th, 2022 to March 31st, 2022 to help avoid the risk of interactions with Eulachon returning to spawn.

In regards to the mandatory use of LEDs on shrimp trawl gear, DFO (2021b, appendix 1, p. 7) stated:

> The vessel master shall ensure that vessels fishing for shrimp by trawl use footrope lighting devices (LEDs) on their trawl nets in all shrimp trawl management areas of the coast. At all times when the trawl net is in the water;
>
> (a) the lighting devices must be operational;
>
> (b) lighting devices are emitting a green colour;
>
> (c) lighting devices are securely attached within 6 inches (15.24cm) of the forward leading edge of the bottom panel of trawl netting; and
>
> (d) each trawl net has a minimum of five (5) lighting devices spaced 4 feet (1.22 m) apart in the central 16 feet (4.88 m) of each net.

*Pinniped Predation*

Columbia River Basin—to address the severity of pinniped predation throughout the Columbia River Basin, NMFS, on August 14, 2020, issued a permit under section 120(f) of the MMPA to the states and tribes (eligible entities)[27] to remove CSL and SSL in select areas of the Columbia River Basin to reduce sea lion predation on salmon and steelhead, white sturgeon, lamprey, and eulachon.

## 2.4 Synthesis

The ESA defines an endangered species as one that is in danger of extinction throughout all or a significant portion of its range, and a threatened species as one that is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. Under ESA section 4(c)(2), we must review the listing classification of all listed species at least once every 5 years. While conducting these reviews, we apply the provisions of ESA section 4(a)(1) and NMFS's implementing regulations at 50 CFR part 424.

To determine if a reclassification is warranted, we review the status of the species and evaluate the five factors, as identified in ESA section 4(a)(1): (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or man-made factors affecting a species continued existence. We then make a determination based solely on the best available scientific and commercial information, taking into account efforts by states and foreign governments to protect the species.

This updated 5-year review indicates that eulachon abundance in monitored populations has decreased for the Columbia River subpopulation, but increased for the Fraser River subpopulation. The near-term outlook for eulachon productivity in the CCE is positive, based on the presence of good ocean conditions. The productivity potential as indicated by life history characteristics such as low age-at-maturity, small body size, planktonic larvae, and perhaps their high fecundity, confers eulachon with some resilience to environmental perturbations, as they retain the ability to rapidly respond to favorable ocean conditions.

The Northwest Fisheries Science Center concluded, after reviewing the available new information that the biological risk category for this DPS has not changed since the time of the last 5-year review (Gustafson et al. 2022).

*Listing Factor A (Habitat):* Although not targeted specifically for eulachon, many habitat restoration projects have been implemented in California, Oregon, and Washington for salmon and

[27] Eligible Entities: Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, the Idaho Department of Fish and Game, on behalf of their respective states; the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Nation; and the Willamette Committee.

steelhead since the last 5-year review, incrementally improving habitat conditions, e.g., nutrient influx, for eulachon. However, widespread areas of degraded habitat persist across the West Coast, with disconnected floodplains, impaired instream flow, and loss of cold water refugia. Climate change impacts on ocean conditions continues to pose a major risk to eulachon. Therefore, we conclude that since the last 5-year review, the risk to eulachon persistence because of habitat conditions has remained unchanged since the 2016 5-year review.

*Listing Factor B (Overutilization):* The risk to the species' persistence because of overutilization remains essentially unchanged since the 2016 5-year review. New information available since the last 5-year review indicates harvest impacts have remained relatively constant.

*Listing Factor C (Disease and Predation*): Information available since the last 5-year review suggests that pinnipeds are consuming a large number of adult eulachon in the Columbia River Basin. The information available since the last 5-year review clearly indicates that predation by pinnipeds poses an adverse impact on the recovery of this DPS, although consumptions rates since 2016 have likely declined somewhat due to lower eulachon run estimates over the past 5 years. Therefore, we conclude that since the last 5-year review, the risk to eulachon persistence because of predation have remained relatively constant.

*Listing Factor D (Regulatory Mechanisms*): New information available since the last 5-year review indicates that the adequacy of a number of regulatory mechanisms has stayed the same on average, with some mechanisms showing the potential for some improvement, whereas others made it more challenging to protect and recover this species.

*Listing Factor E (Other Natural and Manmade Factors*): Information available since the last 5-year review suggests that bycatch of eulachon in the West Coast groundfish fishery and the ocean shrimp trawl fishery has slightly decreased. Therefore, we conclude that since the last 5-year review, the risk to eulachon persistence because of bycatch has slightly decreased.

Our analysis of the ESA section 4(a)(1) factors indicates that the collective risk to the persistence of eulachon has not changed significantly since our final listing determination in 2010; however, predation from an increase in pinniped populations in the Columbia River remains a concern, as do the impacts that climate variability on ocean conditions poses to long-term recovery.

After considering the available information of its ESA section 4(a)(1) factors, in addition to new information on eulachon abundance, we conclude that the status of the southern DPS of eulachon has not improved since it was last reviewed in 2016.

### 2.4.1 DPS Delineation

NMFS found that no new information that has become available since the previous 5-year review that would justify a change in composition for the southern DPS of eulachon.

### 2.4.2 DPS Viability and Statutory Listing Factors

The NWFSC's review of updated information does not indicate a change in the biological risk category of eulachon since the time of the last 5-year review (Gustafson et al. 2022).

Our analysis of ESA section 4(a)(1) factors indicates that the collective risk to the eulachon's persistence has not changed significantly since our listing determination in 2016. The overall level of concern remains the same.

# 3 Results

## 3.1 Classification

**Listing Status:**

Based on the information identified above, we recommend that the southern DPS of eulachon remain classified as a threatened species.

**DPS Delineation:**

NMFS found no new information that has become available since the previous 5-year review that would justify a change in composition for the southern DPS of eulachon.

## 3.2 Recovery Priority Number

Since the 2016 5-year review, NMFS revised the recovery priority number guidelines and twice evaluated the numbers (NMFS 2019, NMFS 2022). Table 2 indicates the number in place for the southern DPS of eulachon at the beginning of the current review (9C). In January 2022, the number remained unchanged.

As part of this 5-year review we reevaluated the number based on the best available information and concluded that the current recovery priority number remains 9C.

# 4 References

Adams, K. A., J. A. Barth, and F. Chan. 2013. Temporal variability of near-bottom dissolved oxygen during upwelling off central Oregon. Journal of Geophysical Reearch: Oceans 118:4839–4854. Available: DOI: org/10.1002/jgrc.20361.

Amaya, D. J., A. J. Miller, S.-P. Xie, and Y. Kosaka. 2020. Physical drivers of the summer 2019 North Pacific marine heatwave. Nature Communications 11:1903. Available: www.nature.com/articles/s41467-020-15820-w. (November 2021).

Bakun, A. 1973. Coastal Upwelling Indices, West Coast of North America, 1946-71. U.S. Department of Commerce, NOAA Technical Report NMFS SSRF-671. Available: repository.library.noaa.gov/view/noaa/9041. (November 2021).

Bancroft, M. P., and S. D. Groth. 2019. Common bycatch in the Pink Shrimp fishery (Roundfishes). Information sheet. Available: dfw.state.or.us/MRP/shellfish/commercial/shrimp/docs/Roundfish-FINAL.pdf. (November 2021).

Bates, S. S., K. A. Hubbard, N. Lundholm, M. Montresor, and C. P. Leaw. 2018. *Pseudo-nitzschia*, *Nitzschia*, and domoic acid: new research since 2011. Harmful Algae 79:3–43. DOI: org/10.1016/j.hal.2018.06.001.

Beacham, T. D, Hay, D. E., and Le, K. D. 2005. Population structure and stock identification of eulachon (Thaleichthys pacificus), an anadromous smelt, in the Pacific Northwest. Mar. Biotech. 7:363–372.

Benson, I. M., C. R. Kastelle, T. E. Helser, J. A. Short, and D. M. Ander. 2019. Age interpretation in eulachon (*Thaleichthys pacificus*) as suggested by otolith microchemical signatures. Environmental Biology of Fishes 102:629–643. Available: link.springer.com/article/10.1007%2Fs10641-019-00858-7. (November 2021).

Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Arístegui, V. A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M. S. Karim, L. Levin, S. O'Donoghue, S. R. Purca Cuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson. 2019. Changing Ocean, Marine Ecosystems, and Dependent Communities. Pages 447–587 *in* H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, and N. M. Weyer, editors. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. Available: www.ipcc.ch/srocc/. (November 2021).

Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophysical Research Letters 42: 3414-3420. doi: 10.1002/2015GL063306.

Brady, R. X., M. A. Alexander, N. S. Lovenduski, and R. R. Rykaczewski. 2017. Emergent anthropogenic trends in California Current upwelling. Geophysical Research Letters 44: 5044–5052. DOI: 10.1002/2017GL072945.

Broadhurst, M. K., P. Suuronen, and A. Hulme. 2006. Estimating collateral mortality from towed fishing gear. Fish and Fisheries 7:180–218. DOI: 10.1111/j.1467-2979.2006.00213.x.

Brodeur, R. D., T. D. Auth, and A. J. Phillips. 2019. Major shifts in pelagic micronekton and macrozooplankton community structure in an upwelling ecosystem related to an unprecedented marine heatwave. Frontiers in Marine Science 6:212. DOI: org/10.3389/fmars.2019.00212.

Buil, M. P., M. G. Jacox, J. Fiechter, M. A. Alexander, S. J. Bograd, E. N. Curchitser, C. A. Edwards, R. R. Rykaczewski, and C. A. Stock. 2021. A dynamically downscaled ensemble of future projections for the California Current System. Frontiers in Marine Science 8:612874. DOI: 10.3389/fmars.2021.612874.

Canadell, J. G., P. M. S. Monteiro, M. H. Costa, L. Cotrim da Cunha, P. M. Cox, A. V. Eliseev, S. Henson, M. Ishii, S. Jaccard, C. Koven, A. Lohila, P. K. Patra, S. Piao, J. Rogelj, S. Syampungani, S. Zaehle, and K. Zickfeld. 2021. Global Carbon and other Biogeochemical Cycles and Feedbacks. Pages 5-1–5-221 *in* V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, editors. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Available: www.ipcc.ch/. (November 2021).

Candy, J. R., N. R. Campbell, M. H. Grinnell, T. D. Beacham, W. A. Larson, and S. R. Narum. 2015. Population differentiation determined from putative neutral and divergent adaptive genetic markers in eulachon (Thaleichthys pacificus, Osmeridae), an anadromous Pacific smelt. Molecular Ecology Resources. doi: 10.1111/1755-0998.12400.

Carretta, J.V., Forney, K.A., Oleson, E.M., Weller, D.W., Lang, A.R., Baker, J., Muto, M.M., Hanson, B., Orr, A.J., Huber, H., Lowry, M.S., Barlow, J., Moore, J.E., Lynch, D., Carswell, L., and Brownell Jr., R.L. 2019. U.S. Pacific Marine Mammal Stock Assessments: 2018. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-617.

Cavole, L. M., A. M. Demko, R. E. Diner, A. Giddings, I. Koester, C. M. L. S. Pagniello, M. -L. Paulsen, A. Ramirez-Valdez, S. M. Schwenck, N. K. Yen, M. E. Zill, and P. J. S. Franks. 2016. Biological impacts of the 2013–2015 warm-water anomaly in the Northeast Pacific: Winners, losers, and the future. Oceanography 29(2):273–285. DOI: org/10.5670/oceanog.2016.32.

Chan, F., J. A. Barth, K. J. Kroeker, J. Lubchenco, and B. A. Menge. 2019. The dynamics and impact of ocean acidification and hypoxia: Insights from sustained investigations in the Northern California Current Large Marine Ecosystem. Oceanography 32(3):62–71. Available: tos.org/oceanography/article/the-dynamics-and-impact-of-ocean-acidification-and-hypoxia (November 2021). doi.org/10.5670/oceanog.2019.312.

Chan, F., J. Barth, J. Lubchenco, A. Kirincich, H. Weeks, W. T. Peterson, and B. Menge. 2008. Emergence of anoxia in the California Current large marine ecosystem. Science 319:920. Available: www.science.org/doi/10.1126/science.1149016. (November 2021).

Chen, Z., J. Shi, Q. Liu, H. Chen, and C. Li. 2021. A persistent and intense marine heatwave in the Northeast Pacific during 2019–2020. Geophysical Research Letters 48:e2021GL093239. DOI: 10.1029/2021GL093239.

Chopin, F. S., and T. Arimoto. 1995. The condition of fish escaping from fishing gears—a review. Fisheries Research 21:315–327. DOI: 10.1016/0165-7836(94)00301-C.

Davis, M. W., and C. H. Ryer. 2003. Understanding fish bycatch discard and escapee mortality. Alaska Fisheries Science Center Quarterly Research Reports. Available: apps-afsc.fisheries.noaa.gov/Quarterly/jfm03/featurejfm03.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2013. Integrated fisheries management plan, Fraser River eulachon April 1, 2013 to March 31, 2014. Department of Fisheries and Oceans, Canada, Pacific Region, 41 p. Online at: http://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/2013/eulachon-eulakane-2013-eng.pdf [accessed June 2015].

DFO (Department of Fisheries and Oceans Canada). 2014. Integrated Fisheries Management Plan Shrimp Trawl April 1, 2014 to March 31, 2015. Department of Fisheries and Oceans, Canada, Pacific Region, 134 p. Online at: http://www.dfo-mpo.gc.ca/Library/352880.pdf.

DFO (Department of Fisheries and Oceans Canada). 2013. Pacific Region integrated fisheries management plan, Fraser River eulachon April 1, 2013 to March 31, 2014. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/40607690.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2014. Pacific Region integrated fisheries management plan, Fraser River eulachon, April 1, 2014 to March 31, 2015. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/40607781.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2015. Pacific Region integrated fisheries management plan, Fraser River eulachon, April 1, 2015 to March 31, 2016. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/4060780x.pdf. (November 2020).

DFO (Department of Fisheries and Oceans Canada). 2016. Pacific Region integrated fisheries management plan, Fraser River eulachon April 1 to December 31, 2016. Department of Fisheries and Oceans, Canada, Pacific Region, 37 p. Available: waves-vagues.dfo-mpo.gc.ca/Library/40607896.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2017. Pacific Region integrated fisheries management plan, Fraser River eulachon, January 1 to December 31, 2017. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/40607938.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2018. Pacific Region integrated fisheries management plan, Fraser River eulachon, January 15 – December 31, 2018. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/40651617.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2019. Pacific Region integrated fisheries management plan, Fraser River eulachon, January 1 – December 31, 2019. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/40751089.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2020. Pacific Region integrated fisheries management plan, Fraser River eulachon, January 1 – December 31, 2020. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/40851606.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2021a. Pacific Region integrated fisheries management plan, Fraser River eulachon, January 1 – December 31, 2021. Department of Fisheries and Oceans, Canada, Pacific Region. Available: waves-vagues.dfo-mpo.gc.ca/Library/40930506.pdf. (November 2021).

DFO (Department of Fisheries and Oceans Canada). 2021b. Integrated Fisheries Management Plan Shrimp Trawl April 1, 2021 to March 31, 2022. Department of Fisheries and Oceans, Canada, Pacific Region, 52 p. + appendices. Available: waves-vagues.dfo-mpo.gc.ca/Library/40940421.pdf. (November 2021).

Di Lorenzo, E., and N. Mantua. 2016. Multi-year persistence of the 2014/15 North Pacific marine heatwave. Nature Climate Change 6:1042-1048. DOI: 10.1038/nclimate3082.

Di Lorenzo, E., N. Schneider, K. M. Cobb, P. J. S. Franks, K. Chhak, A. J. Miller, J. C. McWilliams, S. J. Bograd, H. Arango, E. Curchister, T. M. Powell, and P. Riviere. 2008. North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophysical Research Letters 35:L08607. DOI: 10.1029/2007GL032838.

Feely, R. A., S. R. Alin, B. Carter, N. Bednaršek, B. Hales, F. Chan, T. M. Hill, B. Gaylord, E. Sanford, R. H. Byrne, and C. L. Sabine. 2016. Chemical and biological impacts of ocean acidification along the west coast of North America. Estuarine, Coastal and Shelf Science 183:260–270. DOI: 10.1016/j.ecss.2016.08.043.

Fisher, J. L., W. T. Peterson, and R. R. Rykaczewski. 2015. The impact of El Niño events on the pelagic food chain in the northern California Current. 21:4401–4414. DOI: 10.1111/gcb.13054.

Fox-Kemper, B., H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, A. B. A. Slangen, and Y. Yu. 2021. Ocean, Cryosphere and Sea Level Change. Pages 9-1–9-257 *in* V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, editors. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the

Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. In Press. Available: www.ipcc.ch/. (November 2021).

Frimodig, A. 2008. Informational Report: Bycatch Reduction Devices Used in the Pink Shrimp Trawl Fishery. Report to the California Fish and Game Commission. California Department of Fish and Game, Marine Region, State Fisheries Evaluation Project. Available: nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=36114&inline=true. (November 2021).

Frimodig, A., M. C. Horeczko, M. W. Prall, T. J. Mason, B. C. Owens, and S. P. Wertz. 2009. Review of the California trawl fishery for Pacific ocean shrimp, Pandalus jordani, from 1992 to 2007. Marine Fisheries Review 71(2): 1–13.

Frölicher, T. L., E. M. Fischer, and N. Gruber. 2018. Marine heat waves under global warming. Nature 560:360–364. DOI: doi.org/10.1038/s41586-018-0383-9.

García-Reyes, M., and J. Largier. 2010. Observations of increased wind-driven coastal upwelling off central California. Journal of Geophysical Research 115:C04011. DOI: 10.1029/2009JC005576.

García-Reyes, M., W. J. Sydeman, B. A. Black, R. R. Rykaczewski, D. S. Schoeman, S. A. Thompson, and S. J. Bograd. 2013. Relative influence of oceanic and terrestrial pressure systems in driving upwelling-favorable winds. Geophysical Research Letters 40:5311–5315. DOI: 10.1002/2013GL057729.

Gentemann, C. L., M. R. Fewings, and M. García-Reyes. 2017. Satellite sea surface temperatures along the West Coast of the United States during the 2014–2016 northeast Pacific marine heat wave. Geophysical Research Letters 44:312–319. DOI: 10.1002/2016GL071039.

Gilman, E., P. Suuronen, M. Hall, and S. Kennelly. 2013. Causes and methods to estimate cryptic sources of fishing mortality. Journal of Fish Biology 83:766–803. DOI: 10.1111/jfb.12148.

Groth, S. D., and J. M. Smith. 2020. 31st annual pink shrimp review. Oregon Department of Fish and Wildlife, Marine Resources Program, Newport, Oregon. Available: www.dfw.state.or.us/MRP/shellfish/commercial/shrimp/docs/31st_APSR_2020.pdf. (November 2021).

Groth, S. D., and M. P. Bancroft. 2019. Evolution of bycatch reduction: Pink Shrimp. Information sheet. Available: dfw.state.or.us/MRP/shellfish/commercial/shrimp/news_publications.asp. (November 2021).

Groth, S. D., J. M. Smith, and E. Anderson. 2021. 32nd annual pink shrimp review. Oregon Department of Fish and Wildlife, Marine Resources Program, Newport, Oregon. 16 p. Available: dfw.state.or.us/MRP/shellfish/commercial/shrimp/docs/32nd_APSR_2021.pdf. (November 2021).

Groth, S. D., M. Blume, and J. M. Smith. 2018. 29th annual pink shrimp review. Oregon Department of Fish and Wildlife, Marine Resources Program, Newport, Oregon. Available: www.dfw.state.or.us/MRP/shellfish/commercial/shrimp/docs/29th_APSR_2018.pdf. (November 2021).

Gustafson, R., K. Richerson, K. Somers, V. Tuttle, and J. Jannot. 2022. Information in Support of a Five-Year Status Review of Eulachon (*Thaleichthys pacificus*) Listed under the Endangered Species Act: Southern Distinct Population Segment. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC (In review).

Gustafson, R., K. Richerson, K. Somers, V. Tuttle, J. Jannot, and J. McVeigh. 2021. Observed and Estimated Bycatch of Eulachon in 2002–2019 U.S. West Coast Groundfish Fisheries. Available: www.pcouncil.org/documents/2021/06/g-4-a-nmfs-report-2-observed-and-estimated-bycatch-of-eulachon-in-2002-2019-u-s-west-coast-groundfish-fisheries.pdf/. (November 2021).

Gustafson, R., K. Richerson, K. Somers, V. Tuttle, J. Jannot, and J. McVeigh. 2019. Observed and Estimated Bycatch of Eulachon in 2002–2017 US West Coast Groundfish Fisheries. Available: www.pcouncil.org/documents/2019/06/agenda-item-i-4-a-nmfs-report-2-observed-and-estimated-bycatch-of-eulachon-in-2002-2017-us-west-coast-groundfish-fisheries-electronic-only.pdf/. (November 2021).

Gustafson, R., Y.-W. Lee, E. Ward, K. Somers, V. Tuttle, and J. Jannot. 2015. Observed and Estimated Bycatch of Eulachon in 2002–2013 US West Coast Groundfish Fisheries. Available: www.pcouncil.org/documents/2015/06/agenda-item-d-4-supplemental-attachment-3.pdf/. (November 2021).

Gustafson, R. G., M. J. Ford, D. Teel, and J. S. Drake. 2010. Status review of eulachon (Thaleichthys pacificus) in Washington, Oregon, and California. US Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-105. Online at: http://www.nwfsc.noaa.gov/assets/25/7092_06162010_142619_EulachonTM105WebFinal.pdf.

Hannah, R. W., and S. A. Jones. 2007. Effectiveness of bycatch reduction devices (BRDs) in the ocean shrimp (Pandalus jordani) trawl fishery. Fisheries Research 85: 217–225.

Hare, J. A., W. E. Morrison, M. W. Nelson, M. M. Stachura, E. J. Teeters, R. B. Griffis, M. A. Alexander, J. D. Scott, L. Alade, R. J. Bell, A. S. Chute, K. L. Curti, T. H. Curtis, D. Kircheis, J. F. Kocik, S. M. Lucey, C. T. McCandless, L. M. Milke, D. E. Richardson, E. Robillard, H. J. Walsh, M. C. McManus, K. E. Marancik, and C. A. Griswold. 2016. A vulnerability assessment of fish and invertebrates to climate change on the Northeast U.S. Continental Shelf. PLoS ONE 11(2):e0146756. DOI: 10.1371/journal.pone.0146756.

Harvey, C. J., N. Garfield, G. D. Williams, and N. Tolimieri, editors. 2021c. Ecosystem Status Report of the California Current for 2020–21: A Summary of Ecosystem Indicators Compiled by the California Current Integrated Ecosystem Assessment Team (CCIEA). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-170. Available: repository.library.noaa.gov/view/noaa/32902. (November 2021).

Harvey, C., N. Garfield, G. Williams, N. Tolimieri, K. Andrews, K. Barnas, E. Bjorkstedt, S. Bograd, J. Borchert, C. Braby, R. Brodeur, B. Burke, J. Cope, A. Coyne, D. Demer, L. deWitt, J. Field, J. Fisher, P. Frey, T. Good, C. Grant, C. Greene, E. Hazen, D. Holland, M. Hunter, K. Jacobson, M. Jacox, J. Jahncke, C. Juhasz, I. Kaplan, S. Kasperski, S. Kim, D. Lawson, A. Leising, A. Manderson, N. Mantua, S. Melin, R. Miller, S. Moore, C. Morgan, B. Muhling, S. Munsch, K. Norman, J. Parrish, A. Phillips, R. Robertson, D. Rudnick, K. Sakuma, J. Samhouri, J. Santora, I. Schroeder, S. Siedlecki, K. Somers, B. Stanton, K. Stierhoff, W. Sydeman, A. Thompson, D. Trong, P. Warzybok, C. Whitmire, B. Wells, M. Williams, T. Williams, J. Zamon, S. Zeman, V. Zubkousky-White, and J. Zwolinski. 2020. Ecosystem Status Report of the California Current for 2019–20: A Summary of Ecosystem Indicators Compiled by the California Current Integrated Ecosystem Assessment Team (CCIEA). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-160. Available: repository.library.noaa.gov/view/noaa/27303. (November 2021)

Harvey, C., T. Garfield, G. Williams, and N. Tolimieri, editors. 2021a. California current integrated ecosystem assessment (CCIEA) California current ecosystem status report, 2021. A report of the NOAA CCIEA Team to the Pacific Fishery Management Council, March 10, 2021. Available: www.pcouncil.org/documents/2021/02/i-1-a-iea-team-report-1.pdf/. (November 2021).

Harvey, C., T. Garfield, G. Williams, and N. Tolimieri, editors. 2021b. Supplementary materials to the California Current Integrated Ecosystem Assessment (CCIEA) California Current Ecosystem Status Report, 2021. Available: www.pcouncil.org/documents/2021/02/i-1-a-iea-team-report-2.pdf/. (November 2021).

Hay, D. E., and McCarter, P. B. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145, Ottawa, Ontario. Available: waves-vagues.dfo-mpo.gc.ca/Library/251499.pdf. (November 2021).

Hay, D. E., R. Harbo, J. Boutillier, E. Wylie, L. Convey, and P. B. McCarter. 1999a. Assessment of bycatch in the 1997 and 1998 shrimp trawl fisheries in British Columbia, with emphasis on eulachons. Canadian Stock Assessment Secretariat Research Document 1999/179, Canadian Department of Fisheries and Oceans, Ottawa, Ontario. Available: www.dfo-mpo.gc.ca/csas-sCCE/publications/resdocs-docrech/1999/1999_179-eng.htm. (November 2021).

Hay, D. E., R. Harbo, K. Southey, J. E. Clarke, G. Parker, and P. B. McCarter. 1999b. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch, with emphasis on eulachons. Canadian Stock Assessment Secretariat research document 99/26. DFO, Ottawa, ON.

Hobday, A. J., L. V. Alexander, S. E. Perkins, D. A. Smale, S. C. Straub, E. C. J. Oliver, J. A. Benthuysen, M. T. Burrows, M. G. Donat, M. Feng, N. J. Holbrook, P. J. Moore, H. A. Scannell, A. Sen Gupta, and T. Wernberg. 2016. A hierarchical approach to defining marine heatwaves. Progress in Oceanography 141:227-238. DOI: 10.1016/j.pocean.2015.12.014.

Hooff, R. C., and W. T. Peterson. 2006. Copepod biodiversity as an indicator of changes in ocean and climate conditions of the northern California Current ecosystem. Limnology and

Oceanography 51:2607–2620. Available: aslopubs.onlinelibrary.wiley.com/doi/pdf/10.4319/lo.2006.51.6.2607. (November 2021).

Howard, E. M., H. Frenzel, F. Kessouri, L. Renault, D. Bianchi, J. C. McWilliams, and C. Deutsch. 2020. Attributing Causes of Future Climate Change in the California Current System with Multimodel Downscaling. Global Biogeochemical Cycles 34:e2020GB006646. DOI: 10.1029/2020GB006646.

Ingólfsson, O. A., A. V. Soldal, I. Huse, and M. Breen. 2007. Escape mortality of cod, saithe, and haddock in a Barents Sea trawl fishery. ICES Journal of Marine Science 64:1836–1844.

IPCC (Intergovernmental Panel on Climate Change). 2014. Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (Intergovernmental Panel on Climate Change). 2018. Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla,

Jacox, M. G., C. A. Edwards, E. L. Hazen, and S. J. Bograd. 2018b. Coastal upwelling revisited: Ekman, Bakun, and improved upwelling indices for the U.S. West Coast. Journal of Geophysical Research: Oceans 123:7332–7350. DOI: 10.1029/2018JC014187.

Jacox, M. G., M. A. Alexander, N. J. Mantua, J. D. Scott, G. Hervieux, R. S. Webb, and F. E. Werner. 2018a. Forcing of multiyear extreme ocean temperatures that impacted California Current Living Marine Resources in 2016. Bulletin of the American Meteorological Society 99:S27-S33. DOI: 10.1175/BAMS-D-17-0119.1.

JCRMS (Joint Columbia River Management Staff). 2017. 2017 Joint Staff Report Concerning Stock Status and Fisheries for Sturgeon and Smelt, January 30, 2017. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife. Available: wdfw.wa.gov/sites/default/files/publications/01942/wdfw01942.pdf (November 2021).

JCRMS (Joint Columbia River Management Staff). 2018. 2018 Joint Staff Report Concerning Stock Status and Fisheries for Sturgeon and Smelt, January 18, 2018. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife. Available: wdfw.wa.gov/sites/default/files/publications/01959/wdfw01959.pdf. (November 2021).

JCRMS (Joint Columbia River Management Staff). 2019. 2019 Joint Staff Report Concerning Stock Status and Fisheries for Sturgeon and Smelt, January 18, 2019. Oregon Department of

Fish and Wildlife and Washington Department of Fish and Wildlife. Available: wdfw.wa.gov/publications/02040/wdfw02040.pdf (November 2021).

JCRMS (Joint Columbia River Management Staff). 2020. 2020 Joint Staff Report Concerning Stock Status and Fisheries for Sturgeon and Smelt, January 16, 2020. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife. Available: wdfw.wa.gov/sites/default/files/2020-01/2020_or_wa_jsr_sturgeon-smelt.pdf (November 2021).

JCRMS (Joint Columbia River Management Staff). 2021. 2021 Joint Staff Report Concerning Stock Status and Fisheries for Sturgeon and Smelt, January 14, 2021. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife. Available: www.dfw.state.or.us/fish/OSCRP/CRM/reports/21_reports/2021%20OR%20WA%20Sturgeon-Smelt%20Joint%20Staff%20Report.pdf (November 2021).

Joh, Y., and E. Di Lorenzo. 2017. Increasing coupling between NPGO and PDO leads to prolonged marine heatwaves in the Northeast Pacific. Geophysical Research Letters 44:663–671. DOI: 10.1002/2017GL075930. (November 2021).

Lindegren, M. D. M. Checkley, T. Rouyer, A. D. MacCall, and N. C. Stenseth. 2013. Climate, fishing, and fluctuations of sardine and anchovy in the California Current. Proceedings of the National Academy of Sciences 110:13672–13677. DOI: 10.1073/pnas.1305733110. (November 2021).

Mackas, D. L., R. E. Thomson, and M. Galbraith. 2001. Changes in the zooplankton community of the British Columbia continental margin, 1985–1999, and their covariation with oceanographic conditions. Canadian Journal of Fisheries and Aquatic Sciences 58:685–702.

Mackas, D. L., S. Batten, and M. Trudel. 2007. Effects on zooplankton of a warmer ocean: Recent evidence from the Northeast Pacific. Progress in Oceanography 75:223–252.

Mantua, N. J., and S. R. Hare. 2002. The Pacific decadal oscillation. Journal of Oceanography 58:35–44.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78:1069–1079.

McClure, M., M. A. Haltuch, S. J. Bograd, L. Crozier, E. L. Hazen, D. D. Huff, M. W. Nelson, E. Willis-Norton, K. S. Andrews, L. A. K. Barnett, A. M. Berger, S. Beyer, J. Bizzarro, D. Boughton, J. Cope, M. Carr, H. Dewar, E. Dick, E. Dorval, J. Dunham, V. Gertseva, C. Greene, R. G. Gustafson, O. S. Hamel, C. J. Harvey, S. Heppell, M. Jacox, C. Jordan, I. C. Kaplan, S. T. Lindley, N. Mantua, S. E. Matson, M. Monk, P. Moyle, C. Nicol, J. Pohl, R. Ryckaczewski, J. F. Samhouri, S. Sogard, N. Tolimieri, J. Wallace, and C. Wetzel. A California Current fish stock climate vulnerability assessment. PLOS ONE (in preparation).

McFarlane, G. A., J. R. King, and R. J. Beamish. 2000. Have there been recent changes in climate? Ask the fish. Progress in Oceanography 47:147–169.

McLaughlin, P. A., D. K. Camp, M. V. Angel, E. L. Bousfield, P. Brunel, R. C. Brusca, D. Cadien, A. C. Cohen, K. Conlan, L. G. Eldredge, D. L. Felder, J. W. Goy, T. Haney, B. Hann, R. W. Heard, E. A. Hendrycks, H. H. Hobbs III, J. R. Holsinger, B. Kensley, D. R. Laubitz, S. E. LeCroy, R. Lemaitre, R. F. Maddocks, J. W. Martin, P. Mikkelsen, E. Nelson, W. A. Newman, R. M. Overstreet, W. J. Poly, W. W. Price, J. W. Reid, A. Robertson, D. C. Rogers, A. Ross, M. Schotte, F. R. Schram, C. T. Shih, L. Watling, G. D. F. Wilson, and D. D. Turgeon. 2005. Common and scientific names of aquatic invertebrates from the United States and Canada: Crustaceans. American Fisheries Society, Bethesda, MD.

Montgomery, S. A. 2020. Eulachon (*Thaleichthys pacificus*) marine ecology: applying ocean ecosystem indicators from salmon to develop a multi-year model of freshwater abundance. Master's thesis, University of Washington, Seattle. Available: digital.lib.washington.edu/researchworks/handle/1773/46088. (November 2021).

Morrill, J., R. Bales, and M. Conklin. 2005. Estimating stream temperature from air temperature: Implications for future water quality. Journal of Environmental Engineering 131(1):139 – 146.

Morrison, W. E., M. W. Nelson, J. F. Howard, E. J. Teeters, J. A. Hare, R. B. Griffis, J. D. Scott, and M. A. Alexander. 2015. Methodology for assessing the vulnerability of marine fish and shellfish species to a changing climate. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-OSF-3. Available: repository.library.noaa.gov/view/noaa/5324. (November 2021).

Moyle, P. B., J. D. Kiernan, P. K. Crain, and R. M. Quiñones. 2013. Climate change vulnerability of native and alien freshwater fishes of California: a systematic assessment approach. PLoS ONE 8(5):e63883. DOI: 10.1371/journal.pone.0063883.

Muto M.M. et al. 2019. U.S. Pacific Marine Mammal Stock Assessments: 2019. NOAA Technical memorandum NMFS-AFSC-393. P. 399.

Muto, M. M. et al. 2017. Alaska Marine Mammal Stock Assessments: 2017. Government Reports Announcements and Index. Issue 03, 2005. doi: 10.7289/V5/TM-AFSC-378.

NMFS (National Marine Fisheries Service). 2017. Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, Oregon. Available: repository.library.noaa.gov/view/noaa/15989 (November 2021).

NMFS (National Marine Fisheries Service). 2016. 2016 5-Year Review: Summary and Evaluation of Eulachon. National Marine Fisheries Service, West Coast Region, Portland, Oregon. Available: https://repository.library.noaa.gov/view/noaa/17807. November 2021).

NMFS (National Marine Fisheries Service). 2017. Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, Oregon. Available: repository.library.noaa.gov/view/noaa/15989 (November 2021).

ODFW (Oregon Department of Fish and Wildlife). 2014. 2014 Non-Indian Columbia River mainstem commercial smelt fishery. Online at: http://www.dfw.state.or.us/fish/OSCRP/CRM/landings/14/DISTR_Zones1-5_smelt_2014.pdf [accessed February 2016].

ODFW (Oregon Department of Fish and Wildlife). 2015. 2015 Non-Indian Columbia River mainstem commercial smelt fishery. Online at: http://www.dfw.state.or.us/fish/OSCRP/CRM/landings/15/DISTR_Zones1-5_smelt_2015.pdf [accessed February 2016].

ODFW (Oregon Department of Fish and Wildlife). 2016. 2016 Non-Indian Columbia River mainstem commercial smelt fishery. Online at: http://www.dfw.state.or.us/fish/OSCRP/CRM/landings/16/DISTR_Zones1-5_smelt_2016.pdf [accessed February 2016].

(ODFW et al.) Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, The Idaho Department of Fish and Game, the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Nation, and the 3.6.D Committee. 2019. Request for Marine Mammal Protection Act section 120 authorization to lethally remove California and Steller sea lions from a section of the Columbia River and its tributaries that contain spawning habitat for ESA-listed salmon and steelhead.

Olsen, N., J. A. Boutillier, and L. Convey. 2000. Estimated bycatch in the British Columbia shrimp trawl fishery. Canadian Stock Assessment Secretariat Research Document 2000/168. Available: waves-vagues.dfo-mpo.gc.ca/Library/253557.pdf. (November 2021).

Osgood, G. J., L. A. Kennedy, J. J. Holden, E. Hertz, S. McKinnell, and F. Juanes. 2016. Historical diets of forage fish and juvenile Pacific salmon in the Strait of Georgia, 1966–1968. Marine and Coastal Fisheries 8:580–594. DOI: 10.1080/19425120.2016.1223231.

Pearson, S.F., and Jeffries, S.J. 2018. Estimating Washington's coastal and inland harbor seal populations.

Peterson, J. O., C. A. Morgan, W. T. Peterson, and E. D. Lorenzo. 2013. Seasonal and interannual variation in the extent of hypoxia in the northern California Current from 1998–2012. Limnology and Oceanography 58:2279–2292. DOI: 10.4319/lo.2013.58.6.2279.

Peterson, W. T., and J. E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: A multivariate approach. Deep Sea Research Part II: Topical Studies in Oceanography 50:2499–2517. DOI: 10.1016/S0967-0645(03)00130-9.

Peterson, W. T., J. L. Fisher, P. T. Strub, X. N. Du, C. Risien, J. Peterson, and C. T. Shaw. 2017. The pelagic ecosystem in the Northern California Current off Oregon during the 2014–2016 warm anomalies within the context of the past 20 years. Journal of Geophysical Research: Oceans 122:7267-7290. DOI: 10.1002/2017JC012952.

Quilfen, Y., J. Shutler, J.-F. Piolle, and E. Autret. 2021. Recent trends in the wind-driven California current upwelling system. Remote Sensing of Environment 261:112486. DOI: 10.1016/j.rse.2021.112486.

Raby, G. D., J. R. Packer, A. J. Danylchuk, and S. J. Cooke. 2014. The understudied and underappreciated role of predation in the mortality of fish released from fishing gears. Fish and Fisheries 15:489–505.DOI: 10.1111/faf.12033.

Riemer, S. 2018. California Sea Lion Food Habits at the East Mooring Basin, Columbia River, March-May 2018.

Roemmich, D., and J. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267:1324–1326. DOI: 10.1126/science.267.5202.1324.

Rykaczewski, R. R., and J. P. Dunne. 2010. Enhanced nutrient supply to the California Current Ecosystem with global warming and increased stratification in an earth system model. Geophysical Research Letters 37:L21606. DOI: 10.1029/2010GL045019.

Sangster, G. I., K. M. Lehmann, and M. Breen. 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh codends. Fisheries Research 25:323–345. DOI: 10.1016/0165-7836(95)00430-0.

Schwing, F. B., M. O'Farrell, J. M. Steger, and K. Baltz. 1996. Coastal upwelling indices West Coast of North America, 1946–95. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS–SWFSC-231. Available: www.researchgate.net/publication/252415117_Coastal_Upwelling_Indices_West_Coast_of_North_America_1946-1995. (November 2021).

Seo, H., K. H. Brink, C. E. Dorman, D. Koracin, and C. A. Edwards, 2012. What determines the spatial pattern in summer upwelling trends in the U.S. West Coast? Journal of Geophysical Research: Oceans 117(C8):39. Available: www.researchgate.net/publication/258662742_What_determines_the_spatial_pattern_in_summer_upwelling_trends_on_the_US_West_Coast. (November 2021).

Sharma, R., D. Graves, A. Farrell, and N. Mantua. 2017. Investigating Freshwater and Ocean Effects on Pacific Lamprey and Pacific Eulachon of the Columbia River Basin: Projections within the Context of Climate Change. Columbia River Inter-Tribal Fisheries Commission Technical Report 16-05. Columbia Inter-Tribal Fisheries Commission, Portland, Oregon. Available: www.critfc.org/wp-content/uploads/2017/02/16-05-1.pdf (November 2021).

Siedlecki, S. A., D. Pilcher, E. M. Howard, C. Deutsch, P. MacCready, E. L. Norton, H. Frenzel, J. Newton, R. A. Feely, S. R. Alin, and T. Klinger. 2021. Coastal processes modify projections of some climate-driven stressors in the California Current System. Biogeosciences 18:2871–2890. DOI: 10.5194/bg-18-2871-2021.

Smith, W. E., and R. W. Saalfeld. 1955. Studies on Columbia River smelt *Thaleichthys pacificus* (Richardson). Washington Department of Fisheries, Olympia. Fisheries Research Paper 1(3):3–26.

Somero, G. N., J. Beers, F. Chan, T. Hill, T. Klinger, and S. Litvin. 2016. What changes in the carbonate system, oxygen, and temperature portend for the northeastern Pacific Ocean: a physiological perspective. Bioscience 66:14e26. Available: academic.oup.com/bioscience/article/66/1/14/2463956. (November 2021).

Spangler, R. E. 2020. Spawning migration characteristics and ecology of eulachon (*Thaleichthys pacificus*). Doctoral dissertation. University of Alaska, Fairbanks. Available: hdl.handle.net/11122/12420. (November 2021).

Sutherland, B. J. G., J. Candy, K. Mohns, O. Cornies, K. Jonsen, K. Le, R. G. Gustafson, K. M. Nichols, and T. D. Beacham. 2021. Population structure of eulachon *Thaleichthys pacificus* from Northern California to Alaska using single nucleotide polymorphisms from direct amplicon sequencing. Canadian Journal of Fisheries and Aquatic Sciences 78:78–89. Available: cdnsciencepub.com/doi/10.1139/cjfas-2020-0200. (November 2021).

Suuronen, P. 2005. Mortality of fish escaping trawl gears. FAO Fisheries Technical Paper 478. FAO Rome. 72 p.

Suuronen, P., and D. L. Erickson. 2010. Mortality of animals that escape fishing gears or are discarded after capture: Approaches to reduce mortality. Pages 265–292 *in* P. He, editor. Behavior of Marine Fishes: Capture Processes and Conservation Challenges. Wiley-Blackwell, Ames, Iowa, USA.

Suuronen, P., D. Erickson, and A. Orrensalo. 1996a. Mortality of herring escaping from pelagic trawl cod-ends. Fisheries Research 25:305–321. DOI: 10.1016/0165-7836(95)00446-7. (November 2021).

Suuronen, P., J. A. Perez-Comas, E. Lehtonen, and V. Tschernij. 1996b. Size-related mortality of herring (*Clupea harengus* L.) escaping through a rigid sorting grid and trawl codend meshes. ICES Journal of Marine Science 53:691–700. DOI: 10.1006/jmsc.1996.0088. (November 2021).

Sydeman, W. J., M. García-Reyes, D. S. Schoeman, R. R. Rykaczewski, S. A. Thompson, B. A. Black, and S. J. Bograd. 2014. Climate change and wind intensification in coastal upwelling ecosystems. Science, 345(6192):77–80. DOI: 10.1126/science.1251635.

Wargo, L., and D. Ayres. 2017b. 2017 Washington Pink Shrimp fishery newsletter. Washington Department of Fish and Wildlife, Region 6 Shellfish Management Program, Montesano, Washington. Available: wdfw.wa.gov/sites/default/files/2019-02/newsletter_may2017.pdf. (November 2021).

Wargo, L., and D. Ayres. 2018. 2018 Washington Pink Shrimp fishery newsletter. Washington Department of Fish and Wildlife, Region 6 Shellfish Management Program, Montesano, Washington. Available: wdfw.wa.gov/sites/default/files/2019-02/newsletter_2018.pdf. (November 2021).

Wargo, L., and D. Ayres. 2019. 2019 Washington Pink Shrimp fishery newsletter. Washington Department of Fish and Wildlife, Region 6 Shellfish Management Program, Montesano, Washington. Available: wdfw.wa.gov/sites/default/files/2019-04/pink_shrimp_newsletter_2019.pdf (November 2021).

WDFW (Washington Department of Fish and Wildlife) and ODFW (Oregon Department of Fish and Wildlife). 2001. Washington and Oregon Eulachon Management Plan. Washington Department of Fish and Wildlife, Olympia, and Oregon Department of Fish and Wildlife, Salem. Available: wdfw.wa.gov/sites/default/files/publications/00849/wdfw00849.pdf. (November 2021).

WDFW (Washington Department of Fish and Wildlife). 2018. Impact of pinnipeds on Chinook salmon.

Weatherdon, L. V., Y. Ota, M. C. Jones, D. A. Close, and W. W. L. Cheung. 2016. Projected scenarios for coastal First Nations' fisheries catch potential under climate change: management challenges and opportunities. PLoS ONE 11(1):e0145285. DOI: 10.1371/journal.pone.0145285.

Weber, E. D., T. D. Auth, S. Baumann-Pickering, T. R. Baumgartner, E. P. Bjorkstedt, S. J. Bograd, B. J. Burke, J. L. Cadena-Ramírez, E. A. Daly, M. de la Cruz, H. Dewar, J. C. Field, J. L. Fisher, A. Giddings, R. Goericke, E. Gomez-Ocampo, J. Gomez-Valdes, E. L. Hazen, J. Hildebrand, C. A. Horton, K. C. Jacobson, M. G. Jacox, J. Jahncke, M. Kahru, R. M. Kudela, B. E. Lavaniegos, A. Leising, S. R. Melin, L. E. Miranda-Bojorquez, C. A. Morgan, C. F. Nickels, R. A. Orben, J. M. Porquez, E. J. Portner, R. R. Robertson, D. L. Rudnick, K. M. Sakuma, J. A. Santora, I. D. Schroeder, O. E. Snodgrass, W. J. Sydeman, A. R. Thompson, S. A. Thompson, J. S. Trickey, J. Villegas-Mendoza, P. Warzybok, W. Watson, and S. M. Zeman. 2021. State of the California Current 2019–2020: Back to the Future with Marine Heatwaves? Frontiers in Marine Science 8:709454. DOI: 10.3389/fmars.2021.709454.

Wilson, S. M., G. D. Raby, N. J. Burnett, S. G. Hinch, and S. J. Cooke. 2014. Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals. Biological Conservation 171:61–72. DOI: 10.1016/j.biocon.2014.01.020.

Xiu, P., F. Chai, E. N. Curchitser, and F. S. Castruccio. 2018. Future changes in coastal upwelling ecosystems with global warming: The case of the California Current System. Scientific Reports 8:2866. Available: www.nature.com/articles/s41598-018-21247-7. (November 2021).

Zamon, J. E., and D. W. Welch. 2005. Rapid shift in zooplankton community composition on the northeast Pacific shelf during the 1998–1999 El Niño-La Niña event. Canadian Journal of Fisheries and Aquatic Sciences 62:133–144. DOI: 10.1139/f04-171.

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**NATIONAL MARINE FISHERIES SERVICE**
**5-YEAR REVIEW**
Eulachon (Thaleichthys pacificus)

**Current Classification:** Threatened

**Recommendation resulting from the 5-Year Review**

- [ ] Downlist to Threatened
- [ ] Uplist to Endangered
- [ ] Delist
- [x] No change is needed

**Review Conducted By (Name and Office):**

Robert Anderson, National Marine Fisheries Service, West Coast Region

**REGIONAL OFFICE APPROVAL:**

**Lead Regional Administrator, NOAA Fisheries**

Approve [signature] Date: 7/5/22

**Cooperating Regional Administrator, NOAA Fisheries**

[ ] Concur [ ] Do Not Concur [x] N/A

Signature______________________ Date: _______

**HEADQUARTERS APPROVAL:**

**Assistant Administrator, NOAA Fisheries**

[x] Concur [ ] Do Not Concur

Signature RAUCH.SAMUEL.D.III.1365850948 Digitally signed by RAUCH.SAMUEL.D.III.1365850948 Date: 2022.07.28 14:59:57 -04'00' Date: _______