NOAA Technical Memorandum NMFS-NWFSC-105

Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California

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Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California

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Executive Summary

On 27 November 2007, the National Marine Fisheries Service (NMFS) received a petition seeking to list southern eulachon (*Thaleichthys pacificus*), as a threatened or endangered species under the Endangered Species Act (ESA) of 1973. NMFS evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list a species. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the 27 November 2007 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated an updated status review of eulachon in Washington, Oregon, and California.

The Eulachon Biological Review Team (BRT)—consisting of scientists from the Northwest Fisheries Science Center, Alaska Fisheries Science Center, Southwest Fisheries Science Center, U.S. Fish and Wildlife Service, and U.S. Forest Service—was formed by NMFS, and the team reviewed and evaluated scientific information compiled by NMFS staff from published literature and unpublished data. Information presented at a public meeting in June 2008 in Seattle, Washington, and data submitted from state agencies and other interested parties were also considered. The BRT also reviewed additional information submitted to the ESA Administrative Record.

The BRT was charged with consideration of the following questions:

1. Consider, consistent with the criteria defined by the joint USFWS-NMFS DPS policy (61 FR 4722; 7 February 1996), whether eulachon warrant delineation into one or more DPSs.
2. Once the DPS structure for eulachon has been delineated, assess the level of extinction risk facing the species (including any DPS in the United States) throughout all of its range.
3. In articulating the assessed level of extinction risk, describe the BRT's confidence that the species or DPS is: at high risk of extinction, at moderate risk, or neither.
4. In the BRT's evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document the BRT's consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS, please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or

chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species.

5. If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range.

Guidance on what constitutes a DPS is provided by the joint USFWS-NMFS policy on vertebrate populations. To be considered distinct, a population, or group of populations, must be discrete from the remainder of the species to which it belongs and significant to the species to which it belongs as a whole. Discreteness and significance are further defined by the services in the following policy language (USFWS-NMFS 1996, p. 4,725):

> Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:
>
> 1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
> 2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.
>
> Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used sparingly while encouraging the conservation of genetic diversity. In carrying out this examination, the services will consider available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:
>
> 1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,
> 2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,
> 3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or
> 4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

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

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

The BRT was concerned that although eulachon are a relatively poorly monitored species, the weight of the available information indicates that the southern DPS of eulachon has experienced an abrupt decline in abundance throughout its range. Considering this large decline, in addition to other risk factors, the BRT determined that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range.

Acknowledgments

The status review of eulachon (*Thaleichthys pacificus*) was conducted by a team of scientists. NMFS gratefully acknowledges the commitment and efforts of the Eulachon Biological Review Team (BRT) members and thanks them for generously contributing their time and expertise to the development of this status review.

The Eulachon BRT relied on comments and informational reports submitted by the public and by state, tribal, and federal agencies. The authors acknowledge the efforts of all who contributed to this record, especially the Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), California Department of Fish and Game, and Department of Fisheries and Oceans Canada (DFO).

Numerous individual fishery scientists and managers provided information that aided in preparation of this document and deserve special thanks. We particularly thank Dr. Doug Hay, Nearshore Consulting, Nanaimo, British Columbia (Scientist Emeritus, Pacific Biological Station, DFO); Brad James, WDFW; Olaf Langness, WDFW; and Tom Rien, ODFW; for information, data, opinions, and advice.

We also thank Megan Moody, Nuxalk Nation, Bella Coola, British Columbia; Andy Lecuyer, Environmental Advisor, Rio Tinto Alcan Inc., Kemano, British Columbia; Michael R. Gordon, M. R. Gordon & Associates Ltd., North Vancouver, British Columbia; and Irene Martin, Skamokawa, Washington, for providing documents or steering us toward those who could.

We also thank five anonymous scientists whose peer review of an earlier version of this document provided added clarity.

Introduction: Summary of Information Presented by the Petitioner

In 1999 the National Marine Fisheries Service (NMFS) received a petition (Wright 1999) to list eulachon (*Thaleichthys pacificus*) in the Columbia River and its tributaries as a threatened or endangered species under the U.S. Endangered Species Act (ESA) of 1973. NMFS determined that the 1999 eulachon petition failed to present substantial scientific and commercial information indicating that the petitioned action may be warranted (NMFS 1999).

On 27 November 2007, NMFS received a new petition seeking to list eulachon in Washington, Oregon, and California as a threatened or endangered species under the ESA (Cowlitz Indian Tribe 2007). NMFS evaluated the petition to determine whether the petitioner provided substantial information to list a species as required by the ESA. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the 27 November 2007 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated a status review of eulachon in Washington, Oregon, and California (NMFS 2008).

A Eulachon Biological Review Team (BRT)[1]—consisting of scientists from the Northwest Fisheries Science Center (NWFSC), Alaska Fisheries Science Center (AFSC), Southwest Fisheries Science Center, U.S. Fish and Wildlife Service (USFWS), and U.S. Forest Service—was formed by NMFS, and the team reviewed and evaluated scientific information compiled by NMFS staff from published literature and unpublished data. Information presented at a public meeting in June 2008 in Seattle, Washington, and data submitted to the ESA Administrative Record from state agencies and other interested parties were also considered.

The BRT proceeded on the directives included in the Draft BRT Eulachon Instructions Memo that was received from the NMFS Northwest Region on 19 May 2008. In the memo the BRT was charged with consideration of the following questions:

1. Consider, consistent with the criteria defined by the joint USFWS-NMFS DPS policy (61 FR 4722; 7 February 1996), whether eulachon warrant delineation into one or more DPSs.

[1] The Eulachon BRT consisted of: Jonathan Drake, Robert Emmett, Kurt Fresh, Richard Gustafson, Mindy Rowse, and David Teel, NWFSC; Matthew Wilson, AFSC; Peter Adams, SWFSC; Elizabeth A. K. Spangler, USFWS; and Robert Spangler, U. S. Forest Service.

2. Once the DPS structure for eulachon has been delineated, assess the level of extinction risk facing the species (including any DPS in the United States) throughout all of its range.
3. In articulating the assessed level of extinction risk, describe the BRT's confidence that the species or DPS is at high risk of extinction, at moderate risk, or neither.
4. In the BRT's evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document the BRT's consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species.
5. If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range.

The Eulachon BRT submitted a summary status review document (BRT 2008) to the NMFS Northwest Region in December 2008. In April 2009 we asked a number of scientists with expertise in eulachon biology or viability analysis to review that document (BRT 2008). Substantial scientific comments received from five peer reviewers and our responses to these comments can be found in Appendix E. Numerous changes have been incorporated into the present document in response to suggestions made by the peer reviewers.

The DPS Question: Evidence for Discreteness and Significance

The petitioner noted that early mitochondrial DNA (mtDNA) genetic information (McLean et al. 1999) suggested that eulachon did not exhibit genetic discreteness and gave little support for subdivision of population structure throughout the species' range. However, other biological data including the number of vertebrae, size-at-maturity, fecundity, river-specific spawning times, and population dynamics indicated that there is substantial local stock structure (Hart and McHugh 1944, Hay and McCarter 2000). The petitioner described these latter observations as consistent with the hypothesis that there is local adaptation and genetic differentiation among populations. Recent microsatellite genetic work (Beacham et al. 2005) appears to confirm the existence of significant differentiation among populations. The petitioner summarized these findings as indicating that although the Fraser River, mainstem Columbia River, and Cowlitz River spawning populations are genetically distinct from each other, they are more closely related to one another than either population is to the more northerly British Columbia populations (Beacham et al. 2005). Although the petitioner felt that the available information is inconclusive, the petitioner noted that eulachon may be composed of several DPSs separated by differences in run timing, spawn timing, meristics, and genetic characteristics.

The petitioner concluded that the available genetic, meristic, and life history information is inconclusive regarding the discreteness of eulachon populations. However, the petitioner argued that under the DPS policy, eulachon populations in Washington, Oregon, and California are collectively discrete from more northerly populations because they are delimited by an international governmental boundary (i.e., the U.S.-Canada border between Washington and British Columbia) across which there is a significant difference in exploitation control, habitat management, or conservation status. The petitioner noted that the United States and Canada differ in their regulatory control of commercial, recreational, and tribal or First Nations eulachon harvest, and also differ in their management of eulachon habitat. The petitioner concluded that there is no assurance that the United States and Canada will coordinate management and regulatory efforts sufficiently to conserve eulachon and their habitat, and thus the DPS should be delineated at the border between Washington and British Columbia.

The petitioner argued that the southern eulachon population segment is significant under the DPS policy because the loss of the discrete population segment would cause a significant gap in the taxon's range. The petitioner stated that eulachon have largely disappeared in rivers throughout the southern portion of their range, and that eulachon in the Columbia River probably represent the southernmost extant population for the species. The petitioner argued that the loss of the Columbia River eulachon population and any dependent coastal spawning populations could represent the loss of the species throughout its range in the United States, as well as the loss of a substantial proportion of its historical range.

Summary of Abundance and Population Trends

The petitioner stated that although eulachon abundance exhibits considerable year-to-year variability, nearly all spawning runs from California to southeastern Alaska have declined in the past 20 years, especially since the mid-1990s (Hay and McCarter 2000). Historically, the Columbia River has exhibited the largest returns of any spawning population throughout the species' range. The petitioner noted that from 1938 to 1992, the median commercial catch of eulachon in the Columbia River was approximately 1.9 million pounds (lb). From 1993 to 2006, the median catch had declined to approximately 43,000 lb, representing a 97.7% reduction in catch from the prior period. Although there was an increasing trend in Columbia River eulachon catch from 2000 to 2003, recent catches have been extremely low. The petitioner also presented catch per unit effort (CPUE) and larval survey data (JCRMS 2006) for the Columbia River and tributaries in Oregon and Washington that similarly reflect the depressed status of Columbia River eulachon during the 1990s, a relative increase during 2001 to 2003, and a decline back to low levels in recent years.

The petitioner also noted that eulachon returns in the Fraser River showed a similar pattern to those in the Columbia River; a rapid decline in the mid-1990s, increased returns during 2001 to 2003, and a recent decline to low levels. The petitioner stated that egg and larval surveys conducted in the Fraser River since 1995 also demonstrate that, despite the implementation of fishing restrictions in British Columbia, the stock has not recovered from its mid-1990s collapse and remains at a precariously low level. An offshore index of Fraser and

Columbia rivers eulachon biomass, calculated from eulachon bycatch in an annual trawl survey of shrimp biomass off the west coast of Vancouver Island, illustrates highly variable biomass over the time series since 1973, but also reflects stock declines in the mid-1990s and in recent years, according to the petitioner. With respect to eulachon populations further south in the species' range, the petitioner noted that populations in the Klamath River, Mad River, Redwood Creek, and Sacramento River are likely extirpated or nearly so.

Summary of Risk Factors

The petitioner described a number of threats facing eulachon range-wide and facing populations in U.S. rivers in particular. The petitioner expressed concern that habitat loss and degradation threaten eulachon, particularly in the Columbia River basin. The petitioner argued that hydroelectric dams block access to historical eulachon spawning grounds and affect the quality of spawning substrates through flow management, altered delivery of coarse sediments, and siltation.

The petitioner expressed strong concern regarding the siltation of spawning substrates in the Cowlitz River due to altered flow management and the accumulation of fine sediments from the Toutle River. The petitioner believes that efforts to retain and stabilize fine sediments generated by the 1980 eruption of Mount St. Helens are inadequate. The petitioner noted that the release of fine sediments from behind a U.S. Army Corps of Engineers (USACE) sediment retention structure (SRS) on the Toutle River has been negatively correlated with Cowlitz River eulachon returns 3 to 4 years later. The petitioner also expressed concern that dredging activities in the Cowlitz and Columbia rivers during the eulachon spawning run may entrain and kill fish, or otherwise result in decreased spawning success.

The petitioner also noted that eulachon have been shown to carry high levels of chemical pollutants (EPA 2002), and although it has not been demonstrated that high contaminant loads in eulachon result in increased mortality or reduced reproductive success, such effects have been shown in other fish species (Kime 1995). The petitioner concluded that no evidence suggests that disease currently poses a threat to eulachon, but noted that information presented in the 1999 petition (Wright 1999) to list eulachon suggested that predation by pinnipeds may be substantial.

The petitioner expressed concern that depressed eulachon populations are particularly susceptible to overharvest in fisheries where they are targeted or taken as bycatch. The petitioner acknowledged that eulachon harvest has been curtailed significantly in response to population declines, and that were it not for continued low levels of harvest, there would be little or no status information available for some populations. However, the petitioner concluded that existing regulatory mechanisms have proven inadequate in recovering eulachon stocks, and that directed harvest and bycatch may be important factors limiting the recovery of impacted stocks. The petitioner emphasized the need for further fishery-independent monitoring and research.

Finally, the petitioner concluded that global climate change is one of the greatest threats facing eulachon, particularly in the southern portion of its range where ocean warming trends may be the most pronounced. The petitioner felt that the risks facing southerly eulachon populations in Washington, Oregon, and California will be exacerbated by such a deterioration of marine conditions. According to the petitioner, these southerly populations, already exhibiting dramatic declines and impacted by other threats (e.g., habitat loss and degradation), might be at risk of extirpation if unfavorable marine conditions predominate in the future.

The Species Question

As amended in 1978, the ESA allows listing of DPSs of vertebrates as well as named species and subspecies. Guidance on what constitutes a DPS is provided by the joint USFWS-NMFS (1996) policy on vertebrate populations. To be considered distinct, a population, or group of populations, must be discrete from the remainder of the taxon to which it belongs and significant to the taxon to which it belongs as a whole. Discreteness and significance are further defined by the services in the following policy language (USFWS-NMFS 1996, p. 4,725):

> Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:
>
> 1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
> 2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the [Endangered Species] Act.
>
> Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used sparingly while encouraging the conservation of genetic diversity. In carrying out this examination, the services will consider available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:
>
> 1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,
> 2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,
> 3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or
> 4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

The interagency policy states that international boundaries within the geographical range of the species may be used to delimit a distinct population segment in the United States. This criterion is applicable if differences in the control of exploitation of the species, the management of the species' habitat, the conservation status of the species, or regulatory mechanisms differ between countries that would influence the conservation status of the population segment in the United States. However, in past assessments of DPSs of marine fish, NMFS has placed the emphasis on biological information in defining DPSs and has considered political boundaries only at the implementation of ESA listings. Therefore, the BRT focused only on biological information in identifying whether DPSs of eulachon could be delineated.

Eulachon Life History and Ecology

Taxonomy and Species Description

Scientific Nomenclature

Eulachon are an anadromous smelt in the family Osmeridae and are distinguished from other osmerids by having 4–6 gill rakers on the upper half of the arch (others have 8–14 gill rakers), distinct concentric striae on the operculum and suboperculum (other osmerids lack these concentric striae), and 8–11 pyloric caeca (others have 0–8 pyloric caeca) (McAllister 1963, Hart 1973, Mecklenburg et al. 2002). McAllister (1963) provides a taxonomic synonymy for the species, which was originally described from the Columbia River as *Salmo (Mallotus) pacificus* by Richardson (1836). The genus *Thaleichthys* has only one species and valid subspecies have not been described (McAllister 1963). The binomial species name is derived from Greek roots; *thaleia* meaning rich, *ichthys* meaning fish, and *pacificus* meaning of the Pacific (Hart 1973).

Common Names

Native, Indian, and First Nations languages

The common name officially recognized by the American Fisheries Society (Nelson et al. 2004) for *Thaleichthys pacificus* is eulachon (pronounced you-la-kon in the United States), which is originally derived from the Chinook Indian trade language of the lower Columbia River (Hart and McHugh 1944, Moody 2008). Numerous variations include hoolakan, hooligan, hoolikan, olachan, ollachan, oolachan, oolichan, oulachan, oulachon, oulacon, ulchen, ulichan, uthlecan, yshuh (Hart and McHugh 1944), ooligan, olachen, and olachon (Moody 2008). The Yurok Tribe of the lower Klamath River call eulachon quat-ra (Larson and Belchik 1998) and the Quinault Tribe named the fish páagwáls (Olson 1936). Each First Nations group in British Columbia has a unique name for eulachon (Hay and McCarter 2000, Moody 2008). The First Nations of the lower Fraser River called eulachon swavie or chucka (Hart and McHugh 1944); and the Haisla and Tlingit of Alaska call it juk'wan or za'xwen and ssag or saak, respectively (Krause 1885, Betts 1994, Willson et al. 2006).

English

Besides eulachon, *Thaleichthys pacificus* is known by numerous local common English names including candlefish, small fish, savior fish, salvation fish, little fish, fathom fish (because it was sold by the fathom) (Hart and McHugh 1944), and Columbia River smelt.

Eulachon and Human Cultural History

Eulachon were, and still are, highly important ceremonially, nutritionally, medicinally, and economically to First Nations people in British Columbia and Native American tribes in northern California and the Pacific Northwest. Many ethnographers and historians have stressed the cultural and nutritional importance of eulachon to the Tlingit of Southeast Alaska (Mills 1982, Olson and Hubbard 1984, Krause 1885, Betts 1994), Tsimshians of the north coast of British Columbia (Stewart 1975, Halpin and Seguin 1990, Martindale 2003), Haisla of Douglas Channel and Gardner Canal of British Columbia (Hawthorn et al. 1960, Hamori-Torok 1990), Haihais and Oowekeeno of Rivers Inlet in British Columbia (Hilton 1990), Nuxalk (formerly known as the Bella Coola) of the central coast of British Columbia (Kuhnlein et al. 1982, Kennedy and Bouchard 1990), Kwakwaka'wakw (formerly known as the Kwakiutl) of the north and central coast of British Columbia (Curtis 1915, Rohner 1967, Macnair 1971, Mitchell 1983, Codere 1990), Stó:lō of the Fraser River (Duff 1952), Quinault of the Washington coast (Willoughby 1889, Olson 1936), Chinook and Cowlitz on the lower Columbia River (Boyd and Hajda 1987, Byram and Lewis 2001), and Yurok on the Klamath River (Pilling 1978, Byram and Lewis 2001). In many areas, eulachon returned in the late winter and early spring when other food supplies were scarce and were known, for this reason, as savior or salvation fish (Boyd and Hajda 1987, Byram and Lewis 2001).

Major aboriginal subsistence fisheries for eulachon reportedly occurred on the Stikine, Nass, Skeena, Kitimat, Bella Coola, Kingcome, Klinaklini, Fraser (Macnair 1971, Kuhnlein et al. 1982, Mitchell 1983), and Columbia rivers (Boyd and Hajda 1987). Eulachon were eaten fresh, smoked, dried, and salted, and rendered as oil or grease. Especially to the north of the Fraser River, the fat of the eulachon was rendered into oil, or what is commonly called grease, which is solid at room temperature and was a common traditional year-round condiment with many foods, as well as a medicine for skin rashes and internal ailments among First Nations people on the central and north coasts of British Columbia and in some parts of Alaska (Kuhnlein et al. 1982). Kuhnlein et al. (1982, p. 155) stated that:

> The cultural significance of ooligan grease cannot be underestimated, as it was (and continues to be) a prominent food and gift during feasts and potlatch ceremonies. Early ethnographers among the Nuxalk and Kwakiutl people noted that it was a sign of poverty for a family to be without ooligan grease.

Eulachon grease was widely traded to First Nations such as the Haida and Nootka of Vancouver Island and First Nations in the interior of British Columbia that had no rivers with eulachon runs (Krause 1885, Green 1891, Martindale 2003). Sutherland (2001, p. 8) has stated that "by trading the grease [First Nations people] obtained wealth, prestige, and power." Ancient trade routes up the Nass and Bella Coola river valleys, in particular, and through the mountains, became known as "grease trails" after the traffic in eulachon grease, packed in wooden boxes (Collison 1941, Hart and McHugh 1944, Stewart 1977, Byram and Lewis 2001, Hirch 2003). Numerous sources describe the methods, which varied slightly from area to area, of extracting the oil by boiling the fish bodies (MacFie 1865, Lord 1866, Swan 1881, Krause 1885, Green 1891, Macnair 1971, Stewart 1977).

The largest and most important eulachon fisheries for grease production were on the Nass and Klinaklini rivers of British Columbia (Stacey 1995), although grease was produced by all the First Nations with fishing rights on eulachon rivers north of the Fraser River (Swan 1881, Macnair 1971). As many as 2,000 people annually migrated to the eulachon fishing grounds (Tsawatti) on the Klinaklini River at the head of Knight Inlet (Macnair 1971, Mitchell 1983, Stacey 1995), some traveling from as far as 402 km (250 miles) away by canoe (Codere 1990). The assemblage on the Klinaklini River included nine winter village groups of the Southern Kwakwaka'wakw (formerly known as the Southern Kwakiutl) (Mitchell 1983). A comparable assemblage of five other Southern Kwakwaka'wakw winter village groups and the bulk of the Nimpkish First Nation people from Vancouver Island congregated at Quaee at the head of Kingcome Inlet on the Kingcome River to harvest the spring run of eulachon (Mitchell 1983). Kennedy and Bouchard (1990, p. 325) in an ethnographic summary of the Bella Coola First Nation noted that "Because of their abundance and their value as a trade item, eulachons (particularly when rendered into highly valued grease) were second only to salmon in importance to the Bella Coola."

Historical and Current Distribution

Freshwater Spawning Distribution

Eulachon spawn in the lower portions of certain rivers draining into the northeastern Pacific Ocean ranging from northern California to the southeastern Bering Sea in Bristol Bay, Alaska (Hubbs 1925, Schultz and DeLacy 1935, McAllister 1963, Scott and Crossman 1973, Willson et al. 2006) (Table A-1 in Appendix A, Figures 1 through 3). This distribution coincides closely with the distribution of the coastal temperate rain forest ecosystem on the west coast of North America (Figure 1). Both Willson et al. (2006) and Moody (2008) have recently reviewed the coast-wide spawning distribution of eulachon in North America.

Monaco et al. (1990) and Emmett et al. (1991) summarized distribution and abundance of fishes in U.S. West Coast estuaries (see Table A-2) and based on the references cited therein described adult eulachon as common in Grays Harbor and Willapa Bay on the Washington coast, abundant in the Columbia River, common in Oregon's Umpqua River, and abundant in the Klamath River in northern California. In addition, a number of estuaries where eulachon were thought to occur in rare relative abundance included Puget Sound and Skagit Bay in Washington; Siuslaw River, Coos Bay, and Rogue River in Oregon; and Humboldt Bay in California (Monaco et al. 1990, Emmett et al. 1991). Hay and McCarter (2000) and Hay (2002) identified 33 eulachon spawning rivers in British Columbia and 14 of these were classified as supporting regular yearly spawning runs. Willson et al. (2006) and Moody (2008) list numerous rivers that support eulachon runs in Southeast and Southcentral Alaska and on the coastline of Alaska in the southeastern Bering Sea (Table A-1). McPhail and Lindsey (1970, p. 198) suggested that eulachon "apparently survived glaciation south of the ice sheet along the Pacific coast of North America" and likely "entered the Bering Sea from the south" following the Wisconsian glaciation.

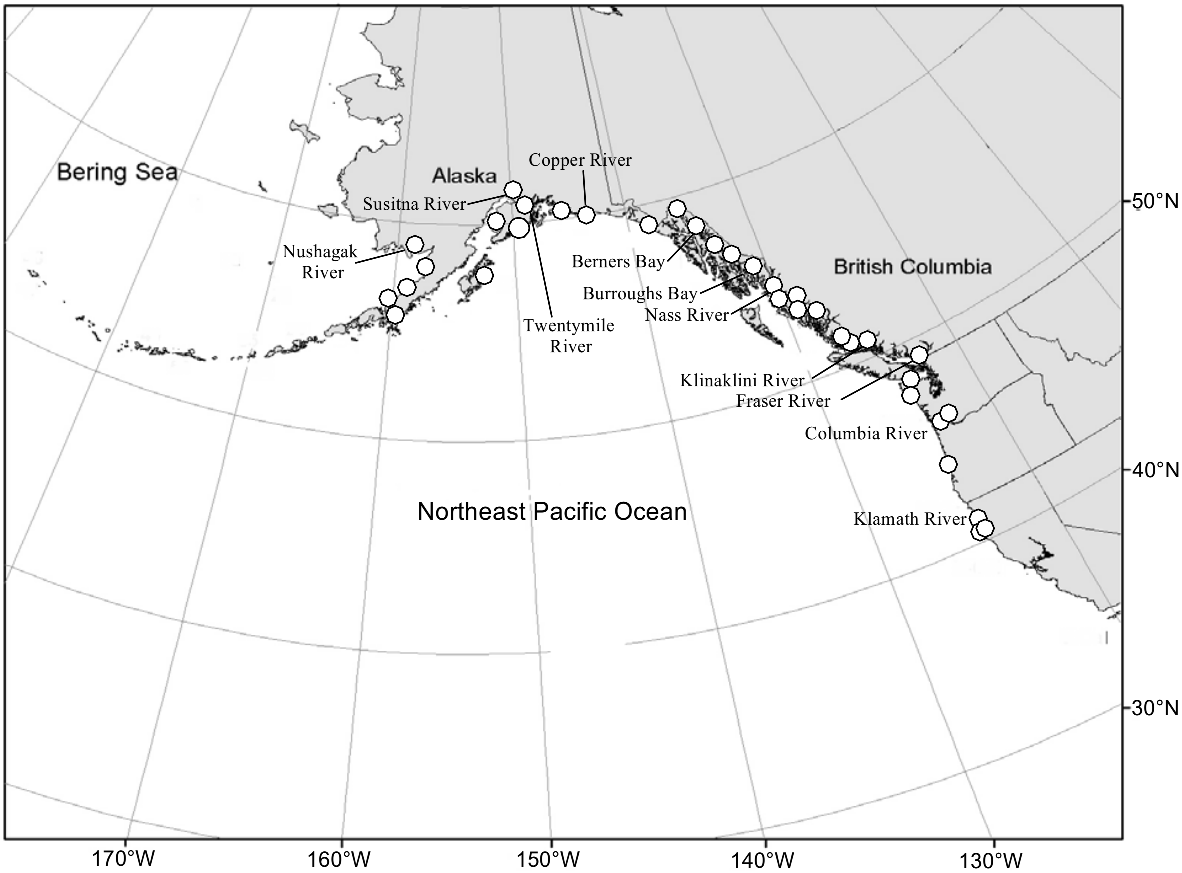

Figure 1. Distribution of eulachon spawning rivers (open circles) in the Northeast Pacific Ocean.

California

Hubbs (1925) and Schultz and DeLacy (1935), leading ichthyologists of their day, described the Klamath River in northern California as the southern limit of the range of eulachon. Miller and Lea (1972, p. 62) in the California Department of Fish and Game's (CDFG) Guide to the Coastal Marine Fishes of California reported that the eulachon "spawns in rivers from Mad River north." More recent compilations state that large spawning aggregations of eulachon were reported to have once regularly occurred in the Klamath River (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Moyle 2002, Hamilton et al. 2005) and on occasion in the Mad River (Moyle et al. 1995, Moyle 2002) and Redwood Creek (Ridenhour and Hofstra 1994, Moyle et al. 1995) (Table A-1, Figure 2).

In addition, Moyle et al. (1995) and Moyle (2002) state that small numbers of eulachon have been reported from the Smith River (Table A-1). CDFG's Status Report on Living Marine Resources (Sweetnam et al. 2001, p. 477–478) states that "The principal spawning run [of eulachon] in California is in the Klamath River, but runs have also been recorded in the Mad and Smith rivers and Redwood Creek." Allen et al. (2006) indicated that eulachon usually spawn no further south than the lower Klamath River and Humboldt Bay tributaries. The California

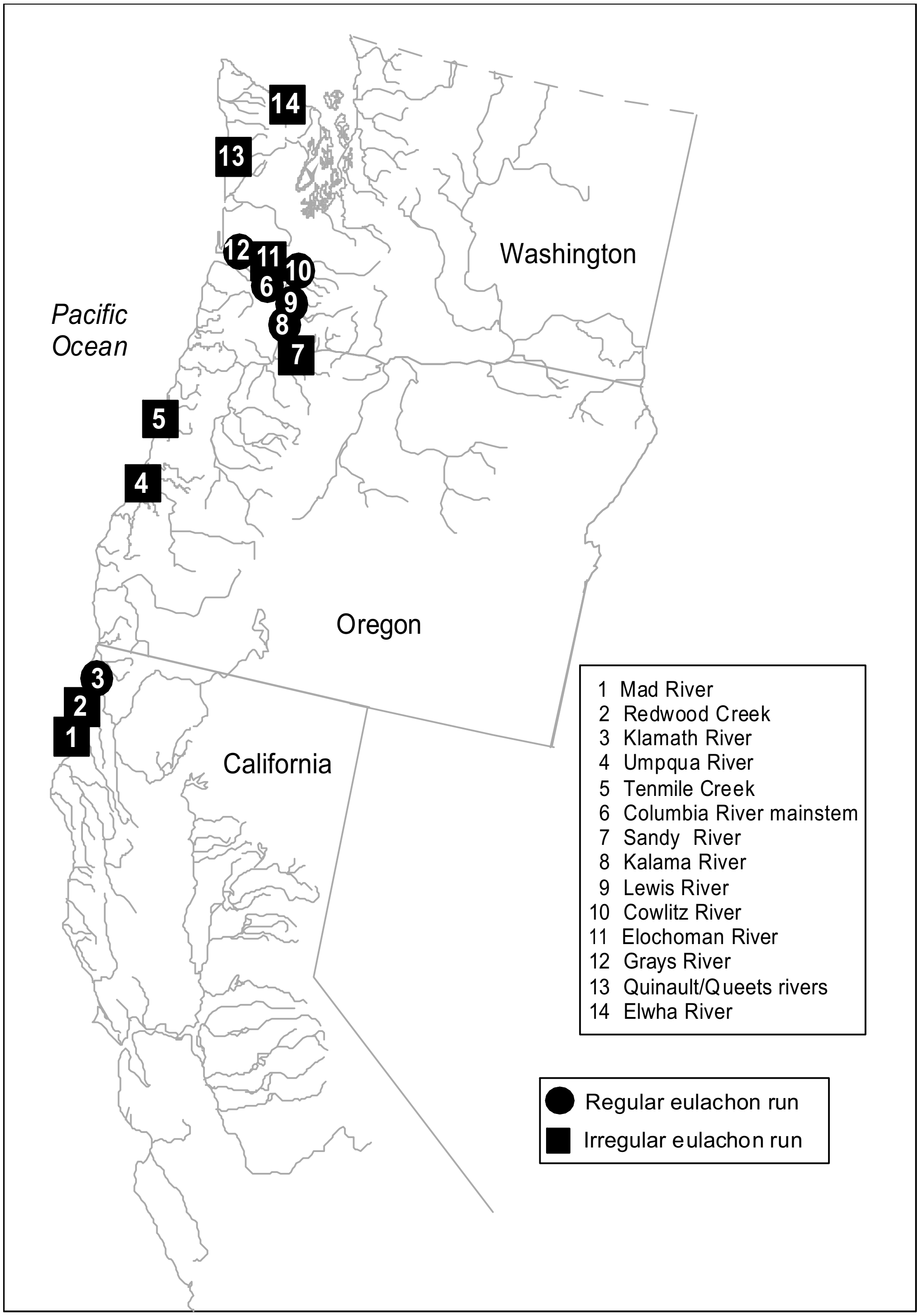

Figure 2. Eulachon spawning areas mentioned in the text in the conterminous United States.

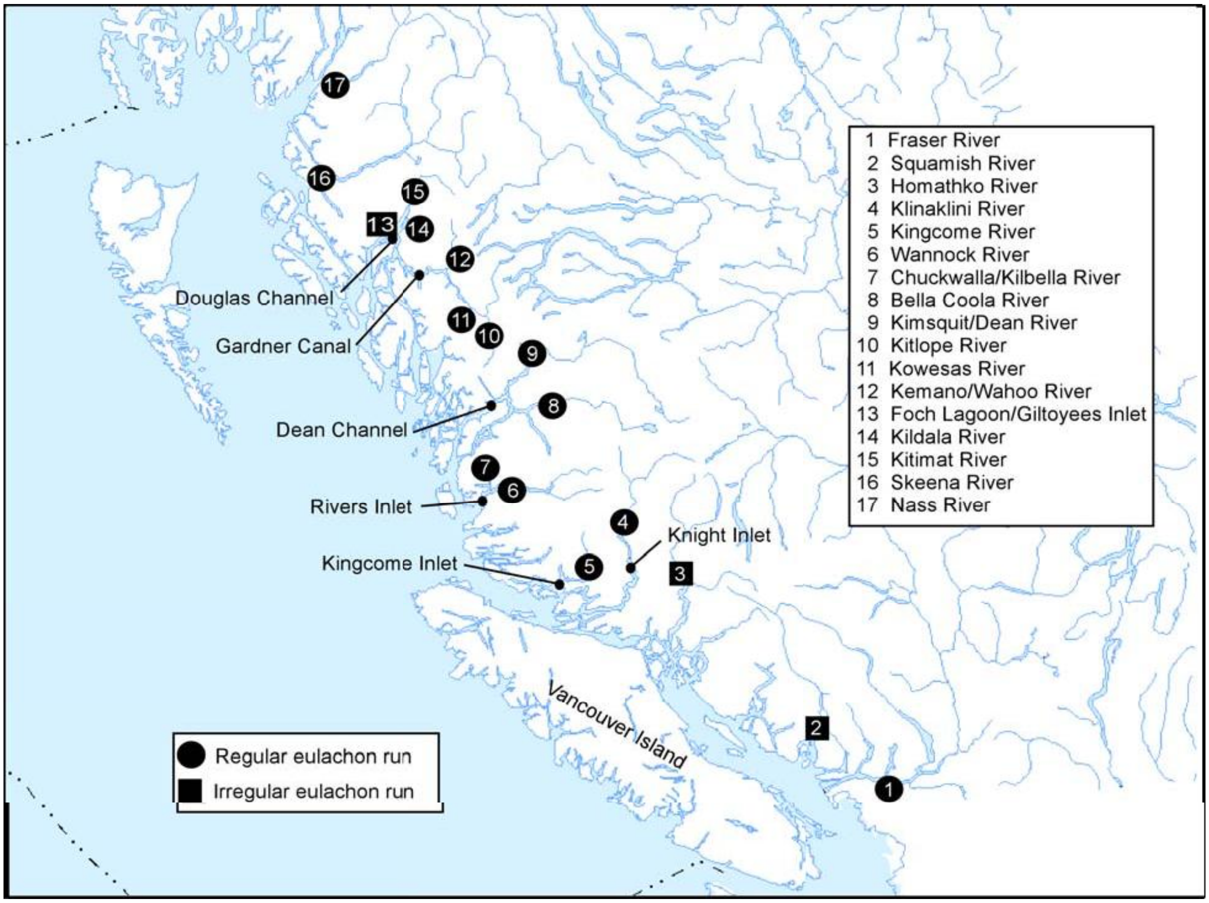

Figure 3. Major known eulachon spawning rivers in British Columbia (based on Hay and McCarter 2000 and Hay 2002).

Academy of Sciences (CAS) ichthyology collection database (online at http://research .calacademy.org/research/Ichthyology/collection/index.asp) lists eulachon specimens collected from the Klamath River in February 1916, March 1947, and March 1963, and in Redwood Creek in February 1955.

A search of available online digital newspaper resources (listed in Table B-1) revealed an early account of eulachon (aka candlefish in northern California) in the Klamath River in a newspaper article in 1879 (Appendix B). Runs large enough to be noted in available local newspaper articles occurred in the Klamath River in February 1919, March 1968, April 1963, and April 1969, in Redwood Creek in April 1963 and April 1967, and in the Mad River in April 1963 (Table A-3 and Appendix B). An early memoir by a traveler surveying timber resources on the Klamath River reported eulachon being harvested (15–20 lb in a single dip net haul) by Yurok tribal members in the early 1890s (Pearsall 1928) (Appendix C). Petersen (2006) reported on interviews with Yurok and Karuk tribal fishers on the lower Klamath River that indicated eulachon were abundant in the river in the 1960s. Petersen (2006, p. 88) stated that “one fisher remembered picking up 75 pounds of fish in one dip” and that another remembered “filling the back of a pickup truck in one hour” with eulachon in 1966.

Young (1984) collected eulachon in Redwood Creek in April 1978 and in the Klamath River in April 1978, March and April of 1979, and 1980. Bowlby (1981) documented eulachon in the diet of California sea lions (*Zalophus californianus*) through gastrointestinal content analysis and in harbor seals (*Phoca vitulina*) through scat analysis and gastrointestinal content analysis in the Klamath River during spring 1978 and 1979. One California sea lion contained 186 eulachon in its gut on 10 April 1978 when the carcass was recovered 1 km upriver from the river mouth, and sea lions "were observed at Klamath Glenn, 9.6 km upriver, while fishermen dipnetted these congregating fish from shore" (Bowlby 1981, p. 59). Eulachon have been reported to spawn at least as far as 40 km upstream on the Klamath River (Fry 1979, Hamilton et al. 2005). Larson and Belchik (1998, p. 5) noted that "In the Klamath, adults generally migrate as high as Pecwan Creek …, have been witnessed as high as Weitchpec …, but specific spawning areas are unknown."

Eulachon have been occasionally reported from other freshwater streams of California. Fry (1979, p. 90) reported that the largest eulachon run in California occurred in the Klamath River, and that eulachon occurred in "fresh water from the Gualala River, California, northward." Although Odemar (1964) has been cited as evidence that eulachon occurred in the Russian River, Odemar (1964) actually stated that "No runs of *T. pacificus* have been reported in the Russian River, or in any river south of the Mad River, and it does not appear that the fish examined off the Russian River in May 1963 were destined to spawn there."

Eulachon were not observed by Eldridge and Bryan (1972) in a larval fish survey of Humboldt Bay, California, and Barnhart et al. (1992, p. 101) stated that eulachon are "not reported in Humboldt Bay tributaries," although they are occasionally recorded in Humboldt Bay itself. Monaco et al. (1990) described eulachon as rare in Humboldt Bay and, in addition to several personal communications, cited Gotshall et al. (1980) and Young (1984) as supporting references (Table A-2). Gotshall et al. (1980, p. 229) recorded eulachon as an "occasional visitor" in winter to Humboldt Bay, California. Young (1984) stated that:

> Specimens [of eulachon] have occasionally been taken, during the spawning season, in Jolly Giant and Jacoby creeks (George Allen, pers. comm., 1980). Both of these streams empty into Humboldt Bay.

Jennings (1996) reported on observations of adult eulachon in creeks tributary to Humboldt Bay, California, in May 1977. A single spawned-out adult male eulachon was collected in a downstream migrant trap on Jolly Giant Creek, approximately 7 km south of Mad River, and a total of seven adult eulachon were observed in another downstream migrant trap in Jacoby Creek, located 8.5 km south of Mad River (Jennings 1996).

Although Minckley et al. (1986, their Table 15.1, p. 541) indicate that eulachon were native to the Sacramento River and drainages within the south California Coastal to Baja California region, no verifying references for these assertions were given. Recently, Vincik and Titus (2007) reported on the capture of a single mature male eulachon in a screw trap at RKM 228 (RM 142) on the Sacramento River.

Coastal Oregon

Monaco et al. (1990) and Emmett et al. (1991) summarized distribution and abundance of eulachon in major Oregon estuaries and listed the Rogue River, Coos Bay, Siuslaw River, and Umpqua River as possessing records of eulachon presence. More recently, Willson et al. (2006, p. 36–37) listed the following drainages on the coast of Oregon as supporting eulachon spawning runs (based on Emmett et al. [1991] and personal communications with fish biologists of ODFW): Winchuck, Chetco, Pistol, Rogue, Elk, Sixes, Coquille, Coos, Siuslaw, Umpqua, and Yaquina rivers; and Hunter, Euchre, Tenmile (draining Tenmile Lake), and Tenmile (near Yachats, Oregon) creeks (Table A-1).

Monaco et al. (1990) described eulachon as rare in the Rogue River and, in addition to a personal communication, cited Ratti (1979b) as a supporting reference (Table A-2). Although smelt and surf smelt (*Hypomesus pretiosus*) were reported from the Rogue River estuary by Ratti (1979b), no specific mention of eulachon occurs in this report. Roffe and Mate (1984) reported the presence of otoliths representing at least 120 eulachon from harbor seal scat collected in April 1978 on the Rogue River, which represented 16.7% of the identified harbor seal prey.

Reimers and Baxter (1976) reported that adult eulachon were caught in a downstream migrant trap in the lower portion of the Sixes River in Oregon between 1964 and 1972, although dates of occurrence or numbers caught were not provided. Reimers and Baxter (1976) suggested that these adults had possibly been spawning and were headed downstream at the time of capture.

Gaumer et al. (1973) recorded the taking of 28 eulachon in June 1971 by recreational fishers at the city docks of Bandon, Oregon, in the Coquille River estuary. Kreag (1979) also lists eulachon as occurring in the marine portion of the Coquille River estuary.

Monaco et al. (1990) described eulachon as rare in Coos Bay, Oregon, and, in addition to a personal communication, cited Cummings and Schwartz (1971), Hostick (1975), Roye (1979), and Wagoner et al. (1988) as supporting references (Table A-2). Cummings and Schwartz (1971) included eulachon in their list of fishes occurring in Coos Bay and indicated that eulachon were found up to 11 km (6.8 miles) upstream of the mouth of the bay. Although whitebait smelt (*Allosmerus elongatus)* and surf smelt were reported from Coos Bay by Hostick (1975), no specific mention of eulachon occurs in this report. Roye (1979, p. 36) referenced Cummings and Schwartz (1971) in describing eulachon as occurring in the lower 14.5 km (9 miles) of the Coos Bay estuary. The final version of the draft report, cited by Monaco et al. (1990) as Wagoner et al. (1988), stated that "eulachon may have occurred in large numbers in past years [in the Coos Bay estuary], but they have apparently not been abundant enough in recent years to attract an active dipnet fishery" (Wagoner et al. 1990, p. 100). More recently, Miller and Shanks (2005) surveyed the distribution of 28 identified larval and juvenile fish species in Coos Bay for more than three years between 1998 and 2001, but did not encounter eulachon.

Two reports (Gestring 1991, ODFW 1991) were found that list eulachon as a native fish species occurring in Tenmile and North Tenmile lakes, although no further information on frequency of occurrence or abundance were provided in these reports.

OFC (1970) reported that from 4,000 to 5,000 lb of eulachon were landed by two commercial fishermen in the Umpqua River during 31 days of drift gill net fishing from late December 1966 to mid-March 1967. OFC (1970, p. 34) stated that "The fishing area extended from the Highway 101 bridge at Reedsport upstream about 4 miles." A sport fishery for eulachon also operated over this period in the Umpqua River (OFC 1970). Monaco et al. (1990) described eulachon as common in the Umpqua River estuary and, in addition to a personal communication, cited Mullen (1977), Ratti (1979a), and Johnson et al. (1986) as supporting references (Table A-2). Neither Mullen (1977) nor Ratti (1979a) mention eulachon and Johnson et al. (1986, their Table 1) list eulachon as occurring in trace amounts in their trawl and beach-seine samples from April 1977 to January 1986.

Williams (2009, p. 2) reported that the Oregon Department of Fish and Wildlife (ODFW) has "no direct observations of eulachon spawning in the Umpqua" River, but provided additional information "on eulachon observations and captures during inventories." Williams (2009, p. 2) noted that:

> two random observations of eulachon [were reported] from Little Mill Creek [a tributary of the lower Umpqua River] on December 8, 1954 and January 26, 1955. The fish found in 1954 measured 6 inches in total length.

Williams (2009, p. 3) also reported on the results of seine collections conducted during March to November from 1995 to 2003 in Winchester Bay estuary on the Lower Umpqua River, which documented the

> presence … [of eulachon] in 4 of the last 14 years. Forty-four fish were found in May 1995, 80 fish during April and July 1998, 54 fish during March and May 1999, and 2 fish during June 2003. Seining was also conducted in the lower Smith River estuary [a tributary of the Lower Umpqua] at three sites during 1999 during February and March, but no eulachon were captured.

A search of available online digital newspaper resources (listed in Appendix B) revealed anecdotal evidence that an extensive recreational fishery for eulachon occurred in the lower Umpqua River at least from 1969 to 1982 during January to April. The last reference to eulachon in the Umpqua River in these digital newspaper resources occurred in 1989 (Appendix B).

Monaco et al. (1990) described eulachon as rare in the Siuslaw River estuary and, in addition to a personal communication, cited Hutchinson (1979) as a supporting reference (Table A-2); however, we have been unable to locate a copy of this document.

WDFW and ODFW (2008) describe the occasional occurrence of small numbers of eulachon in Tenmile Creek (not be confused with the Tenmile Lakes Basin), just south of Yachats, Oregon. Between 1992 and 2008, a total of 75 eulachon were caught in traps designed to catch outmigrating salmonid smolts located 0.8 km upstream from the ocean. Eulachon were caught in 1992 (24), 1993 (6), 1994 (1), 1995 (1), 1996 (1), 2001 (26), 2003 (3), 2005 (10), 2007 (1), and 2008 (2). As reported in WDFW and ODFW (2008):

> Eulachon were seen in February (3 years), March (6 years), April (7 years) and May (1 year). The earliest observed arrival was the week of February 3 in 1992.

> The latest observed presence was the week of May 21 in 2001. Fish lengths (annual averages) ranged from 155 to 208 mm FL. Local biologists suspect the eulachon spawn in the creek based on the trapping location, fish size, and that some fish appear to be spawned out.

Although Monaco et al. (1990) describe eulachon as not found in the Yaquina River (based on several personal communications) (Table A-2), Borgerson et al. (1991) list eulachon as occurring in the Yaquina River basin, but do not elaborate further on the evidence for this opinion.

Columbia River

Large spawning runs of eulachon occur in the mainstem lower Columbia River and the tributary Cowlitz, Lewis, Sandy (Craig and Hacker 1940), Grays (Smith and Saalfeld 1955), Kalama, and Elochoman (DeLacy and Batts 1963) rivers and Skamokawa Creek (WDFW and ODFW 2001, 2008). Smith and Saalfeld (1955) stated that eulachon were occasionally reported to spawn up to the Hood River on the Oregon side of the Columbia River prior to the construction of Bonneville Dam in the 1930s. In times of great abundance (e.g., 1945, 1953), eulachon have been known to migrate as far upstream as Bonneville Dam (Smith and Saalfeld 1955, WDFW and ODFW 2008) and may extend above Bonneville Dam by passing through the ship locks (Smith and Saalfeld 1955). Eulachon likely reached the Klickitat River on the Washington side of the Columbia River in 1945 via this route (Smith and Saalfeld 1955).

On average, the highest incidence of spawning occurs in the Cowlitz River (Smith and Saalfeld 1955, Wydoski and Whitney 2003), although on occasion eulachon may avoid the Cowlitz entirely, due to unfavorable environmental conditions (Wydoski and Whitney 2003). Sporadic spawning runs occur in the Grays, Elochoman, Kalama, Lewis, and Sandy rivers (JCRMS 2007, 2008, 2009). Stockley (1981, p. 1) stated that "occasionally, with very large runs, smelt ascend and enter the Washougal" River on the Washington side of the Columbia River at RKM 195. Stockley and Ellis (1970) suggested that in years of low abundance eulachon may not enter the Columbia River tributaries but remain within the mainstem Columbia River. In 2001 eulachon migrated upstream to Bonneville Dam at RKM 234 and spawned in all the major tributaries of the lower Columbia River, including the Sandy River (Howell et al. 2001). In 1953 eulachon were observed spawning in Tanner Creek on the Oregon side of the Columbia River near the base of Bonneville Dam (OFC 1953, WDFW and ODFW 2008).

Craig and Suomela (1940, p. 11) stated that "smelt are reported to confine their spawning activities to the lower 5 miles of the [Sandy] river" and that "this section is characterized, especially near the mouth, by moderate riffles and an abundance of glacial silt and sand." Anderson (2009) noted that eulachon have been observed on the Sandy River, Oregon, as far upstream as Gordon Creek at RKM 20.9 (RM 13). In addition, ODFW (Williams 2009, p. 1) stated that:

> The Sandy River in Oregon is the only Oregon tributary known to support a run of eulachon. However, it is sporadic and none have been seen in the last 6 to 8 years. … Based on observed sport fishing activity in the Sandy, we believe that spawning took place from the mouth up to RM 2.5.

Williams (2009) also reported on the onetime observation by an ODFW stream surveyor in February 1991 of eulachon in Conyers Creek, a tributary of the Clatskanie River, which is in turn a tributary of the lower Columbia River on the Oregon side of the river. The stream surveyor reported that eulachon were seen holding in pools within the lower 0.8 km (0.5 mile) of Conyers Creek during a daytime flood tide, but none were observed in the main stem of the Clatskanie River.

WDFW and ODFW (2008, p. 4) indicated that eulachon "used [Grays River] more frequently than commercial landings would suggest." Furthermore, Anderson (2009, his Table 1, p. 2) stated that the normal extent of eulachon spawning on the Grays River extended to the "covered bridge (RKM 17.4)."

Smith and Saalfeld (1955, p. 22) reported that:

> The lowest suitable spawning ground on the Cowlitz is located just below Kelso and the upper limit of spawning was noted in 1946, when smelt eggs were found in river bottom samples taken upstream almost to the mouth of the Toutle River, 20 river miles [32.2 km] from the Columbia.

In describing the principle spawning reaches of eulachon in the Cowlitz River, WDFW and ODFW (2008, p. 4) stated that eulachon:

> typically move upstream about 16 miles [25.7 km] (Castle Rock/Toutle River mouth area), often up to 34 miles [54.7 km] (Toledo area), and on occasion up to 50 miles [80.5 km] upstream (Cowlitz Salmon Hatchery barrier dam). … Upstream movement during the past 15 years or so has apparently been limited to the Castle Rock/Toutle River mouth area.

Stockley (1981, p. 1) indicated that eulachon "have been known to ascend the Toutle River [tributary of the Cowlitz River] occasionally," particularly before the 1980 eruption of Mount St. Helens (WDFW and ODFW 2008). Anderson (2009, p. 3) stated that:

> Adult eulachon were observed to enter the Toutle River prior to the eruption of Mount St. Helens. … Though the Washington Department of Fish and Wildlife (WDFW) has no reports of eulachon using the Toutle River since the eruption … WDFW considers the Toutle River as potential primary habitat due to its past use and vicinity to primary Cowlitz River spawning grounds.

WDFW and ODFW (2008, p. 4) indicated that eulachon "used [the Kalama River] more frequently than commercial landings would suggest." In addition, Anderson (2009, his Table 1, p. 2) said that the normal extent of eulachon spawning on the Kalama River extended "downstream of Modrow Bridge (RKM 4.5)."

Anderson (2009, his Table 1, p. 2) indicated that the normal extent of eulachon spawning on the Lewis River extended to the "upper end of Eagle Island (RKM 18.8)." WDFW and ODFW (2008, p. 4) stated that eulachon:

> typically move upstream about 10 miles [on the Lewis River] but on occasion upstream 19.5 miles [31.4 km] to Ariel [aka Merwin] Dam. … Biologists believed that a natural sediment blockage prevented upstream movement past river mile 7

> [11.3 km] for a number of years, from 1977 until the mid-1980s. Spawning eulachon have since been observed upstream of river mile 7 [11.3 km].

Anderson (2009, p. 2) noted that "eulachon spawn within the main stem of the Columbia River, but spawning ground locations are not well known." Smith and Saalfeld (1955) reported that spawned out and partially spawned out eulachon captured near Eagle Cliff on the main stem of the Columbia River identified this area as a eulachon spawning ground. Howell et al. (2001, p. 12) also noted that Eagle Cliff at RKM 82 "on the Washington shore [is] historically recognized as a major mainstem eulachon spawning area" and that "spawning in the main stem of the Columbia River has never been recorded upstream of Martin's Bluff" at RKM 117. Romano et el. (2002) collected eulachon eggs between RKM 56 and RKM 118 on the Washington side of the main stem of the Columbia River; however, mapping the extent of spawning on the main stem will require much additional sampling (Anderson 2009). Anderson (2009, p. 3) noted that:

> In years of very high eulachon abundance, spawning has been observed in the main stem of the Columbia River upstream of RKM 137 as eulachon travel to the Lewis and Sandy rivers and as far as Bonneville Dam on rare occasion. Primary spawning habitat could, therefore, extend from the estuary upstream to at least as far as the Sandy River (RKM 193).

The earliest mention of eulachon in the Columbia River occurs in the journals of members of the Lewis and Clark Expedition during February and March 1806 (Gass 1807, Moulton 1990, Moring 1996) (Appendix C). Throughout the 1810s–1820s, the journals of several fur trappers and explorers (e.g., Gabriel Franchère [Franchère 1967, 1968, 1969], Robert Stuart [Rollins (ed.) 1995], Wilson Price Hunt [Rollins (ed.) 1995], Alexander Henry [Gough (ed.) 1992], and Alexander Ross [Ross 1849]) describe the appearance of large eulachon runs in the lower Columbia River and their importance to the local Native American tribes (Appendix C).

Subsequently, several contemporary references (Suckley 1860, Lord 1866, Anderson 1872, 1877, Crawford 1878, Huntington 1963) (Appendix C) indicate a major decline in Columbia River eulachon abundance occurred between the mid to late 1830s and mid to late 1860s. Similarly, several secondary references (Summers 1982, Urrutia 1998, Hinrichsen 1998, Martin 2008, 2009) cite additional sources that indicate eulachon were at low levels of abundance prior to about 1867, when eulachon were once again seen in large numbers. Anderson (1872, footnote on p. 30–31) (Appendix C) stated that eulachon:

> were formerly very abundant in spring on the lower Columbia; but suddenly, about the year 1835, they ceased to appear, and thence-forward up at least to 1858, none frequented the river. I have been informed, however, that they have since reappeared, and that there is now a regular supply as formerly.

Subsequently, Anderson (1877, p. 345) (Appendix C) said:

> Formerly resorting in enormous shoals to the estuary of the Columbia River, [eulachon] disappeared suddenly about the year 1837, and continued to absent itself for many years, until recently, when it suddenly reappeared in shoals as numerous as of yore.

Similarly, Lord (1866, p. 96) (see Appendix C) observed that:

> Some 50 years ago, vast shoals of eulachon used regularly to enter the Columbia; but the silent stroke of the Indian paddle has now given place to the splashing wheels of great steamers, and the Indian and the candle-fish have vanished together.

An early settler on the Cowlitz River, Edwin Huntington (Huntington 1963, p. 5) (Appendix C), recalled that:

> Not within the memory of the oldest white inhabitant had there been any smelt in the Cowlitz River until some time in the early sixties. I am not certain what year I first saw them, but there was a heavy run and nobody paid much attention to them—not even the Indians. … After the second or third year of their return, people began to sit up and take notice. In 1865, a young lady school teacher, Miss Baker (afterward my wife) having learned how to make hair nets, conceived the idea of making dip nets in which to catch them and soon everybody had nets and were catching them by the ton and shipping them to Portland. The Indians had a tradition that there had been smelt here many many years before, but to punish them for some offense the Sahely Tyee had taken them away and it must have been a good many years as the oldest of them did not seem to know much about tradition.

Summers (1982, p. 31) in a local history of the town of Kelso, Washington, at the confluence of the Cowlitz and Columbia rivers, related that:

> The earliest record of a smelt run was found in a 1867 diary written by W. A. L. McCorkle, a settler at Lexington. He tells of small silvery fish coming into the Cowlitz during that year and that no smelt had been observed by Americans earlier than that. Settlers came beginning 1850. Of course, the Cowlitz Indians and other tribes had caught smelt in the Cowlitz many years before the Americans came.

However, a memoir written by Peter W. Crawford (Crawford 1878, p. 369) indicates that early settlers were aware of "small numbers" of eulachon on the Cowlitz River, and that large runs were noted, after an absence of 17 years, in the spring of 1865. Crawford (1878, p. 369) (Appendix C) stated that:

> In Feby and March 1865 there appeared a strange little fish unknown to the early settlers of Cowlitz or lower Columbia River. Although the Indians declared that those little finny swarming beings of the deep had frequented the waters of the Cowlitz River before but had absented themselves for 17 years, during which period no Indian had seen a school. … The early settlers on the lower Cowlitz remember having a few such little fellows in small numbers.

Hinrichsen (1998, p. 16) reported that "According to historian Duncan Stacey, Hudson's Bay Company documents describe very low returns in the Columbia River from about 1835 to 1865." However, examination of microfilmed records from the Hudson's Bay Company Archives (Fort Vancouver Report 1826–1845 [reel #1M783] and Fort Vancouver Post Journal

1825–1836 [reel # 1M148]) did not reveal any reference to eulachon or smelt in these records. Fort Vancouver was a Hudson's Bay Company post from 1825 to 1860 near the present location of Vancouver, Washington, on the lower Columbia River. Another early reference (Swan 1881, p. 258) mentions that "eulachon are found in limited numbers at certain seasons in the Columbia River."

A search of available online digital newspaper resources (listed in Appendix B) revealed mention of eulachon in the Columbia River or "smelt" as items for sale in local fish markets in the spring of 1867. A two sentence article in the Vancouver Register (Vancouver, Washington Territory) for 6 April 1867 (Appendix B) indicates that large numbers of "smelt" were present in the Columbia River off the city of Vancouver (at about RKM 170) at that time. This newspaper article said that previously "this … fish ... [had] never before been known to come up higher than Lewis River," which indicates that eulachon were known to occur in some numbers prior to 1867 in the Lewis River or in the Columbia River, downstream of the Lewis River.

Two advertisements of "smelt" for sale in Portland, Oregon, fish markets appeared in early newspapers, one in April 1867 and another in April 1868. Since April is near the tail end of the traditional period for eulachon run timing in the Columbia River, and other species of smelt are available at that time, it is uncertain whether these advertisements (Appendix B) refer to eulachon or some other species of smelt. An advertisement of eulachon for sale (referred to as Oak Point smelt) in a local fish market appeared on 15 January 1869 in the Daily Oregonian (Portland) (Appendix B). In later years the eulachon commercial fishery commonly operated in the vicinity of Oak Point on the Lower Columbia River indicating that this advertisement of "Oak Point smelt" likely refers to eulachon and not some other smelt species.

A newspaper article published in the Daily Oregonian on 13 March 1885 (Appendix B) reported that:

> a pioneer, who resided for many years on the lower Columbia, says that there were no smelt or oolachan, as they were called by Indians, in the Columbia from the time he came here till in 1863, when they appeared in vast numbers about the middle of February, and have been plentiful every season since. In Irving's "Astoria" mention is made of the great quantities of smelt in the Columbia in 1826. Shortly after they forsook the river entirely and did not return till 1863, having been absent nearly 40 years.

Coastal Washington

Outside of the Columbia River Basin, eulachon have been occasionally reported from other coastal Washington rivers. Swan (1881, p. 258) noted that "eulachon are found in limited numbers at certain seasons in … Shoalwater bay [Willapa Bay], Gray's Harbor, and at the mouth of various small streams of the coast." WDFW and ODFW (2001) stated that "Washington rivers outside the Columbia Basin where eulachon have been known to spawn include the Bear, Naselle, Nemah, Wynoochee, Quinault, [and] Queets … rivers." Willson et al. (2006) listed Willapa Bay (North, Naselle, Nemah, Bear, and Willapa rivers), Grays Harbor (Humptulips, Chehalis, Aberdeen, and Wynoochee rivers), and the Copalis, Moclips, Quinault, Queets, and Bogachiel rivers as supporting eulachon spawning runs.

Monaco et al. (1990) described eulachon as common in Willapa Bay based on a personal communication (Table A-2). Smith (1941) noted that:

> A small smelt run was noted in the north fork of the Nemah River on 7 February 1941. The fish ascended the Nemah River as far as the mouth of Williams Creek, which stream they entered for a distance of about 100 yards. … An old resident of the community reported that this was the first smelt run that had occurred during his 48 years in the section.

According to WDFHMD (1992), adult eulachon "were found in the Naselle and Bear rivers, tributaries of Willapa Bay (B. Dumbauld, WDF, pers. comm.)" in 1992. WDFW and ODFW (2001, p. 12) reported "that in 1993, when the eulachon run into the Columbia River was delayed (presumably due to cold water conditions), they were noted in large abundance in the Quinault and Wynoochee rivers, outside the Columbia Basin."

Monaco et al. (1990) described eulachon as "common" in Grays Harbor and, in addition to a personal communication, cited Deschamps et al. (1970) as a supporting reference (Table A-2). Deschamps et al. (1970, p. 16) reported the capture of a single adult eulachon in a seine catch in March 1966 and stated that "It is unlikely that the Chehalis system [which drains into Grays Harbor] has a run of any consequence, although strays or feeding fish from other areas probably visit the upper harbor at times." WDFW and ODFW (2001, p. 12) reported that eulachon "were noted in large abundance in the … Wynoochee" River, a tributary of the Chehalis River, in 1993. Simenstad et al. (2001) recorded eulachon as of "rare" occurrence in sloughs of the Chehalis River estuary in 1990 and 1995.

Willoughby (1889) and Olson (1936) record the Quinault Indian Tribe as taking eulachon in the lower Quinault River with dip nets. Olson (1936, p. 36) stated that:

> The people of the lower villages often came down to the river mouth to catch smelt (komólnil) and candlefish (páagwáls). Both were taken in the surf of the beach, though the candlefish often ascend the river for several miles. There was usually a big run every three or four years, when the water was literally filled with fish. The time of the run varied, usually occurring between January and April.

The Washington Department of Fisheries annual report for 1960 (Starlund 1960) and statistical report for 1970 (Ward et al. 1971) listed commercial eulachon landings in the Quinault River in 1936 (36,315 lb [16,507 kg]), 1940 (6,917 lb [3,144 kg]), 1953 (93,387 lb [42,449 kg]), 1958 (34,387 lb [15,630 kg]), 1960 (135 lb [61 kg]), and 1961 (1,051 lb [477 kg]). Fiedler (1939, p. 213) also records 36,300 lb (16,500 kg) of eulachon taken by dip net in the coastal district of Washington State in 1936. WDFW and ODFW (2001, p. 12) reported that eulachon "were noted in large abundance in the Quinault" River in 1993. Quotations from unattributed sources were presented in Workman (1997) that described eulachon occurring in and about the Quinault River in January 1936 and February 1993. NWIFC (1998, p. 11) reported that "candlefish, or Columbia River smelt, were caught in significant numbers at the mouth of the Queets River for the second time in 5 years in late January [1998]." A noticeable number of eulachon make an appearance in the Queets, Quinault, and occasionally, the Moclips rivers at 5–6 year intervals and were last observed in the Quinault River in the winter of 2004–2005.[2]

Shaffer et al. (2007) reported on the capture of 58 adult eulachon in the Elwha River on Washington's Olympic Peninsula (Figure 2) between March 18 and June 28, 2005. This was the first formal documentation of eulachon in the Elwha River, although anecdotal observations suggest that eulachon "were a regular, predictable feature in the Elwha until the mid 1970s" (Shaffer et al. 2007, p. 80). Other Olympic Peninsula rivers draining into the Strait of Juan de Fuca have been extensively surveyed over many years for salmonid migrations; however, eulachon have not been observed in any of these other systems (Shaffer et al. 2007).

Puget Sound

Girard (1858) based his description of a new species *Thaleichthys stevensi* (later synonymized with *Salmo* [*Mallotus*] *pacificus* Richardson, 1836 as *T. pacificus* [Richardson, 1836] [McAllister, 1963]) on a single specimen collected in Puget Sound by George Suckley. The published figure (Girard 1858, his Plate LXXV, his Figure 1 through Figure 4) of this single specimen is detailed enough to be identifiable as a eulachon. Later, Suckley (1860, p. 348–349) in his Report Upon the Fishes Collected on the Survey (text republished in Suckley and Cooper 1860) stated that eulachon were "a very delicious fish, in some years coming in great shoals in the bays in the lower part of Puget Sound, and along the coast near the mouth of Frazer's River." Suckley (1860, p. 348–349) also stated that eulachon were "abundant in Puget Sound" and that "several eulachon in the recent state [dried] were obtained by me from different portions of the lower end of Puget Sound;" however, these specimens were lost when in transit to "Washington city" and their identification cannot be verified. Similarly, Lord (1866, p. 96), in his The Naturalist in Vancouver Island and British Columbia, stated that "the eulachon has also disappeared from Puget's Sound."

Curiously, although these early authorities (Girard 1858, Suckley 1860, Lord 1866) describe Pacific herring (*Clupea pallasii*) and eulachon as occurring in Puget Sound, they make no mention of surf smelt, longfin smelt (*Spirinchus thaleichthys*), or Pacific sand lance (*Ammodytes hexapterus*) in Puget Sound. Swan (1881, p. 258) also stated that eulachon were found "in limited numbers at certain seasons … in the waters of Puget Sound" and they are "found on Puget Sound occasionally with the sand-smelt *Hypomesus olidus*." Since *H. olidus*, or pond smelt, is a freshwater species, Swan may have meant to refer to the abundant surf smelt.

Jordan and Starks (1895, p. 793) also listed eulachon as "abundant in spring" in Puget Sound, although they did not obtain specimens themselves. They cite a local fisherman as reporting "that this species buries itself in the sand of the beach," which indicates that the fish referred to by the local fisherman were not eulachon, but were possibly either surf smelt or Pacific sand lance. Both surf smelt and Pacific sand lance are currently common in Puget Sound and spawn on Puget Sound beaches, and Pacific sand lance are locally known as "candlefish" (Penttila 2007). Therefore, there is substantial reason to believe that mention of abundant eulachon in Puget Sound in some nineteenth century references (Suckley 1860, Lord 1866,

[2] L. Gilbertson, Quinault Indian Nation, Taholah, WA. Pers. commun., 27 June 2008.

Jordan and Starks 1895) results from misidentification with either the common longfin smelt or surf smelt, neither of which were mentioned in Suckley (1860) or Lord (1866).

DeLacy et al. (1972) gathered available fish collection records for Puget Sound from academic and fisheries agencies sources and indicated that between 10 and 49 reports of eulachon exist in these records for the San Juan Islands. However, no more than 10 reports of eulachon specimens exist for each of the Juan de Fuca Strait, Everett, Seattle, central Puget Sound, and south Puget Sound regions (DeLacy et al. 1972). Monaco et al. (1990) described eulachon as rare in Puget Sound and, in addition to a personal communication, cited Miller and Borton (1980) as a supporting reference. Miller and Borton (1980) list five eulachon specimens collected in Puget Sound (one each in Port Susan, off Everett, and in Carr Sound, and two at Carkeek Park), which are deposited in the University of Washington Fish Collection, and seven eulachon specimens reported in the University of Washington Boat Log (one each at Golden Gardens, Port Madison, Herron Island, Penn Cove, and three in or near Carr Inlet). Currently, 12 specimens of eulachon collected in Puget Sound are deposited in the University of Washington Fish Collection (searchable database at http://www.washington.edu/burkemuseum/collections/ichthyology/index.php).

Miller and Borton (1980) also reported a personal communication dated 22 April 1976 from a biologist with the Puyallup Tribe indicating that eulachon "spawn in Wapato Creek, 1 mile upstream from the mouth of the Puyallup River." Fiedler (1941, p. 463) recorded 10,200 lb (4,636 kg) of eulachon landed in Puget Sound in 1938 in a commercial fishery using drag bag net gear. The precise location of this fish catch is not recorded (Fiedler 1941).

There are some records of transplant efforts to Puget Sound rivers from Columbia River source populations. An article in a Centralia, Washington, newspaper in 1932 (Centralia Daily Chronicle, 1 February 1932, p. 2, col. 8) (Appendix B) reported that:

> Another attempt will probably be made this year by the state fisheries department to transplant Columbia River smelt to streams flowing into Puget Sound. Attempts have been made in the past and a large number of smelt were planted in the Nisqually River several years ago. Floyd [Lloyd] Royal of the state biological department is making a study of the matter here, and it is probable that smelt spawn will be hatched in the state hatchery on the Kalama river and the young smelt planted in both the Snohomish and Skagit rivers if the attempt to hatch them proves successful.

Similarly, Wendler and Nye (1962, p. 9) stated that:

> A smelt transplant was initiated in 1959 from the Lewis River to the Puyallup River.... Approximately 4,500 fish were transplanted with an estimated egg potential of 40 million. This was considered a minimal number to plant for a species which requires mass spawning for successful reproduction. However, a measure of success may be seen if Columbia River smelt are present in the Puyallup during the spring of 1962.

A recent WDFW technical report entitled Marine Forage Fishes in Puget Sound (Penttila 2007, p. 19) presents detailed data on the biology, status, and trends of surf smelt and longfin smelt in Puget Sound, but states that "there is virtually no life history information within the

Puget Sound basin" available for eulachon. Similarly, detailed notes provided by WDFW and ODFW (2008) as part of this review, do not provide evidence of spawning stocks of eulachon in Puget Sound rivers. Interestingly, a newspaper account in The Daily Oregonian of Portland for 4 March 1876, cautions the public "against buying Puget Sound smelt [a likely reference to surf smelt] for Columbia River smelt [eulachon]" (Appendix B).

Monaco et al. (1990) described eulachon as rare in Skagit Bay and, in addition to a personal communication, cited Miller and Borton (1980) as a supporting reference (Table A-2). Miller and Borton (1980) report on a total of 20 eulachon specimens collected in the San Juan Islands, southern Strait of Georgia, and Strait of Juan de Fuca and recorded in boat logs and museum collection records; however, samples from Skagit Bay were not included in this list.

The Nooksack River has been frequently listed as supporting a run of eulachon (WDFW and ODFW 2001, Wydoski and Whitney 2003, Willson et al. 2006, Moody 2008); however, Anchor Environmental (2003, p. 27) stated that:

> Longfin smelt [*Spirinchus thaleichthys*] are also called "hooligans" and are sometimes mistaken for eulachon. Eulachon occurrence and spawning has not [been] documented in the Nooksack River.

The run of hooligans into the Nooksack River commonly occurs in November, which is outside of the normal spawn timing period for eulachon, and these fish have recently been positively identified as longfin smelt.[3]

British Columbia

Hay and McCarter (2000, their Table 1) listed a total of 33 eulachon spawning rivers in British Columbia; however, only about 14 of these river systems were thought to have regular yearly eulachon returns (Table A-1). These 14 river systems and the estuaries or inlets they are associated with from south to north are the Fraser River (Strait of Georgia), Klinaklini River (Knight Inlet), Kingcome River (Kingcome Inlet), Wannock River (Rivers Inlet), Chuckwalla/Kilbella rivers (Rivers Inlet), Kimsquit and Dean rivers (Dean Channel), Bella Coola River (Dean Channel), Kemano/Wahoo rivers (Gardner Canal), Kowesas River (Gardner Canal), Kitlope River (Gardner Canal), Kildala River (Douglas Channel), Kitimat River (Douglas Channel), Skeena River (Chatham Sound), and Nass River (Portland Inlet) (Hay and McCarter 2000, Hay 2002).

Many of these distributions were discovered or verified during a series of ichthyoplankton surveys of eulachon larvae on the mainland coast of British Columbia (McCarter and Hay 1999). These surveys "suggested the occurrence of eulachon spawning in … rivers not previously known to support eulachon spawning" (McCarter and Hay 1999, p. 8). In particular, small spawning runs of eulachon may be detected through ichthyoplankton surveys "that might be missed by conventional fishing techniques (gill nets or seine nets) on adults" (McCarter and Hay 2003, p. 17). Willson et al. (2006) and Moody (2008) recently listed numerous rivers in British Columbia thought to support eulachon runs and these distribution data, essentially the same as in Hay and McCarter (2000), are provided in Table A-1.

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[3] G. Bargmann, WDFW, Olympia, WA. Pers. commun., June 2008.

Fraser River—Early reference to eulachon being caught by First Nations groups on the Fraser River in 1827–1830 appear in the journals of the Hudson's Bay Company post Fort Langley, located on the south bank of the lower Fraser River near the Salmon River (MacLachlan 1998) (Appendix C). According to Swan (1881, p. 258) eulachon "taken in Fraser's River near the boundary line between Washington Territory and British Columbia are superior to those taken further south, and are sold in the Victoria market, where their excellence is highly prized."

Recent surveys of the Fraser River indicate that eulachon primarily spawn in the lower 50 km (Hay et al. 2002), although earlier studies reported spawning occurred at least up to RKM 100 (McHugh 1940), and perhaps as far upstream as Hope, more than 150 km from Vancouver, British Columbia (Moody 2008). McHugh (1940) surveyed eulachon egg distribution in the Fraser River using a bottom dredge and determined that spawning in 1940 occurred mainly between the towns of Mission and Chilliwack, over a distance of about 13 km. Samis (1977, p. 1) stated that "localized areas of spawning may occur in the north and south arms of the Fraser River, in the Pitt and Alouette rivers, and in other tributaries." However, similar to the findings of Hart and McHugh (1944), Samis (1977) found the highest concentration of eulachon eggs in the Fraser River in May 1976 to occur upstream of Mission, adjacent to Nicomen Island. Higgins et al. (1987, p. 2) noted that "potential [eulachon] spawning sites exist in the lower Fraser River adjacent to Barnston, McMillan, and Matsqui islands (Samis 1977), which are approximately 100 km, 130 km, and 175 km from the Fraser River mouth, respectively." Interannual variation in spawning locations in the Fraser River occur (Hay and McCarter 2000, Hay et al. 2002), with most spawning being above New Westminster in 1995, below New Westminster in 1996, and in the tributary Pitt River in 1999 (Hay and McCarter 2000).

Other British Columbia rivers—Outside of the Fraser River, only limited aspects of the biology of eulachon have been studied in other spawning rivers in British Columbia, including: the Kingcome (Berry and Jacob 1998), Wannock (Berry and Jacob 1998, Moody 2008), Bella Coola (Moody 2008), Kemano (Lewis et al. 2002, Ecometrix 2006), Kitimat (Pedersen et al. 1995, Kelson 1997, Ecometrix 2006), Skeena (Lewis, 1997, Stoffels 2001), and Nass (Langer et al. 1977) rivers.

Eulachon were normally located no further upstream in the Kemano River, British Columbia, than RKM 2.7, about 1.5 km above saltwater, although they have been rarely observed up to RKM 4.3 (Lewis et al. 2002). Eulachon spawning is limited to the lower 1.6 km of the nearby Wahoo River (Lewis et al. 2002). Stoffels (2001, p. 4) described areas of the lower mainstem Skeena River and several tributaries (Table A-1) and stated that:

> The eulachon spawn in the main stem Skeena, with high value spawning grounds around the lower Skeena River Islands and around the mouth of the Kwinitsa River (D. De Leeuw, WLAP, pers. comm.). Eulachon also spawn throughout the Ecstall River system, almost up to Johnston Lake and in the Khyex, the Scotia, the Khtada, Kasiks, Gitnadoix and other tributaries in the vicinity (Don Roberts, Terrace, pers. comm.).

Eulachon reportedly spawn upriver in the Nass River to about RM 32 (RKM 51.5), which is the near the limit of tidal influence (Langer et al. 1977).

Although eulachon are not thought to maintain populations in island rivers (Hay and McCarter 2000), anomalous spawning events have reportedly occurred in the Somass, Nimpkish (Hay and McCarter 2000), and Kokish rivers (Willson et al. 2006) on Vancouver Island, as well as in "unnamed rivers on Haida G'waii [Queen Charlotte Islands]" (Willson et al. 2006, p. 35).

Alaska

Moffitt et al. (2002) indicated that at least 35 rivers in Alaska have spawning runs of eulachon, including one in a glacial stream on Unimak Island, the first island in the Aleutian Island chain off the western end of the Alaska Peninsula. According to Moffitt et al. (2002, p. 3), "this is probably the only island in Alaska with a glacial river of the type similar to mainland systems used for spawning." Armstrong and Hermans (2007, p. 2) stated that "no eulachon runs in island rivers have been reported in Southeast [Alaska]." Aspects of the biology of eulachon have been studied in the following Alaska rivers: the Stikine (Franzel and Nelson 1981), Taku (Flory 2008b), Chilkoot (Betts 1994), Chilkat (Mills 1982, Betts 1994), Copper (Moffitt et al. 2002), Eyak, Alaganik (Moffitt et al. 2002, Joyce et al. 2004), Twentymile (Kubik and Wadman 1977, 1978, Spangler 2002, Spangler et al. 2003), and Susitna (Barrett et al. 1984, Vincent-Lang and Queral 1984).

Both Willson et al. (2006) and Moody (2008) listed numerous other Alaska rivers thought to support eulachon runs and these distribution data are provided in Table A-1. In some years, commercial harvests have occurred on eulachon in the Copper, Stikine, Unuk, Chickamin, and Bradfield rivers (Moffitt et al. 2002, Armstrong and Hermans 2007). Jordan and Gilbert (1899, p. 439) indicated that eulachon occurred in the "Nushagah [Nushagak] River" that flows into Alaska's Bristol Bay in the southeastern Bering Sea. Other more recent compilations also list the Nushagak River as supporting a run of eulachon (Mecklenburg et al. 2002, Willson et al. 2006). The Nushagak River is the northern most system reported to support a run of eulachon.

Larval plankton surveys suggest that the upstream limit of eulachon distribution in the Taku River occurs at about RKM 44 (Flory 2008b). During exceptionally large runs, eulachon have reportedly been seen "at Bull Slough, near the Tulsequah River in Canada" (Flory 2008b, p. 16). Tidal influence affects the Taku River up to about RKM 35 (Flory 2008b). Eulachon were observed from the mouth of the Susitna River up to about RKM 80 in 1982 and 1983, although the greatest concentration of spawning occurred within the lower 46.6 km of the main channel of the Susitna River (Barrett et al. 1984).

Physical characteristics of spawning rivers

Hay and McCarter (2000, p. 12) noted that some eulachon rivers are "large or turbid, with high sediment loads; others are small and clear." Despite these apparent differences, they recognized that "virtually all [eulachon rivers] have spring freshets, which are characteristic of rivers draining large snow packs or glaciers." Although this is true of most rivers supporting eulachon in British Columbia and Alaska (Hay et al. 2002), many eulachon rivers in the lower Columbia River basin and on the coasts of California, Oregon, and Washington are not fed by extensive snowmelt or glacial runoff. However, most systems that support eulachon and are not fed by snowmelt still possess extensive spring freshets. Hay and McCarter (2000, p. 12) suggested that the apparent requirement for snow pack or glacier-fed spring freshets may be the reason why "there are no known eulachon spawning rivers found on any large coastal islands, including Vancouver Island, Queen Charlotte Islands, Kodiak, or any of the small coastal islands in northern British Columbia or southeastern Alaska."

The lack of eulachon larvae in waters examined during ichthyoplankton surveys off Vancouver Island and the Queen Charlotte Islands in April and May (Hay and McCarter 1997) "reinforce the conclusion that eulachon spawning is mainly confined to coastal rivers that have a distinct spring freshet and drain major glaciers or snowpacks" (McCarter and Hay 2003, p. 16). Typically, eulachon spawn well before the spring freshet, near the seasonal flow minimum, especially on the mainland coast of British Columbia (Lewis et al. 2002); however, Fraser River eulachon appear to spawn during the height of the freshet (Stables et al. 2005). In many rivers, eulachon spawning appears to be timed so that egg hatching will coincide with peak spring river discharge (Flory 2008b).

Marine Distribution

Although they spend 95–98% of their lives at sea (Hay and McCarter 2000), little is known concerning the saltwater existence of eulachon. They are reported to be present in the "food rich" and "echo scattering layer" of coastal waters (Barraclough 1964, p. 1,337), and "in near-benthic habitats in open marine waters" of the continental shelf between 20 and 150 m depth (Hay and McCarter 2000, p. 14). Hay and McCarter (2000, their Figure 5) illustrated the offshore distribution of eulachon in British Columbia as determined in research trawl surveys, which indicate that most eulachon were taken at around 100 m depth, although some were taken as deep as 500 m and some at less than 10 m. Schweigert et al. (2007, p. 11) stated that "the marine distribution of adults in British Columbia includes the deeper portions of the continental shelf around Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island, generally at depths of 80–200 m." Mueter and Norcross (2002) reported eulachon were present in 32% of triennial bottom trawl surveys on the upper slope and continental slope in the Gulf of Alaska between 1984 and 1996 and were caught at depths down to 500 m in the Kodiak, Yakutat, and southeast areas of Alaska. Armstrong and Hermans (2007) indicated that eulachon are commonly caught in trawls in the coastal fjords of Southeast Alaska. Further information on eulachon distribution in research bottom trawl surveys is below and in Table A-4 and Table A-5.

Smith and Saalfeld (1955, p. 12) reported the occasional capture of eulachon in the offshore "otter trawl fishery," particularly in November to January near the mouth of the Columbia River "as the mature smelt approach the Columbia River." Emmett et al. (2001) reported the capture of small numbers of eulachon by nighttime surface trawls targeted on pelagic fishes off the Columbia River in April to July of 1998 and 1999. About 10% of hauls in 1999 contained from one to a maximum of eight eulachon (Emmett et al. 2001). Eulachon also occur as bycatch in some U.S.-based groundfish fisheries (Bellman et al. 2008) off the U.S. West Coast and more commonly in the California and Oregon ocean shrimp (*Pandalus jordani*) fisheries (NWFSC 2008). The Pacific Fishery Management Council has prohibited at-sea directed harvest of eulachon in U.S. West Coast waters and eulachon are not an actively managed or monitored species (PFMC 2008); therefore there is a paucity of data on at-sea distribution of eulachon off the U.S. West Coast.

U.S. West Coast groundfish trawl surveys

Fishery-independent surveys conducted off the U.S. West Coast that provide data on distribution or abundance of eulachon in the ocean are very limited (Table A-4). The Northwest and Alaska Fisheries Center (NWAFC, before it split into NWFSC and AFSC) and AFSC conducted groundfish trawl surveys on the continental slope (at depths of 184–1,280 m) periodically from 1984 to 1987, and annually beginning in 1988. Continental shelf (at depths of 55–183 m) surveys were conducted triennially from 1977 to 2001 by the NWAFC and AFSC. The NWFSC assumed responsibility for the slope portion of the groundfish survey starting in 1998 and expanded the depth coverage to include the continental shelf as well as the continental slope in 2003. Many of these groundfish surveys report catch as occurring in one of five International North Pacific Fisheries Commission (INPFC) statistical areas. These INPFC areas from north to south are: 1) Vancouver (U.S.-Canada border to lat 47°30′N), 2) Columbia (lat 47°30′ to 43°00′N), 3) Eureka (lat 43°00′ to 40°30′N), 4) Monterey (lat 40°30′ to 36°00′N), and 5) Conception (lat 36°00′N to the U.S.-Mexico border) (Figure 4).

Eulachon were reported in the triennial groundfish bottom trawl surveys on the U.S. West Coast continental shelf in 1977 (Gabriel and Tyler 1980), 1980 (Coleman 1986), 1983 (Weinberg et al. 1984), 1986 (Coleman 1988), 1989 (Weinberg et al. 1994a, 1994b), 1992 (Zimmermann 1994, Zimmermann et al. 1994), 1995 (Wilkins 1998, Wilkins et al. 1998), 1998 (Shaw et al. 2000, Wilkins and Shaw 2000), and 2001 (Weinberg et al. 2002, Wilkins and Weinberg 2002) (Table A-4). These surveys targeted rockfish from 1977 to 1986, and were subsequently designed to estimate Pacific hake (*Merluccius productus*) and juvenile sablefish (*Anoplopoma fimbria*) abundance, as well as other commercially important groundfish (Weinberg et al. 1994a). However, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon.

The 1977 shelf groundfish survey recorded eulachon in six of nine assemblages off the Washington and Oregon coasts, being most abundant within the Nestucca Intermediate Assemblage (90–145 m) off Oregon (Gabriel and Tyler 1980). Trawl surveys in 1980–1986 occurred between Monterey Bay, California, and either Northern Vancouver Island (1980), Estevan Point, Vancouver Island (1983), or the U.S.-Canada border (1986) at depths of 55–366 m (Coleman 1986, 1988, Weinberg et al. 1984). From 1989 to 2001 triennial groundfish bottom trawl surveys covered all West Coast INPFC areas from Vancouver to Monterey, inclusive. In 1980 eulachon were recorded as the fifteenth most common fish encountered at depths of 55–183 m in the INPFC Eureka area, but were not recorded within the top 20 species encountered in the INPFC Vancouver, Columbia, or Monterey areas (Coleman 1986).

Latitudinal and longitudinal range and minimum, maximum, and mean depth distribution of eulachon captured in the triennial surveys from 1989 to 2001 are provided in Table A-4. Eulachon were found into the far south Monterey INPFC area in the 1989 survey but were not recorded in either the Monterey or Eureka INPFC areas in surveys conducted between 1992 and 2001. Mean depth of occurrence of eulachon in these surveys varied between 137 and 147 m, with minimum depths of 59–79 m and maximum depths of 322–466 m (Table A-4).

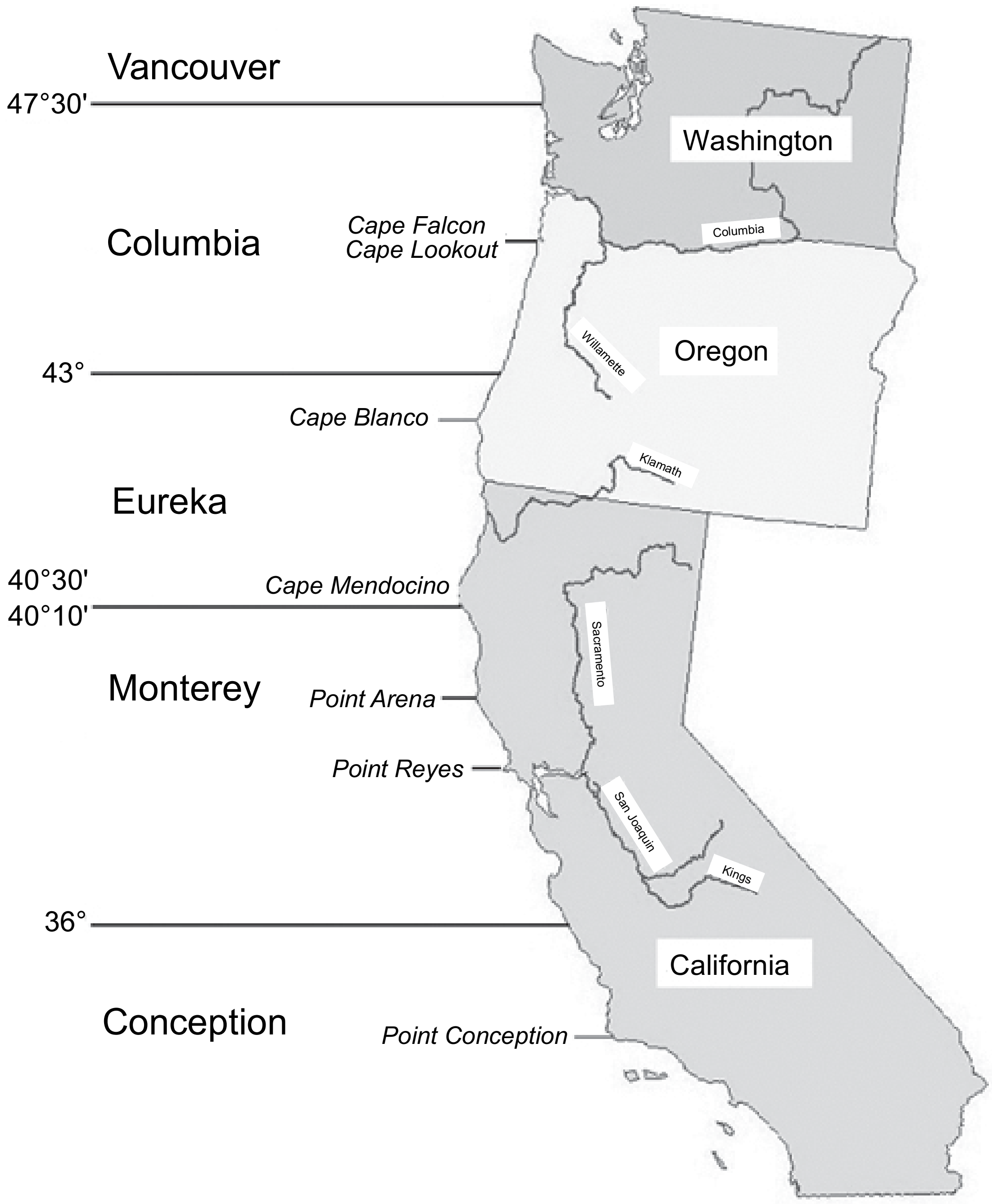

Figure 4. INPFC statistical areas off the U.S. West Coast. Modified from Pacific Fishery Management Council Web site at http://www.pcouncil.org/wp-content/uploads/georock.pdf.

Eulachon were occasionally sampled in West Coast upper continental slope groundfish trawl surveys conducted between 1984 and 1999 by the NWAFC and AFSC (Raymore and Weinberg 1990, Parks et al. 1993, Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000) and between 1999 and 2002 by the NWFSC (Builder Ramsey et al. 2002, Keller et al. 2005, 2006a, 2006b). These surveys covered habitat between 183 and 1,280 m from the U.S.-Canada border to lat 30°30′N (Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000, Keller et al. 2005, 2006a, 2006b), although annual surveys prior to 1997 covered only a portion of the area each year (Table A-4). This depth range is deeper than is preferred by eulachon (Hay and McCarter 2000), so these surveys likely missed the vast majority of eulachon, which occur on the continental shelf and not the slope.

Minimum, maximum, and mean depths of eulachon captured during the 1989–2002 survey years are given in Table A-4; however, eulachon were seldom encountered at these depths (below 183 m) and their reported occurrence in trawl hauls ranged from 6% of trawls conducted between 1989 and 1993 to fewer than 1% of all trawls in 2001. Presumably, eulachon were not encountered during the NWFSC 1999 bottom survey of the U.S. West Coast continental slope, as this species is not included in the comprehensive list of species encountered (Builder Ramsey et al. 2002). Eulachon were captured as deep as 608 m during the 2001 survey (Keller et al. 2005).

Starting in 2003, the NWFSC conducted combined slope and shelf surveys for groundfish between depths of 55 and 1,280 m (Keller et al. 2007a, 2007b, 2008) off the U.S. West Coast (Table A-4). Sampling in these slope and shelf surveys, in contrast to the NWAFC and AFSC triennial bottom trawl surveys (discussed above), did not extend into the Canadian portion of the Vancouver INPFC area where the triennial surveys had encountered the majority of eulachon. Currently, eulachon abundance in the Canadian portion of the Vancouver INPFC is tracked by the Department of Fisheries and Oceans Canada (DFO) during the annual surveys of shrimp biomass off the west coast of Vancouver Island (DFO 2008a). Eulachon were found at depth extremes of 51 to 237 m in the NWFSC surveys, with mean depths of 119 to 130 m during the three survey years (Table A-4) (Keller et al. 2007a, 2007b, 2008); however, eulachon biomass estimates were not presented in these survey documents. Some eulachon were found as far south as 34°N in the INPFC Conception area in 2003 and 2004 (Keller et al. 2007a, 2007b), a southern distribution that had not been recorded in groundfish surveys since 1989 (Weinberg et al. 1994a) (Table A-4). Pacific hake trawl surveys in U.S. and Canadian waters off the Pacific Coast have also reported incidental catch of eulachon (Fleischer et al. 2005, 2008), although details on catch location were not provided.

Alaska trawl surveys

Latitudinal and longitudinal range and minimum, maximum, and mean depth distribution of eulachon captured in AFSC bottom trawl surveys in the Gulf of Alaska (triennially from 1984 to 1996, biennially from 1999 to 2007), Eastern Bering Sea (annually from 1982 to 2008), and Aleutian Islands (triennially from 1983 to 1997, biennially from 2000 to 2006) regions of Alaska are summarized in Table A-5. Eulachon are a common species in the Gulf of Alaska trawl surveys (Stark and Clausen 1995, Martin and Clausen 1995, von Szalay et al. 2008) and are particularly abundant in the Chirikof and Kodiak INPFC areas (von Szalay et al. 2008). In the

2007 trawl survey, eulachon were present in about 31% of the hauls under 300 m deep and 9% of hauls below that depth, although none were seen deeper than 700 m (von Szalay et al. 2008).

Eulachon distribution and abundance were also incidentally reported in two summer echo integration-trawl (EIT) surveys of prespawning walleye pollock (*Theragra chalcogramma*) on the Gulf of Alaska continental shelf in 2003 (Shumagin Islands to Prince William Sound) and 2005 (Islands of Four Mountains to south Prince William Sound) (Guttormsen and Yasenak 2007). Eulachon were the fourth and third most abundant species by numbers of fish caught in midwater trawls in the Gulf of Alaska in 2003 (10% of total) and 2005 (18% of total), respectively. Eulachon constituted 6.6% of the fish caught during EIT bottom trawls in 2003 in the Gulf of Alaska, but were not recorded in bottom trawls in 2005 (Guttormsen and Yasenak 2007).

Marine distribution maps of eulachon captured in AFSC research bottom trawl surveys of the Eastern Bering Sea continental shelf between 2001 and 2007 are provided in Nebenzahl (2001), Acuna et al. (2003), Acuna and Kotwicki (2004, 2006), Lauth and Acuna (2007a, 2007b), and Acuna and Lauth (2008). Abundance estimates for eulachon are not generally provided in these documents as they are "not adequately represented in the samples," which is "due to the bottom sampling nature of the survey" (Nebenzahl 2001, p. 27).

Ichthyoplankton surveys

Ichthyoplankton surveys in the northeastern Pacific Ocean commonly report the capture of osmerid larvae, but few studies have identified smelt larvae to the species level (Waldron 1972, Richardson and Pearcy 1977, Doyle et al. 2002, Auth and Brodeur 2006, Parnell et al. 2008). It is also possible that by the time eulachon reach the open ocean where these ichthyoplankton surveys occur, they may have grown sufficiently to be able to avoid capture in slowly towed, fine-mesh ichthyoplankton nets.

Mixed stock genetic analysis

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

Beacham et al. (2005) concluded that although eulachon marine migrations are largely unknown, there is spatial structure to the distributions of fish from different rivers. Their data indicate that Queen Charlotte Sound is an area inhabited by eulachon from very diverse origins including fish from nearby rivers as well as from more northern and southern sources. Analysis of samples in the south (off Vancouver Island) were dominated by Columbia River and Fraser River fish, whereas eulachon in the most northern marine region sampled, Chatham Sound, were largely from British Columbia coastal rivers north of the Fraser River.

Life History Stages

Eggs

Eulachon eggs from the Columbia River are reported to be approximately 1 mm in diameter (Parente and Snyder 1970, WDFW and ODFW 2001). In the Fraser River, eggs have been variously reported to "have an average diameter between 0.03 and 0.04 inches [0.76–1.02 mm] after preservation in formalin" (Hart and McHugh 1944, p. 9), to measure " less than 1.0 mm diameter" (Hay and McCarter 2000, p. 18), or to be "small (≈0.8 mm)" (Hay et al. 2002, p. 20). According to Garrison and Miller (1982, p. 119), "the eggs show considerable irregularity in shape and have numerous oil globules in the yolk." This irregularity in shape likely refers to unfertilized eggs.

Mature eggs are reported to have an outer sticky membrane that turns inside out after the broadcast spawned eggs are fertilized and remains attached to the egg by a short stalk, which serves to adhere the egg to particles of sand or other substrates (McHugh 1940, Hart and McHugh 1944, Smith and Saalfeld 1955, Hay and McCarter 2000). Hay et al. (2002, p. 18) speculated that as eulachon eggs may attach to small sediment particles and appear to develop while being actively carried downstream by river currents that "the mobile incubation (or 'tumble' incubation) may even have a selective advantage because it may spread the eggs over a broad space, thereby reducing predation and optimizing environmental conditions."

Pedersen et al. (1995) found no significant relationship between egg weight and female body length in the Kitimat River, British Columbia. Eggs weighed 0.26–0.58 mg with a mean and standard error of 0.43 ± 0.01 mg (n = 58) (Pedersen et al. 1995). Similarly, Hay and McCarter (2000) reported eggs from the Fraser River to weigh 0.36–0.68 mg (0.51 ± 0.01 mg, n = 106) in 1995 and 0.30–0.68 mg (0.44 ± 0.01 mg, n = 100) in 1996 in the Fraser River. Mean eulachon egg weight in the Kemano River, British Columbia, was estimated at 0.43 mg (± 0.16 SD, n = 429) (Lewis et al. 2002).

Smith and Saalfeld (1955) reported that eulachon eggs from the Columbia River required 388, 378, and 370 daily cumulative degree Fahrenheit days (equivalent to 198, 192, and 188 degree Celsius days) to hatch in the Naselle River Hatchery, Kalama River Hatchery, and the University of Washington School of Fisheries hatchery, respectively. In hatchery conditions, Smith and Saalfeld (1955) reported eggs taken from the Cowlitz River hatched in 19 days at temperatures that varied from 9.4 to 12.7ºC. These data led Smith and Saalfeld (1955) to estimate that eulachon eggs would hatch in 30–40 days, given the usual water temperatures in February and March in the Cowlitz River. Assuming similar thermal requirements for incubation, Langer et al. (1977) estimated that it would take 30–40 days for eulachon eggs to hatch in the Nass River, British Columbia. Artificially spawned and incubated eulachon eggs from the Cowlitz River hatched in 21–25 days when reared at 6.5–9.0ºC (Parente and Snyder 1970). Berry and Jacob (1998 p. 4) reported the incubation period in the Kingcome River in Kingcome Inlet, British Columbia "to be approximately 21 days." Flory (2008b, p. 3) cited a personal communication indicating that the incubation period for eulachon in Southeast Alaska ranges from four to six weeks, longer than the typical three to five weeks common in more southern regions.

Lewis et al. (2002) estimated that the number of accumulated thermal units (ATUs, one ATU equal to one degree Celsius for one day) between the peak of adult spawning and larval migration for eulachon in the Kemano River, British Columbia, in 1990 to be 204 degree-days based on daily recorded temperatures. In 1997 the number of ATUs to reach 50% larval hatch were estimated to be 340 in the Kemano River and 235 in the nearby Wahoo River (Lewis et al. 2002). Duration of egg incubation in the Kemano River was calculated at 50 days (Lewis et al. 2002). Similarly, 51% of eulachon larvae hatched in the Kitimat River, British Columbia, in 1993 after accumulating 258 ATUs and 87% of hatch occurred at an estimated 307 ATUs (Pedersen et al. 1995). The shortest duration of incubation of eulachon eggs from deposition to hatch was 35–39 days, the earlier time period equating to approximately 168 ATUs (Pedersen et al. 1995).

In the Twentymile River in Southcentral Alaska, incubation was estimated during three time periods at 47–50 days, which equated to between 294 and 321 ATUs, based on calculations using mean daily water temperatures (Spangler 2002, Spangler et al. 2003). Moody (2008, p. 3) reported that earlier studies had found eulachon eggs from the Bella Coola River hatched in 54 days at about 6ºC, equivalent to about 340 ATUs. Howell (2001) reported that 400ºC ATUs (752ºF ATUs) were accumulated prior to hatching, after a minimum of 47 days, by eulachon eggs stripped from Cowlitz River broodstock and incubated at a constant temperature of 48ºC under artificial hatchery conditions. The anomalously high number of ATUs required for hatching in this experiment may have been an artifact of the experimental conditions (Howell 2001).

Pedersen et al. (1995) postulated that incubation requirements may vary with latitude, and Spangler (2002) and Spangler et al. (2003) noted that, in general, the number of ATUs required for eulachon egg incubation appears to increase with increasing latitude.

Parente and Snyder (1970) provide the only published observations on eulachon embryonic development, which is typical of teleost fishes. In laboratory conditions at temperatures ranging from 6.5°C to 9°C; a blastodisc appears at 3 hours after fertilization, cleavage is occurring by 30 hours, invagination of the gastrula is in process at 60 hours, and the head and auditory capsule are apparent at 120 hours. At 300 hours (12–13 days) a weak heart beat is present, which is stronger by 400 hours. By this time the yolk sac is about one-half its original size. The active embryo begins hatching at about 500 hours (20–21 days) and all eggs under observation hatched within 5 days of each other (Parente and Snyder 1970).

Larvae

Newly hatched larvae are transparent, slender, and about 4–8 mm in length in the Columbia River (Parente and Snyder 1970, WDFW and ODFW 2001), 4.0–6.5 mm in the Fraser River (Hay et al. 2002), and 4–6 mm in the Kemano River (Lewis et al. 2002). Eulachon larvae are reported to be feeble swimmers and are rapidly carried downstream to estuarine portions of rivers and inlets within hours or days of hatching (McHugh 1940, Hart and McHugh 1944, Smith and Saalfeld 1955, Parente and Snyder 1970, Samis 1977, Howell 2001). In the Columbia River, larval eulachon are usually located near the bottom during their downstream migration (Smith and Saalfeld 1955, Howell et al. 2001). Larval nutrition is provided by the yolk sac prior to first feeding (WDFW and ODFW 2001). Spangler et al. (2003) detected higher levels of downstream drifting larval eulachon during low light intensity periods at night than during the day in the Twentymile River, Alaska. Care must be taken in many parts of the range that larval eulachon in rivers are not confused with superficially similar cottid (sculpin) larvae (Kelson 1997, Flory 2008b).

Ichthyoplankton surveys indicate that larval eulachon may be retained for weeks or months in estuaries (McCarter and Hay 1999, 2003), especially in inlets or fjords on the British Columbia mainland coast (McCarter and Hay 2003). These surveys also indicate that eulachon larvae are mostly present in the top 15 m of the water column, with few larvae occurring below 20 m (McCarter and Hay 1999, Hay and McCarter 2000). Hay and McCarter (2000, p. 19) showed that newly hatched larvae were about 3.6–8 mm in length and that in mainland inlets on the British Columbia coast "mean eulachon larval size (mm) generally increased at each sampling station in a seaward direction away from eulachon spawning rivers." Although larvae disperse seaward from their spawning rivers, they also "appear to be retained in inlets" and fjords to some degree on the British Columbia coast (Hay and McCarter 2000, p. 21). Ichthyoplankton surveys also showed that larvae were smaller in shallow water than those captured in deeper depths (McCarter and Hay 1999, Hay and McCarter 2000). During the period from April to August, larval eulachon on the central British Columbia coast were estimated to grow from an initial size of 3–4 mm to 30–35 mm in length (McCarter and Hay 1999, 2003).

Robinson et al. (1968b, their Table I) determined that almost all eulachon larvae in the Strait of Georgia, off the Fraser River during daylight on 6 June 1967, were distributed in the top 6.5 m of the water column, with the greatest density (50–150 larvae/m^3) occurring between 1.7 and 3.5 m depth. McCarter and Hay (1999) found that eulachon larvae (mostly ≤15 mm in length) in mainland inlets on the central coast of British Columbia were mainly found within the top 15 m of the water column during springtime plankton tows and suggested that larval densities were greater near the surface at night than during daytime tows.

Juveniles

Information on the distribution and ecology of juvenile eulachon is scanty, owing to these fish being too small to occur in most fisheries and too large to occur in ichthyoplankton surveys (Hay and McCarter 2000). Eulachon that range 30–100 mm in length, exhibit schooling behavior, and have developed pigmentation and lateral scales are generally classified as juveniles (Hay and McCarter 2000). Barraclough (1964) sampled juvenile eulachon in the Strait of Georgia in winter and spring with midwater trawls and shrimp trawls and indicated that Fraser

River eulachon may spend their first year of life in the Strait of Georgia; however, observer data indicate that virtually no eulachon were caught as bycatch in the late 1990s in the Strait of Georgia shrimp fishery (Hay et al. 1999a). A larger mesh size is used in commercial shrimp trawls, compared to the mesh size used in Barraclough's (1964) studies (Hay and McCarter 2000), suggesting that juvenile eulachon may be present in coastal waters but are difficult to detect without a directed effort. Hay and McCarter (2000, p. 22) reported that "it seems that … [juveniles] disperse to open, marine waters within the first year of life and perhaps within the first few months."

Adults and Spawners

Age composition

The two common methods of estimating age in eulachon, either through counting rings on scales or on otoliths, have not been validated for any population of eulachon (Ricker et al. 1954, DeLacy and Batts 1963, Higgins et al. 1987, Hay and McCarter 2000, Moffitt et al. 2002, Clarke et al. 2007). Age as determined from scales is typically one to three years less than age determined from otolith increments (Ricker et al. 1954, Langer et al. 1977, Higgins et al. 1987). Several early studies expressed doubt as to the reliability of using otolith rings to determine eulachon age (Smith and Saalfeld 1955, DeLacy and Batts 1963). Consequently, the determination of age from scales and otoliths are not considered reliable methods by many researchers (Ricker et al. 1954, Hay and McCarter 2000, Hay et al. 2003, Clarke et al. 2007). Clarke et al. (2007, p. 1,480) noted that many dark bands or pseudo-annuli are present in whole and polished otoliths "that have been interpreted as winter growth zones in past ageing attempts" and that "sectioned otoliths viewed under transmitted light can reveal fewer zones," indicating some of the problems with this ageing methodology.

In some cases "there is no corresponding increase in size (length or weight) with putative [increase in] age" (Hay and McCarter 2000, p. 15). Higgins et al. (1987) also reported overlap in fork lengths (FL) between putative age classes of eulachon. However, in the Twentymile River, Alaska, eulachon body length has been shown to increase with age in both males and females, as expected (Spangler 2002). Beamish and McFarlane (1983) highlighted the importance of proving that a technique for ageing a species is accurate (age validation). Age validation "requires either a mark-recapture study or the identification of known-age fish in the population" (Beamish and McFarlane 1983, p. 741). It is important to point out that age validation is different than determining the precision of an ageing technique by assessing the level of agreement among several age readers. Despite the acknowledged problems with age determination in eulachon, numerous studies have reported age composition of spawning populations of eulachon based on examination of growth increments on either scales or otoliths and these data are presented in Table A-6.

Although age determination of eulachon is admittedly difficult and uncertain, adult spawners are variously reported to be 3–4 years old (Smith and Saalfeld 1955) or 3–5 years old (WDFW and ODFW 2001) in the Columbia River; 2–3 years old (McHugh 1939, Ricker et al. 1954) or mostly 3 years old, with some 2-, 4-, and 5-year-olds in the Fraser River (Hay et al. 2005); and mostly age 3 (Hay and McCarter 2000, Hay 2002) or 2–5 years old (Schweigert et al. 2007) in British Columbia. The majority of adult eulachon on the Columbia River are reported to return at age 3, although some are purported to be up to 9 years old (WDFW and ODFW 2001). Wydoski and Whitney (2003, p. 106) also stated that some eulachon "may live for 9 years;" however, these age estimates are based on the unvalidated otolith methodology.

Clarke et al. (2007) examined seasonal changes in trace elements incorporated into otoliths to estimate age structure of eulachon populations in the Columbia, Fraser, Kemano, Skeena, and Copper rivers. It has been shown that barium (Ba) and calcium (Ca) are incorporated into the aragonitic matrix of fish otoliths in proportion to their concentration in the environment (Bath et al. 2000). Barium concentrations are normally about three times greater in deep ocean waters than in surface waters; however, for about 3 months during the summer, wind-driven upwelling of deep barium-rich waters occurs off the west coast of North America and "these upwelling events should therefore impart a seasonal barium peak … in … [eulachon] otoliths" (Clarke et al. 2007, p. 1,481). As expected, Clarke et al. (2007) found that eulachon otoliths had low Ba:Ca levels in the outer region of the otolith in February and March and high levels in the summer. Clarke et al. (2007, p. 1,488) used laser-ablation inductively coupled plasma mass spectrometry to reconstruct the Ba:Ca profile of eulachon otoliths and stated that:

> a single age class of fish was observed to spawn in the systems examined in this study. Only 3-year-old eulachon were observed from the spawning populations in the Fraser and Kemano rivers, and the majority of fish for the Columbia, Skeena, and Copper rivers were also composed of a single age class; 2-, 3- and 4-year-olds from the Columbia, Skeena, and Copper rivers, respectively.

These data suggest that populations to the south spawn at an earlier age than more northern populations. Clarke et al. (2007, p. 1,489) concluded that "seasonal fluctuations in Ba:Ca observed in this study suggests that, to date, many eulachon have been aged incorrectly" and that "Ba:Ca variations appear to match expected annual shifts in ambient chemistry and so offer a more reliable annual marker for ageing."

Analyses of size frequencies have also been used to estimate age of at-sea (Ricker et al. 1954, Barraclough 1964, Hay and McCarter 2000, Hay et al. 2003, Clarke et al. 2007) and in-river (McHugh 1939) eulachon. These methods have identified age 1+ and age 2+ eulachon in the ocean (Barraclough 1964, Hay et al. 2003) and indicate that "the largest size mode [in the ocean] corresponds to the size modes observed in spawning rivers" (Hay et al. 2003, p. 5). Size frequency analysis indicates that most eulachon in British Columbia are spawning at age 3 (Hay and McCarter 2000).

Body size

Eulachon are reportedly the largest species of smelt in the family Osmeridae on the west coast of North America (Scott and Crossman 1973). Published reports of maximum eulachon body length of 305 mm (Clemens and Wilby 1967, Miller and Lea 1972) are likely in error (Miller and Lea 1976, Mecklenburg et al. 2002). Specimens of 254 mm (Miller and Lea 1976, Mecklenburg et al. 2002) from the Bering Sea represent the maximum known length for eulachon. Mean lengths of male and female eulachon in the Twentymile and Susitna rivers of Southcentral Alaska are greater than 200 mm FL (Table A-7), much larger than mean lengths in rivers further south (Spangler 2002, Spangler et al. 2003). These authors also noted that the mean weight of eulachon in the Susitna and Twentymile rivers was greater than in eulachon spawning in more southern rivers (Spangler 2002, Spangler et al. 2003) (Table A-8).

Moffitt et al. (2002) found mean length of male eulachon on the Copper River to be significantly longer than females in all years analyzed from 1998 to 2002. There were also significant differences in length among years for both male and female eulachon from the Copper River. Male eulachon were also found to be significantly longer and heavier than female eulachon in the Twentymile River, Alaska, in 2000 and 2001 (Spangler 2002, Spangler et al. 2003). Male eulachon were significantly larger than females in the Kemano River, British Columbia, and both sexes were significantly longer than eulachon in the nearby Wahoo River (Lewis et al. 2002).

Length of pelvic and pectoral fins of female eulachon from the Fraser River were both 14.3% of the standard body length, compared to 17.6% for pelvic fins and 15.8% for pectoral fins in male eulachon (McHugh 1939, Hart and McHugh 1944). By comparison, Langer et al. (1977) found that lengths of pelvic and pectoral fins of female eulachon in the Nass River were 11.1% and 11.8% of the standard body length, compared to 13.4% for pelvic fins and 12.7% for pectoral fins in male eulachon. Both sexes of eulachon in the Nass River apparently possess "relatively smaller fins than do Fraser fish" (Langer et al. 1977, p. 33). Craig (1947, p. 3) stated that among Columbia River tributaries:

> fishermen consistently claim to find larger smelt in the runs comprising the Lewis and Sandy river populations than those in the Cowlitz River stocks. Such size variation has been statistically proven sound in 1946 when large samples of fish were measured from both the Cowlitz and Sandy rivers.

Clarke et al. (2007, p. 1,484) found significant differences in length and weight of eulachon from five river systems (Columbia, Fraser, Kemano, Skeena, and Copper) and found a trend towards larger fish in more northerly populations "and the largest fish were from Alaska and northern British Columbia." Clarke et al. (2007) suggested that eulachon likely spawn after reaching a minimum fork length of 160 mm and a body weight greater than 30 g and that these size thresholds are obtained at an earlier age in southern latitudes and later in the far north. Available data on eulachon body length and weight from throughout the species' range are compiled in Table A-7 and Table A-8, respectively.

Vertebrae meristics

Hart and McHugh (1944) and DeLacy and Batts (1963) attempted to identify stocks of eulachon based on differences in the number of vertebrae present in adult fish on the spawning grounds. Hart and McHugh (1944, p. 6) counted vertebrae, which varied from 65 to 72 per fish, in eulachon samples from the Nass River, Rivers Inlet, Knight and Kingcome inlets, and Fraser River and found:

> the Fraser river run to differ in average vertebral number from the runs to the more northern parts of the province.… This indicates that mixing between the runs to the Fraser and more northerly rivers cannot be extensive because, if it were, any differences in vertebral count would soon be eliminated.

Similarly, DeLacy and Batts (1963, p. 33) counted vertebrae, which also varied from 65 to 72 per fish, in eulachon samples taken between 1953 and 1962 in the lower Columbia River and its tributaries and reported that "an indication of heterogeneity was found among eight collections of smelt made in 1956 from the Cowlitz, Kalama, and Sandy rivers." Based on these data, DeLacy and Batts (1963, p. 33) stated that their study found "scant evidence of heterogeneity in the total Columbia River smelt population;" however, "there is enough suggestion of heterogeneity to justify further exploration of the possibility that smelt do move to the spawning grounds in some nonrandom fashion."

Sexual dimorphism

There are a number of morphological differences between male and female eulachon at maturity. Mean length is in general longer in males than in females (McHugh 1939, Higgins et al. 1987, Lewis et al. 2002, Spangler 2002, Spangler et al. 2003, Cambria Gordon 2006). Although age-2 males were statistically greater in length than the same age females on the Nass River in 1971, length of age-3 through age-5 fish did not vary between the sexes (Langer et al. 1977). Mean weight of males was statistically greater than that of females in the Twentymile River, Alaska, in 2000 and 2001 (Spangler 2002, Spangler et al. 2003) and in the Kemano River, British Columbia, from 1988 to 1998 (Lewis et al. 2002). However, mean lengths and weights of male and female eulachon in the Fraser River from 1995 to 2001 as reported by Hay et al. (2002, their Table 3) did not show consistent differences between the sexes. McHugh (1939) was also unable to detect significant difference in size between males and female eulachon from the Fraser River.

Males differ from females in having numerous tubercles on the body, head, and fins, and particularly along the lateral line (McHugh 1939, Hart and McHugh 1944, McAllister 1963, McPhail and Lindsey 1970, Spangler et al. 2003). In males, "the muscles of the body wall have undergone considerable development, so that the body wall is considerably thicker, and the whole fish is more firm and rigid than the female" (McHugh 1939, p. 21). Females are smoother in appearance with far fewer tubercles and do not possess the mass of muscle along the lateral line (McAllister 1963, Spangler et al. 2003). The pelvic fins are also larger at the base and longer in male compared to female eulachon; the ends of the pelvic fins often reach as far posterior as the level of the anus in males, but are much shorter in females (McHugh 1939, Hart and McHugh 1944, McAllister 1963, McPhail and Lindsey 1970, Spangler et al. 2003, Cambria Gordon 2006). Hart and McHugh (1944, p. 4) reported that female eulachon have a more tapered form than male eulachon. Spangler (2002) found females retained teeth to a greater degree (84.0–96.9%) than did males (3.4–32.4%) in the Twentymile River, Alaska.

Proximate analysis

The very high fat content of eulachon led many Native American tribal groups in Southeast Alaska and First Nations in British Columbia, especially to the north of the Fraser River, to render the fat of the eulachon into oil or "grease" (Kuhnlein et al. 1982, Hay and McCarter 2000). Several early studies investigated the chemical characteristics of eulachon oil with regard to its nutritional qualities (Brocklesby and Denstedt 1933, Brocklesby 1941, Bailey et al. 1952). However, Clark and Clough (1926, p. 505) were the first to publish on the proximate composition of eulachon flesh and they reported that a single sample of the edible portion of fresh eulachon from the Columbia River contained 11.2% fat, 13.2% protein, and 1.4% ash. Although Clark and Clough (1926) studied the composition of Columbia River eulachon, these results were subsequently republished in Babcock (1927) as typical for British Columbia. Stansby (1976) found the mean (and range) of percent moisture, oil, protein, and ash in the raw muscle of 16 eulachon specimens from the Columbia River to be 79.6% (76.5–81.3), 6.3% (4.6–9.0), 14.6% (13.2–15.3), and 1.3% (1.1–1.4), respectively. Stansby's (1976) data were also reported in Sidwell (1981).

Whole unprocessed eulachon sampled in Knights Inlet on the British Columbia coast contained 16.7% fat and 72.3% moisture (Kuhnlein et al. 1996). Mean percent values for eulachon caught at sea in the Gulf of Alaska were 18.8% oil (as total lipid), 11.9% protein, 1.6% ash, and 68.1% moisture (Payne et al. 1999). Similar mean values for sea-caught eulachon in the eastern Bering Sea were 19.9% oil (as total lipid), 12.5% protein, 1.5% ash, and 66.7% moisture (Payne et al. 1999). Of 14 species of forage fish in the Gulf of Alaska and Bering Sea, eulachon had the highest oil content (16.8–21.4%) and the lowest moisture content (64.6–70.8%) (Payne et al. 1997, 1999). No significant differences in composition of eulachon were seen between the Gulf of Alaska and the Bering Sea when fish of a common size range collected in the same season of the year were compared (Payne et al. 1999).

In the Gulf of Alaska, eulachon were found to have the lowest mean moisture content (64%), lowest mean ash content as a percentage of dry mass (4%), highest dry mass energy value (7.7 kcal/g), and highest wet mass energy value (2.6 kcal/g) among 18 fish and 5 squid species analyzed (Perez 1994). These energetic values were obtained using bomb calorimetry (Perez 1994). Payne et al. (1999) derived a mean value for eulachon wet mass energy of 2.47 kcal/g derived from calculations of caloric content using energy coefficients for protein and oil from Gulf of Alaska eulachon. These eulachon energy values were the highest in relation to moisture content of the 13 forage fish analyzed (Payne et al. 1999). Similarly, Anthony et al. (2000) reported that eulachon had the highest mean lipid content (50% of dry mass) among 39 forage fish species analyzed in the Gulf of Alaska. Eulachon also had a much higher water content as a percent of wet mass (71%) than would be expected given its high lipid content (Anthony et al. 2000). A sample of 34 eulachon (141–202 mm standard length [SL]) also had the second highest mean energy density, after northern lampfish (*Stenobrachius leucopsarus*): 6.5 kcal/g (27.2 kJ/g) dry mass or 1.8 kcal/g (7.49 kJ/g) wet mass (Anthony et al. 2000).

Iverson et al. (2002) examined fat content and fatty acid composition in 26 species of fish and invertebrates in Prince William Sound, Alaska. Fat content of 20 eulachon samples taken in spring were uniformly the highest in fat content and ranged 15–25% fat with a mean value of 19% fat (Iverson et al. 2002). The next highest fat content was found in adult herring, which ranged 7–20% fat with a mean value of 14% fat (Iverson et al. 2002). Eulachon possessed unique fatty acid signatures that "differed most from all other finfish, cephalopod, or crustacean species studied" (Iverson et al. 2002, p. 177). Eulachon in Prince William Sound had "extremely high levels of 18:1n-9, moderately high levels of 14:0 and 16:1n-7, and extremely low levels of polyunsaturated fatty acids such as 20:5n-3 and 22:6n-3" (Iverson et al. 2002, p. 177). The dietary source of this unique fatty acid signature in eulachon is currently unknown (Iverson et al. 2002).

The apparent differences in fat content between eulachon samples in the Columbia River (6.3% fat; Stansby 1976), Knight Inlet on the British Columbia coast (16.7% fat, Kuhnlein et al. 1996), and in the Gulf of Alaska (19% fat, Payne et al. 1999, Iverson et al. 2002) likely had a significant impact on American Indian and First Nations uses for these fish. MacLachlan (1998, p. 183) stated that:

> On the northern coast, eulachon were a major source of oil, but on the Fraser, as on the Columbia, they were eaten fresh or smoked whole. A difference in oil content may have been the basis of this difference in use.

Reproduction and Development

Sex Ratio

Many studies have reported that sex ratios in eulachon are either biased in favor of males (Smith and Saalfeld 1955, Kubik and Wadman 1977, 1978, Franzel and Nelson 1981, Higgins et al. 1987, Lewis 1997, Lewis et al. 2002, Moffitt et al. 2002, Spangler 2002, Spangler et al. 2003) or are highly variable depending on time and location of sampling (McHugh 1939, Hart and McHugh 1944, Langer et al. 1977, Pedersen et al. 1995). On the other hand, Hay and McCarter (2000) and Hay et al. (2002) report that the ratio of spawning male to female eulachon in their gill net samples from the Fraser River in 1995–2002 was approximately 1 to 1, with the exception of 1998 when the sex ratio was 1.7 to 1.

All reports of eulachon sex ratio should be viewed with caution, as proportions of male to female eulachon have been reported to vary with fishing gear type, distance upriver, distance from the river shoreline, time of the day, and migration time (McHugh 1939, Langer et al. 1977, Moffit et al. 2002, Lewis et al. 2002, Spangler 2002, Spangler et al. 2003). Langer et al. (1977, p. 33) reported that “sex ratios varied with location, within the duration of the run, and between years in the Nass River.” Lewis (1997) suggested that sex ratios skewed in favor of males may be due to longer residence time of male eulachon in freshwater compared to females. Moffit et al. (2002) postulated that as spawning commences, females may avoid the riverbank and disperse to the center of the river, thus skewing sex ratios calculated from dip net sampling along riverbanks. Spangler (2002) and Spangler et al. (2003) reported that sampling with different gear types (gill nets versus dip nets) resulted in different sex ratios in the Twentymile River, Alaska. However, Franzel and Nelson (1981) reported that fishing gear did not significantly change the sex ratio of eulachon captured in the Stikine River, Alaska.

Mc Hugh (1939) and Hart and McHugh (1944) reported that the sex ratio varied during the fishing season in 1939 and 1941 in the Fraser River; males predominated in the early part of the eulachon run, but in the latter part females came to predominate. A similar situation may obtain in the Columbia River basin, where WDFW and ODFW (2001, p. 15) stated that analysis of sex ratios indicated that “female return timing is skewed later than that of males,” although females never appear to dominate. Pedersen et al. (1995, p. 16) reported that earlier studies in the Nass River had found “a changing sex ratio during the spawning season,” whereas another study based on daily monitoring had found 55% males and 45% females. Lewis et al. (2002) also reported changing sex ratios over the duration of the eulachon run in the Kemano River, British Columbia; however, there appeared to be two pulses of female returns, and males rather than females appeared to dominate the later part of the run. The proportion of males was also found to increase as the run progressed in 1971 on the Nass River (Langer et al. 1977) and at Flag Point Channel on the Copper River in 1998 and 2000–2002 (Moffit et al. 2002).

The overall sex ratio reported by Smith and Saalfeld (1955) for the Columbia River basin was 4.5 males to 1 female. Similarly, Higgins et al. (1987) and Rogers et al. (1990) found a sex ratio of 3.4 males to 1 female in Fraser River samples collected in April 1986 and Rogers et al. (1990) reported the ratio to be 5.9 to 1 in 1988. Sex ratios in the early 1930s in Cowlitz River dip net, Lewis River dip net, and Columbia River gill net samples were 3.2 to 1, 12.3 to 1, and 6.8 to 1, respectively (Smith and Saalfeld 1955). In 1946 sex ratios in commercial fisheries were 10.5 to 1 in the Cowlitz River and 2.8 to 1 in the Sandy River, which may reflect the bias in the fishery for the more marketable male eulachon (Smith and Saalfeld 1955). Since males dominate the early part of the run in the Columbia River, they are more prevalent in both the sport and commercial fisheries, which preferentially target the first fish to return (WDFW and ODFW 2001).

Sex ratio of male to female eulachon in the Kemano River, British Columbia, ranged from 1.1 to 1 to 10.7 to 1 with a mean of 4.4 to 1 between 1989 and 1997; however, when weighted by fish abundance over the duration of the run, the true sex ratio was estimated at 1.6 to 1 (Lewis et al. 2002, p. 72). Males predominated in upriver locations in both 1970 and 1971 in the Nass River (Langer et al. 1977). However, in the Fraser River the proportion of male to female eulachon was independent of the distance of upriver capture (along a 31 km gradient) among April 1986 (Higgins et al. 1987, Rogers et al. 1990) and April/May 1988 (Rogers et al. 1990) samples.

Franzel and Nelson (1981) found that gill net–sampled eulachon in the Stikine River, Alaska, over two years had a sex ratio of males to females of 17.5 to 1. Eulachon sex ratios on the Copper River, Alaska, and nearby systems were also dominated by males in all samples (Moffitt et al. 2002). The percentages of males at Flag Point Channel on the Copper River in 1998, 2000, 2001, and 2002 were 78%, 60%, 72%, and 69%, respectively. At 60-km Channel on the Copper River in 2002, males represented 61%–85% of the captured eulachon (Moffit et al. 2002). On the Copper River delta, the percentages of males in 1998 and 2000 were 91% and 66%, respectively, in Alaganik Slough and ranged from 82% to 98% in January to February 2001 in Ibeck Creek (Moffit et al. 2002). Eulachon collected in Twentymile River, Alaska, from May 15 to June 2, 1976, and from April 29 to June 5, 1977, had a cumulative sex ratio of 5 males to 1 female (n = 204) (Kubik and Wadman 1977) and 7.4 males to 1 female (n = 408) (Kubik and Wadman 1978), respectively. Sampling by dip net in the Twentymile River resulted in male to female ratios of 6.7 to 1 in 2000 (n = 394) and 2.1 to 1 in 2001 (n = 2,711) (Spangler 2002, Spangler et al. 2003). Barrett et al. (1984) reported average male to female sex ratios of prespawning eulachon of 1.6 to 1 in late May 1982, 1.3 to 1 in early June 1982, 1.2 to 1 in mid-May 1983, and 0.6 to 1 in mid-May and early June 1983. Spawning and postspawning ratios were higher due to the shorter stream residence time of female eulachon (Barrett et al. 1984).

Smith and Saalfeld (1955, p. 22) first hypothesized “that the type of spawning of smelt may necessitate an excess of males.” Moffitt et al. (2002, p. 26) postulated that in the case of eulachon, which broadcast-spawn eggs and sperm in fast moving rivers, “a large number of males upstream may increase the probability of egg fertilization.” Spangler et al. (2003, p. 46) also postulated that a sex ratio skewed in favor of males "may be a key element to successful spawning" and that "fertilization would increase with more available milt in the water increasing the probability of eggs being fertilized." Hay and McCarter (2000, p. 23) stated that spawning involves groups of fish and eulachons must closely synchronize the timing of spawning between sexes, because the duration of sperm viability in freshwater is short, perhaps only minutes. Interestingly, Langer et al. (1977, p. 32) reported on a second-hand observation of spawning in eulachon, suggesting that a group of males simultaneously released milt upstream of a group of females that laid their eggs as the milt drifted over the downstream female eulachon. Lewis et al. (2002, p. 83) observed spawning eulachon in the Kemano River, British Columbia and reported that:

> At night in the riffles, males lay next the females, beside them and on top of them. We observed small puffs of milt and eggs drifting in the water. We interpret this behaviour as egg laying behaviour because we had not seen it during the day and because we examined rocks at the site during daylight hours … and discovered eggs adhering to the rocks.

Fecundity

Hart and McHugh (1944) noted that fecundity in the Fraser River ranged about 17,300–39,600 eggs in female eulachon measuring 145–188 mm SL. Average fecundity was about 25,000 eggs per female (Hart and McHugh 1944, Hart 1973). Smith and Saalfeld (1955, p. 22) report a fecundity of 20,000–60,000 for female eulachon ranging 140–195 mm length from the Columbia River. Both Clemens and Wilby (1967) and McPhail and Lindsey (1970) report fecundity to be about 25,000 eggs in an average size female. Hay and McCarter (2000) reported total fecundity range of 20,000–40,000 eggs, the number generally increasing with fish size. Depending on fish size, fecundity can range 7,000–31,000 eggs on the Columbia River (Parente and Snyder 1970, WDFW and ODFW 2001).

Mean total fecundity in Fraser River eulachon ranged from a low of about 31,200 to a high of about 34,100 when estimated between 1995 and 1998 (Hay et al. 2002). Mean relative fecundity (total fecundity divided by female body weight) of Fraser River eulachon ranged from a low of 683 eggs/g in 1995 to a high of 898 eggs/g in 1997 (Hay et al. 2002). There are significant differences in fecundity among years in Fraser River eulachon, which are likely related to "significant interannual differences in mean size (length and weight)" (Hay et al. 2002, p. 11).

Mean fecundity of 58 eulachon from the Kitimat River, British Columbia, in 1993 was about 22,900 eggs with a range of 3,242 to 47,798 (Pedersen et al. 1995). Relative fecundity in the Kitimat River was calculated at 504 eggs/g female body weight (Pedersen et al. 1995). Based on 5 years of data, mean eulachon fecundity in Kemano River, British Columbia, was about 27,000 and ranged 6,744–57,260 eggs. Mean relative fecundity of Kemano River eulachon over this 5-year data set was 544 eggs/g female body weight (Lewis et al. 2002).

Mean fecundity of eulachon in the Copper River, Alaska, was estimated at about 35,520 (range: 12,202–52,722) in 2000 and 36,200 (range: 18,645–62,855) in 2001 (Moffitt et al. 2002). From these data, Moffitt et al. (2002) estimated relative fecundity of eulachon from the Copper River in 2000 and 2001 as 790 and 792 eggs/g female body weight, respectively. Fecundity in the Twentymile River, Alaska, ranged from as low as 8,530 to as high as 67,510 and reportedly increased with increasing length, weight, and age (as determined by otolith increment analysis) (Spangler 2002, Spangler et al. 2003).

Homing

Smith and Saalfeld (1955, p. 12) examined migration behavior of eulachon in the Columbia River and its tributaries and stated that:

> The so-called "homing instinct," influencing fish to return as adults to the stream in which they were hatched, has not been established for smelt. … The irregularity of the runs into the various tributaries virtually precludes the existence of a home tributary influence.

McCarter and Hay (1999) and Hay and McCarter (2000) argue that both the short time eulachon larvae spend in the natal freshwater environment and their small size would preclude their ability to imprint on a spawning river. Eulachon larvae are very small, 4–6 mm in length, weigh only a few mg at hatching, and are flushed into the estuarine environment almost as soon as they rise into the water column. Hay and McCarter (2000, p. 13) noted that eulachon larvae are so small that they "may lack the necessary physiological tissue (i.e., olfactory rosette and associated nervous system memory capacity)" to imprint on the freshwater natal spawning river. However, eulachon larvae may spend weeks to months in nearby estuarine environments where they grow significantly in size and may develop the capacity to imprint on large estuaries and eventually home to these areas as adults (McCarter and Hay 1999, Hay and McCarter 2000). These considerations would suggest that large river estuaries, inlets, and fjords may serve as the smallest stock structure unit for eulachon (McCarter and Hay 1999, 2003, Hay and McCarter 2000, Hay 2002, Hay and Beacham 2005).

Spawn Timing

McCarter and Hay (1999, p. 12) emphasized that:

> Based on concepts developed from observation of spawning of Pacific salmon, the timing of [eulachon] spawning runs should be biologically adapted to each river. If so, and if the same model is applied to eulachons, then each population would be adapted to each river.

However, several authors emphasize that there is no clear latitudinal (Hay and McCarter 2000, Cambria Gordon 2006) or other pattern (Hay et al. 2002) apparent in eulachon spawn timing (Table A-9, Figure 5). Over the whole range of eulachon from northern California to the southeastern Bering Sea, Hay and McCarter (2000, p. 17) noted that:

> the most southern runs (i.e., the California and the Columbia River runs) are early, beginning in late January, whereas some of the Alaska runs are much later (May), although not too dissimilar to [eulachon in] the Fraser [River, which run in April through May].

However, eulachon have been known to spawn as early as January in rivers on the Copper River delta of Alaska (Moffitt et al. 2002), as late as May in northern California, and from January to April in various subbasins of the Columbia River (Table A-9, Figure 5, and Figure 6). Analysis

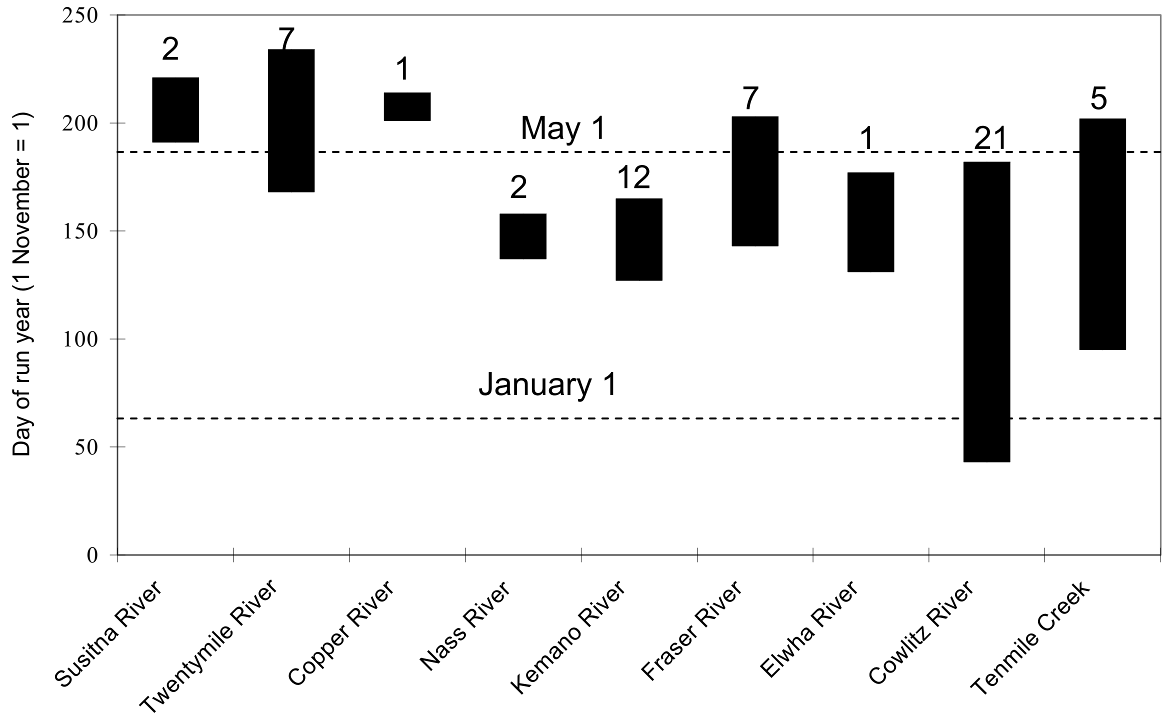

Figure 5. Duration of reported eulachon spawn timing in various river systems arranged north to south from left to right on the x-axis. Dates of spawn timing have been converted relative to the day of the run year beginning on November 1. Numbers above plots indicate the total years of data available for each system. Data from Barrett et al. (1984, reported in Spangler et al. 2003), ADFG (1972, 1973, 1974, reported in Spangler et al. 2003), Kubik and Waldman (1977, 1978), Spangler (2002), Spangler et al. (2003), Morstad (1998, reported in Spangler et al. 2003), Langer et al. (1977), Lewis et al. (2002), Hay et al. (2003), Shaffer et al. (2007), B. James,[4] and WDFW and ODFW (2008).

of spawn timing as a stock identifier in eulachon is also complicated by observed variation in the duration of spawn timing from year to year, the presence of multiple spawning runs in some rivers, and observations of eulachon returning earlier in recent years in some systems relative to historical data (Moody 2008).

California

Historically, eulachon runs in northern California were said to start as early as December and January and peak in abundance during March and April (Table A-9). Larson and Belchik (1998, p. 5) reported that:

> The timing of the Klamath, Redwood Creek, and Mad River spawning migrations were similar to the Columbia's runs, which usually begin in December and January (S. King, ODFW, pers. comm.). The Klamath run continued until around May with peak occurrence between March and April.

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[4] B. James, WDFW, Vancouver, WA. Pers. commun., 12 May 2008.

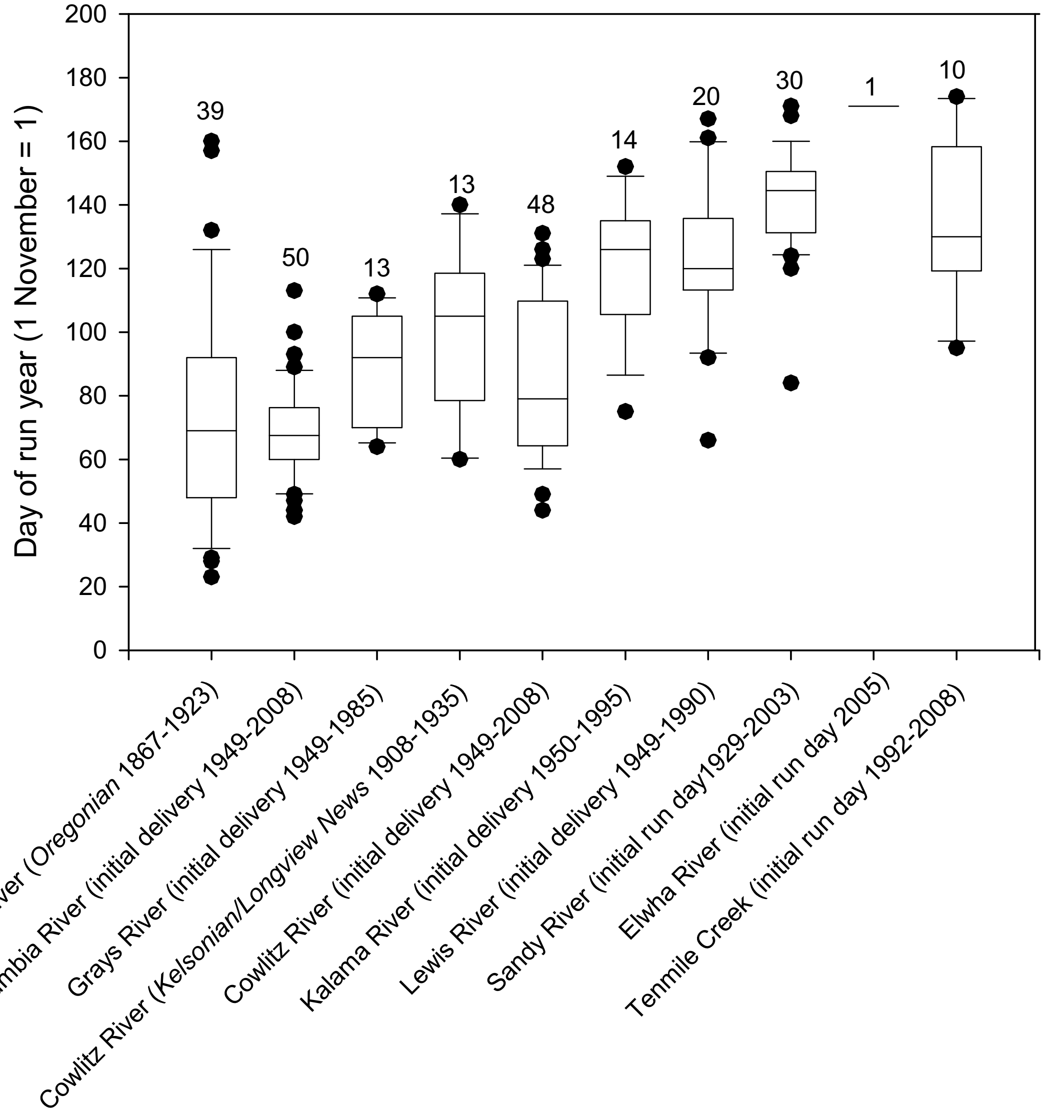

Figure 6. Box plots of the initial day of river entry in various river systems as reported in local newspapers (Appendix B and Smith et al. 1953), commercial fishery deliveries (B. James[5]), Shaffer et al. (2007), and WDFW and ODFW (2008). Dates of initial river entry or fishery delivery have been converted to the day of the run year beginning on November 1. Numbers above plots indicate the total years of data available for each data set.

Similarly, Young (1984) reported on the collection or observation of adult eulachon in the Klamath River and Redwood Creek in April 1978 and in the Klamath River in March and April in both 1979 and 1980. Young (1984, p. 62) further stated that eulachon begin their migration in the Klamath River "in January in small numbers well before the main spawning runs (more than one may occur) in March and April, and then continuing on a smaller scale."

[5] See footnote 4.

Columbia River and tributaries

Smith and Saalfeld (1955, p. 24) noted that eulachon "may be found in the Columbia River between late December and mid-May." Howell and Uusitalo (2000, p. 3) documented that historically eulachon migration into the Columbia River "begins in December, peaks in February, and continues through May." Bargmann et al. (2005, p. 22) stated that "peak [eulachon] abundance [in the Columbia River] is usually in February, but may be as late as April."

Initial arrival of eulachon in the Columbia River and its tributaries can be estimated from historical landings data in the commercial fishery (WDFW,[6] Howell and Uusitalo 2000) (Figure 6). Documented eulachon landings in the Columbia River have occurred as early as December 13 and as late as February 21 with an average date of around January 8 for the years 1949 to 2008, based on data supplied by WDFW.[7] Based on newspaper accounts of eulachon in the fish markets of Portland, Oregon, from 1867 to 1923 (Appendix B), the earliest date of appearance of eulachon in the Portland markets was November 23 and the mean date of initial appearance was February 12 (Figure 6).

Similarly, documented eulachon landings in the Cowlitz River have occurred as early as December 13 and as late as March 11 with an average date of around January 25 for the years 1949 to 2008, based on data supplied by WDFW.[8] Newspaper accounts of initial appearance of eulachon in the Cowlitz River between 1908 and 1935 were summarized in Smith et al. (1953) and give the earliest date of January 30. In the Grays River between 1949 and 1985, initial eulachon landings occurred as early as January 3 with an average initial date of February 20, based on data supplied by WDFW.[9] In the Kalama River between 1950 and 1995, initial eulachon landings occurred as early as January 14 with an average initial date of April 1, based on data supplied by WDFW.[10] In the Lewis River between 1949 and 1990, initial eulachon landings occurred as early as January 5 with an average initial date of April 16, based on data supplied by WDFW.[11]

WDFW and ODFW (2008) provided the initial arrival dates of eulachon in the Sandy River, Oregon, for the years 1929 to 2008, although no run was recorded in 48 of the 79 years. The earliest appearance of eulachon on the Sandy River occurred on January 23 (the next earliest being February 28) and the latest on April 21, with an average data of initial appearance of about March 21 (Figure 6). Craig (1947, p. 3) stated that eulachon "runs into the Sandy and Lewis rivers normally occur later than those in the Cowlitz." Smith and Saalfeld (1955, p. 13) also noted that "the Cowlitz fish [appear] in the early part of the season, and the Sandy fish nearly two months later." Comparison of average dates of initial landings in the commercial fishery in the Cowlitz River (January 25) and in the Sandy River (March 21) confirm that a nearly two-month period separates the average run timing in these two tributaries (Figure 6).

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[6] Statewide eulachon landings database, B. James, WDFW, Vancouver, WA. Pers. commun., 20 June 2008.
[7] See Footnote 6.
[8] See Footnote 6.
[9] See Footnote 6.
[10] See Footnote 6.
[11] See Footnote 6.

British Columbia

On the mainland coast of British Columbia, earliest eulachon spawning occurs in the far north in February to early March in the Nass River, and the latest spawning occurs in April and May in the Fraser River in the far south (Table A-9, Figure 5). This pattern of spawn timing is reversed from the apparent overall range-wide pattern of eulachon spawning earlier in the south and later in the north (Hay and McCarter 2000). Early researchers variously stated that eulachon enter and spawn in rivers in British Columbia "from the middle of March to the middle of May" (Hart and McHugh 1944, p. 7) or "during March, April, and May" (Clemens and Wilby 1967, p. 123). Hart and McHugh (1944, p. 7) also affirmed that "The time of appearance is fairly constant from year to year in each locality and the runs are apparently of progressively shorter duration from south to north." Similarly, McCarter and Hay (2003, p. 16) noted that:

> In some rivers, such as the Kitimat or Kemano, the time of spawning is relatively early, beginning in early March and in others, such as the Fraser or Klinaklini, the timing is later, beginning in April or May.

Fraser River—The early journals of Fort Langley, a Hudson's Bay Company post on the lower Fraser River, indicate that eulachon were observed in the Fraser River on 28–29 April 1828, 14 April 1829, and 4 May 1830 (MacLachlan 1998) (Appendix C). McHugh (1939) suggested that the presence of spent fish in the catch indicated that spawning may occur throughout the two-month period from early April until late May in the Fraser River. Hart and McHugh (1944) sampled eulachon on the Fraser River 12 April–19 May 1939 and 4 April–8 May 1940. Ricker et al. (1954, p. 1) noted that historically the eulachon fishery operated in the Fraser River "between the middle of March and the middle of May, from the mouth of the river up to Mission and Matsqui." More recently, Hay et al. (2002, p. 20) stated that eulachon enter the Fraser River "in late March and April to spawn" and Stables et al. (2005) recorded the capture of eulachon by trawl net in late April and early May of both 2001 and 2002.

Kitimat River—In 1993 eulachon spawned in the lower 4 km of the Kitimat River March 20–30 (Pedersen et al. 1995). Peak spawning in 1997 occurred March 7–19 (Kelson 1997).

Kemano River—Lewis et al. (2002) reported that eulachon run timing in the Kemano River extended from late March to early April in 1980 and typically lasted from March 22 to April 10 between the years 1988 and 1998. Females entered the Kemano River in two distinct pulses separated in time by from several days up to 10 days (Lewis et al. 2002). Typically the run duration was about 15 days in the Kemano River, "ranging from 4 to 20 days" and "over the 11 year study [1988–1998] there was a trend for the eulachon run to begin and end earlier" perhaps in "response to changing sea temperatures" (Lewis et al. 2002, p. 68).

Skeena River—Adult eulachon were present in the Skeena River March 10–20, 1997 (Lewis 1997). Historically, the Skeena River eulachon run was reported to occur between early February and late March (Lewis 1997).

Nass River—Swan (1881) noted that two spawning runs of eulachon appear in the Nass River, one that normally begins between March 16 and 22, but sometimes occurs as late as March 28 to April 4, and a second run that enter the river towards the end of June. Langer et al.

(1977, p. 45) verified that eulachon typically enter the Nass River in mid-March, peaking in late March, and the run may extend into mid-April and may consist of "two overlapping spawning waves."

Alaska

Moffitt et al. (2002, p. 3) stated that "eulachon enter river systems from January through early July" in Alaska. Eulachon typically spawn in early April in the Taku River in Southeast Alaska and may migrate beneath river ice to reach the spawning grounds (Flory 2008b). Franzel and Nelson (1981) reported that the eulachon run in the Stikine River, Alaska, in 1979 and 1980 occurred in early April soon after spring breakup and lasted for up to 3 to 4 weeks. Marston et al. (2002, p. 231) reported that eulachon spawning runs in 1995–1997 in the Antler and Berners rivers in Berners Bay in Southeast Alaska began between May 3–6 and lasted 10–12 days, "although spent fish or a few late spawners remained in the rivers until the end of May." More recently, eulachon have spawned in mid to late April in Berners Bay rivers (Flory 2008a), spawning 26 April–14 May 2004 in the Antler River in particular (Eller and Hillgruber 2005).

Chilkat and Chilkoot rivers—Krause (1885) indicated that two runs of eulachon occurred in the Chilkat River region of Southeast Alaska, a February run and a separate run in late April to mid-May. The later run was characterized as larger in both numbers and individual fish size (Krause 1885). Mills (1992, p. 8) stated that the main eulachon run occurred "between mid and late May" on the Chilkat River. Betts (1994, p. 19) reported that both the Chilkat and Chilkoot rivers supported two runs of eulachon, "a small run in February, and en masse most commonly in mid-May." Eulachon harvest on the Chilkat River occurred 1–7 May 1990 and 6–16 May 1991 (Betts 1994). On the nearby Chilkoot River, harvest occurred 6–9 May 1990 and 9–16 May 1991 (Betts 1994). Betts (1994) also reported that salmon fishwheels on the Chilkat River caught eulachon 7 May–17 June 1991. Eulachon reportedly spawn in several rivers in the Yakutat region of Alaska in March to early June (Rogers et al. 1980).

Copper River delta—Eulachon run timing in the Copper River, Alaska, and in nearby rivers of the Copper River delta is variable, and in many cases two runs separated by weeks to months have been observed in the same rivers (Moffitt et al. 2002, Joyce et al. 2004) (Table A-9). Eulachon were observed in the Eyak River on the western Copper River delta 16–23 June 2002, but did not appear in Ibeck Creek in 2002, a tributary of the Eyak (Joyce et al. 2004). In 2003 there were two separate eulachon runs observed in the Eyak River, February 15–22 and June 9–13. Eulachon were observed in the tributary Ibeck Creek 28 January–17 March 2001 (Moffitt et al. 2002) and 15 February–1 March 2003 (Joyce et al. 2004). On the central Copper River delta, eulachon were present in Alaganik Slough as early as 9 February 2001 (Moffitt et al. 2002), 9–16 June 2002, and during two periods in 2003, February 23–26 and May 29 to June 15 (Joyce et al. 2004). In the Copper River itself, eulachon were present as early as May 19 and as late as May 24 at Flag Point Channel between 1998 and 2002, and the duration of the run lasted 8–14 days (Moffitt et al. 2002). Eulachon were present at Flag Point 20 May–2 June 1998, 19–28 May 2000, 19–30 May 2001, 24 May–6 June and 16–24 June in 2002, and 1–5 March and 17–19 April 2003 (Joyce et al. 2004). Eulachon were also present at 37-mile Bridge on the Copper River 16–23 June 2003 (Joyce et al. 2004).

Twentymile River—The eulachon run in the Twentymile River "spanned a period of 25 days between May 13 and June 6" in 1976 (Kubik and Wadman 1977, p. 37) and "44 days from April 23 to June 5" in 1977 (Kubik and Wadman 1978, p. 54) (Table A-9). Spangler (2002) and Spangler et al. (2003) cited an additional 7 years of observations in the Twentymile River where the spawn period ranged 18–54 days. Eulachon were captured in the Twentymile River by dip nets 4 May–21 June and 17 April–9 June in 2000 and 2001 (Spangler 2002, Spangler et al. 2003). Spangler (2002, p. 27) stated that "the eulachon run lasts over a longer period of time in the Twentymile River than in any other river for which data are available." In contrast, other researchers have stated that the duration of eulachon spawning migrations decreases from south to north (Hart and McHugh 1944, Scott and Crossman 1973).

Susitna River—Based on the presence of adults, two runs of eulachon were observed on the Susitna River in Southcentral Alaska in 1982 (May 16–30 and June 1–8) and 1983 (May 10–17 and May 19 to June 8) (Barrett et al. 1984, Vincent-Lang and Queral 1984). Initial eulachon run timing likely precedes these early dates for the first run, as fish were present as soon as sampling was possible following ice breakup in both years (Vincent-Lang and Queral 1984). Actual spawning occurred on the Susitna River May 21–31 and June 4–9 in 1982, and May 15–22 and May 23 to June 5 in 1983 (Barrett et al. 1984).

Multiple spawning runs

A number of rivers are reported to have two or even more separate spawning runs of eulachon, including the Chilkat River (Krause 1885, Betts 1994), Chilkoot River (Betts 1994), Copper River (Moffitt et al. 2002, Joyce et al. 2004), and Susitna River (Vincent-Lang and Queral 1984) in Alaska, and the Nass River (Swan 1881, Langer et al. 1977) and Kingcome River (Berry and Jacob 1998) in British Columbia. Based on adult run timing, Langer et al. (1977) suggested there could be up to three waves of spawning on the Nass River. Berry and Jacob (1998, p. 4) reported that there appeared to be four waves of eulachon spawning activity in the Kingcome River, British Columbia, in 1997, "with peaks on April 2, April 15, April 21, and May 2." There may also have been an earlier eulachon spawning event in March and a later one in early June in the Kingcome River (Berry and Jacob 1998), based on the presence of eggs and larvae; however, experience in other river systems raises the possibility that some of these eggs and larvae may have been confused with those of sculpins (cottids) (Kelson 1997). Indications of eulachon spawning in May and June, based on egg and larval presence, in the Kitimat (Pedersen et al. 1995), Skeena (Lewis 1997), and other rivers on the central and north coast of British Columbia are suspect, due to the presence of sculpin larvae in these rivers that may have been misidentified as eulachon larvae (Kelson 1997).

Semelparity versus Iteroparity

Numerous references (McPhail and Lindsey 1970, Hart 1973, Scott and Crossman 1973, Samis 1977, Garrison and Miller 1982, Lewis et al. 2002) cite Barraclough (1964) as evidence that eulachon may be iteroparous. In fact, Barraclough (1964, p. 1,337) noted that the presence of dead eulachon found in the Columbia and Fraser rivers indicates many die after spawning. The evidence in Barraclough (1964, p. 1,337) that eulachon may be iteroparous occurs in the statement that: "spent eulachon in good condition caught by trawlers in the Strait of Georgia off the mouth of the Fraser River suggest that some eulachon recover after spawning, and may spawn a second time." However, it is uncertain whether the spent eulachon observed at the mouth of the Fraser River, as reported by Barraclough (1964), recovered and lived long enough to spawn in a subsequent season. Some additional secondary sources indicate that some eulachon are iteroparous (WDFW and ODFW 2001, Mecklenburg et al. 2002, LCFRB 2004b). According to WDFW and ODFW (2001, p. 4), "although adults can repeatedly spawn, most die after spawning." Mecklenburg et al. (2002, p. 175) stated that "most [eulachon] die after spawning, but some survive to spawn once more."

Earlier authorities (McHugh 1939, Hart and McHugh 1944, Clemens and Wilby 1946, Ricker et al. 1954, Smith and Saalfeld 1955) reported that eulachon were semelparous (spawn once in their lifetime and die soon after spawning). McHugh (1939) and Hart and McHugh (1944) noted that the outer edge of the scales in spawning eulachon in the Fraser River were resorbed and showed a characteristic clear margin. This region of the scale is commonly called a spawning mark or spawning check. However, these authors found no eulachon with a previous year's spawning check and "concluded that none of the fish examined had spawned in a previous year" (McHugh 1939, p. 21). Similarly, Langer et al. (1977, p. 39) stated that "since no spawning checks were noted on any scales from the Nass River, repeat spawning is probably minor or nonexistent on the Nass." Eulachon in the Kemano River also showed no evidence of spawning checks on the otoliths (Lewis et al. 2002). Smith and Saalfeld (1955, p. 25) reported that:

> All available evidence indicates that smelt die after one spawning. In all spawning studies where live smelt were allowed to spawn in the confines of [a] hatchery trough, death followed extrusion of the spawn. In addition, commercial fisherman, who fish in the Columbia River after the smelt run, report the tremendous abundance of dead smelt on the river bottom.

The evidence is strong that most, if not all, eulachon in the southern portion of the range (south of about 54°N latitude) are semelparous (Hay and McCarter 2000, Hay 2002, Hay et al. 2002, 2003), "although there may be some iteroparity (survive spawning) at higher latitudes, in Alaska" (Hay et al. 2003, p. 2). Hay et al. (2002, 2003) presented three lines of evidence for semelparity in eulachon from British Columbia: 1) direct observation of postspawning mortality in the form of beached and floating carcasses in many rivers, 2) only eulachon with well developed teeth are found at sea, whereas all spawning eulachon observed in the Fraser River have undergone substantial tooth loss and resorption, and 3) the largest size class of eulachon in British Columbia are found in rivers during the spawning runs and are much larger than any eulachon caught anywhere in the nearby ocean. However, retention of teeth in significant numbers of spawning eulachon in the Twentymile River, Alaska (Spangler 2002, Spangler et al. 2003), indicates that some of these fish may survive spawning, return to the sea, and begin feeding again. Teeth retention rates in spawning eulachon in the Twentymile River were 84% and 97% for females, and 3% and 32% for males in 2000 and 2001, respectively (Spangler 2002, Spangler et al. 2003).

Although age determination in eulachon has not been validated (see above discussion in the Age Composition subsection, p. 35), Lewis et al. (2002) examined age composition as estimated from otolith increments of prespawning eulachon captured in a fishery and postspawning carcasses on the Kemano River and reported that the carcass sample had:

> a greater proportion of fish age 5 years [than did the prespawning sample] (31% versus 21%) and a lower proportion age 3 (18% versus 41%) and 4 years (51% versus 38%). Based on these data, we reject the null hypothesis that Kemano River eulachon are semelparous.

However, Clarke et al. (2007) reported that the pattern of seasonal oscillations in barium and calcium deposited in eulachon otoliths (see discussion in Age Composition subsection on page 36) and the lack of a freshwater strontium signal in otoliths of spawners indicate that eulachon are semelparous. Comparison of length frequencies of eulachon at sea and in the Kemano River also indicate that Kemano River eulachon are semelparous, and are estimated to spawn at age 3 (Clarke et al. 2007). Otoliths of eulachon that had spawned in freshwater in a previous season would be expected to show a corresponding decrease in the strontium to calcium ratio representative of this time spent in freshwater; however, this was not evident in otolith samples from any of five river systems (Clarke et al. 2007). Strontium to calcium ratios are much higher in bony structures of fish secreted while in the marine compared to freshwater environment, have been used to detect migration of fish between these two environments in many studies, and can detect exposure to freshwater conditions of as little as 6 hours. This study "supports the hypothesis that [eulachon] are semelparous" (Clarke et al. 2007, p. 1,490).

Spawn Behavior

Selection of spawn substrate

Eulachon eggs were reportedly preferentially laid on sand in both the Fraser (McHugh 1940, Hay et al. 2002) and Nass rivers (Langer et al. 1977). Eggs were primarily found attached to pea-sized gravel and only secondarily on sand in the Columbia River (Smith and Saalfeld 1955). Eggs laid in areas of silt or organic debris reportedly suffer much higher mortality than those laid over sand or gravel (Langer et al. 1977). Although eulachon eggs are most commonly laid on a sand substrate, eggs have been found on silt, gravel to cobble–sized rock, and organic detritus (Smith and Saalfeld 1955, Langer et al. 1977, Vincent-Lang and Queral 1984, Lewis et al. 2002).

Estuary spawning

Based on movements of adult eulachon tracked with gastrically implanted radio tags in the Twentymile River, Spangler (2002) and Spangler et al. (2003) speculated that a portion of the eulachon population in this river may have spawned in the estuary. Some tagged fish moved in and out of the lower river and did not move upstream of the tagging site. Spangler et al. (2003, p. 52) stated that "if fish are capable of spawning in the estuary, larval sampling [and thus abundance estimation methodology] could be missing a segment of the population leading to erroneous results." However, Armstrong and Hermans (2007, p. 4) cite an unpublished study indicating that eulachon egg survival is reduced on exposure to salinities of 16 ppt and greater, and thus successful spawning in estuarine salinities greater than this is unlikely.

Spawn migration

According to Spangler et al. (2003, p. 2), "There are no consistently reported environmental factors known to influence spawning run timing of adult eulachon throughout their range." These factors include water temperature, tide height, and river discharge rates (Spangler 2002, Spangler et al. 2003). However, both water temperature and river discharge rate are cited as factors that may initiate upriver migration of eulachon in local river basins (Ricker et al. 1954, Smith and Saalfeld 1955, Langer et al. 1977).

Spawn temperature

It is apparent that "the temperature at which eulachon spawning runs commence varies by geographic area" (Spangler 2002, p. 71); however, a clear pattern is not readily discernible. Columbia River eulachon are reported to spawn at temperatures between 4ºC and 10ºC and that the spawning migration is inhibited at temperatures less than 4ºC (WDFW and ODFW 2001). In 2001, most eulachon avoided the Columbia River until mid-February when the temperature rose above 4ºC (Howell et al. 2001). Spawning in the Fraser River reportedly occurs "at temperatures exceeding 6 or 7ºC whereas temperatures in northern rivers, which sometimes are ice covered during spawning, are much lower" (Hay et al. 2003, p. 2). Mean, minimum, and maximum water temperatures during spawning in the Kemano River in March-April between 1992 and 1998 were 3.1ºC, 1.1ºC, and 6.5ºC, respectively (Lewis et al. 2002). Langer et al. (1977, p. 18) reported that "1971 temperature records from the Nass [River] indicated that peak [eulachon] migration was occurring at temperatures as low as 0–1°C." During the 8-day peak eulachon migration in the Nass River in 1971, the mean daily water temperature ranged from 0.3 to 2.0°C (Langer et al. 1977, their Table 6). Temperature at the onset of the eulachon run in the Twentymile River, Alaska, ranged 2.8–6.0°C (Spangler 2002, Spangler et al. 2003); however, over the entire spawning run temperatures varied "from 1.6°C to 12.7°C in 2000 and from 0.5°C to 10.7°C in 2001" (Spangler et al. 2003, p. 28). Eulachon spawned in the Susitna River, Alaska, in 1982 and 1983 when temperatures ranged about 6–11°C (Barrett et al. 1984, Vincent-Lang and Queral 1984).

Spawning under ice

Swan (1881, p. 260) stated that eulachon arrive in the Nass River "about the time the ice begins to break up" and that in "some years the ice remains solid until after the fish are caught, in which case holes have to be cut in the ice to put down the nets." Langer et al. (1977, p. 43) documented this under-ice eulachon fishery on the Nass River in 1969 and stated that "adult migration occurs at colder river temperatures than previously recorded." Hay and McCarter (2000) also noted that spawning may occur under the ice in some northern British Columbia rivers. Eulachon reportedly migrate, and presumably spawn, under the ice on the Unuk River in Southeast Alaska, and this under-ice migratory behavior may have also occurred in the past on the Twentymile River in Southcentral Alaska (Spangler 2002, Spangler et al. 2003). Flory (2008b) reported that in April 2006 on the Taku River in Southeast Alaska, "eulachon schools were observed up river [before ice break up], indicating the fish moved underneath the ice [to] access spawning grounds (E. Jones, pers. comm.)."

Spawning at night or under low light levels

Several authors indicate that eulachon mainly spawn at night (Smith and Saalfeld 1955, Parente and Snyder 1970, Lewis 1997) or under low light conditions (Spangler 2002), and this has been suggested as possible predator avoidance behavior (Spangler et al. 2003). Smith and

Saalfeld (1955) reported that captive eulachon always deposited eggs at night, and when partially spent eulachon were captured at night in the Cowlitz River, freshly deposited eggs were sampled on the river bottom the next morning. Lewis et al. (2002, p. 74) reported that "female eulachon migrated into the [Kemano] river to spawn in darkness on high tides, retreating by day to the lower river" and that egg drift was greatest at night in the Kemano River.

Tidal level during spawning

Periods of low river discharge and high tides are associated with peak adult eulachon migration in both the Nass River, British Columbia (Langer et al. 1977), and the Twentymile River, Alaska (Spangler 2002, Spangler et al. 2003). Higgins et al. (1987, p. 6) were unable to discriminate between interacting effects of light and tide on eulachon migration in the Fraser River but did note that fishing success was best "at dusk on the high slack tide." Lewis et al. (2002) also suggested that eulachon spawning may be tied to nighttime high tides, and noted that "higher tides reduced water velocity, allowing eulachon to swim further upstream."

Flow velocity and depth during spawning

In the Kemano River, British Columbia, eulachon preferred water velocities from 0.1 to 0.7 m/s (Lewis et al. 2002). Earlier studies on Kemano eulachon indicated that many eulachon are unable to maintain long-term position in the stream at flow velocities greater than 0.3 m/s (Lewis et al. 2002). In the Susitna River, Alaska, "water velocities ranging from 0.5 to 2.5 feet/s [0.2–0.8 m/s] are most commonly utilized for spawning" (Vincent-Lang and Queral 1984, p. 5).

McHugh (1940) found the heaviest concentration of eulachon eggs in the Fraser River at a depth of 25 feet (7.6 m). Likewise, Langer et al. (1977) reported eggs to be more abundant at depths greater than 4 m than in shallower waters in the Nass River, British Columbia. In the Columbia River, larval eulachon were recovered in waters from 3 inches (0.1 m) to more than 20 feet (6.1 m) in depth and spent adults have been caught as deep as 75 feet (22.9 m) (Smith and Saalfeld 1955). However, eulachon may live long enough after spawning to be swept far downstream from the spawning grounds, so the presence of spent eulachon may not indicate that spawning occurred in the vicinity. In the Kemano River, British Columbia, eulachon preferred depths between 0.5 and 2.3 m, but used available habitat from 0.2 to more than 4 m in depth (Lewis et al. 2002). In the Susitna River, Alaska, "depths ranging from 0.5 to 3.0 feet [0.2–0.9 m] are most commonly utilized for spawning" (Vincent-Lang and Queral 1984, p. 5).

Trophic Interactions

Diet

Larval and juvenile eulachon are planktivorous (WDFW and ODFW 2001). Barraclough (1967) and Robinson et al. (1968b) examined stomach contents of larval (5–15 mm FL) eulachon caught in surface trawls in the Strait of Georgia in early June of 1966 and 1967, respectively. Although 5–8 mm FL larvae still possessed a yolk sac, larvae as small as 6 mm FL had fed on copepod nauplii. Other stomach contents of larval (≤15 mm FL) eulachon in the Strait of Georgia included phytoplankton, centric diatoms, copepod metanauplii, copepod eggs, barnacle eggs, rotifers, cladocerans (*Podon* sp.), ostracods, and polychaete larvae (Barraclough 1967, Robinson et al. 1968b).

Barraclough (1967), Barraclough and Fulton (1967), and Robinson et al. (1968a, 1968b) examined stomach contents of postlarval and juvenile (20–69 mm FL) eulachon caught in surface trawls in the Strait of Georgia in early June 1966, July 1966, May 1967, and June 1967. Stomach contents of eulachon in the Strait of Georgia included phytoplankton, barnacle eggs, barnacle nauplii, copepod eggs, copepod nauplii, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Acartia* sp., *Microcalanus pygmaeus*, *Calanus* sp.), cladocerans, ostracods, mysiids, larvaceans (*Oikopleura* sp.), and in one case a larval eulachon (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968a, 1968b). Larger specimens of eulachon (91–157 mm FL) collected in the Strait of Georgia had consumed barnacle eggs, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Calanus* sp.), cladocerans, and gammaridean amphipods (Robinson et al. 1968a, 1968b).

Smith and Saalfeld (1955, p. 12) stated that the only recognizable prey found in stomachs of adult eulachon captured off Washington in 1948 were abundant "remains of the cumacean, *Cumacea dawsoni*." Other authorities have reported that juvenile and adult eulachon eat primarily "euphausiids and copepods" (Hart 1973, p. 149) or "euphausiids, crustaceans, and cumaceans" (Scott and Crossman 1973, p. 323). Hay (2002, p. 100) stated that "eulachon stomachs from offshore waters indicate that [they] mainly consume the euphausiid *Thysanoessa spinifera*." Yang et al. (2006) examined the stomach contents of 39 eulachon from a single haul in the Gulf of Alaska in 2001 that ranged in size from 160 to 210 mm FL. Food items and their percent of total stomach content weight included mysids (2.7%), cumaceans (2.1%), hyperiid amphipods (5.9%), the euphausiid *T. inermis* (25.8%), other euphausiids (40.8%), larvaceans (1.7%), teleost fish (13.8%), undetermined fish remains (2.6%), and unidentified material (4.6%) (Yang et al. 2006).

Predators

Marine mammals

Numerous pinnipeds prey on eulachon both at sea and during eulachon spawning runs, including: 1) Stellar sea lions (*Eumetopias jubatus*) (Beach et al. 1981, 1985, Jeffries 1984, Bigg 1988, Marston et al. 2002, Womble 2003, Sigler et al. 2004, Womble and Sigler 2006, Womble et al. 2005, 2009), 2) California sea lions (Beach et al. 1981, 1985, Bowlby 1981, Jeffries 1984), 3) northern fur seals (*Callorhinus ursinus*) (Clemens et al. 1936, Spalding 1964, Antonelis and Fiscus 1980, Antonelis and Perez 1984), and 4) harbor seals (Fisher 1947, 1952, Spalding 1964, Pitcher 1980, Beach et al. 1981, 1985, Bowlby 1981, Jeffries 1984, Roffe and Mate 1984, Olesiuk 1993, Marston et al. 2002). Other nonpinniped marine mammal predators on eulachon include baleen whales, beluga whales (*Delphinapterus leucas*) (Moore et al. 2000, Rugh et al. 2000, Speckman and Piatt 2000), humpback whales (*Megaptera novaeangliae*) (Marston et al. 2002, Witteveen et al. 2004), killer whales (*Orcinus orca*), harbor porpoises (*Phocoena phocoena*) (Jeffries 1984), Dall's porpoises (*Phocoenoides dalli*) (Kajimura et al. 1980, Stroud et al. 1981, Jeffries 1984), and white-sided dolphins (*Lagenorhyncus obliquidens*) (Morton 2000).

Birds

Numerous authors (WDFW and ODFW 2001, Spangler 2002, Willson and Marston 2002, Marston et al. 2002, Maggiulli et al. 2006) report large numbers of gulls (*Larus* spp.), terns (*Sterna* spp.), ducks (Anatidae), bald eagles (*Haliaeetus leucocephalus*), shorebirds (Scolopacidae), corvids, and other birds feeding on live and dead eulachon during spawning events. Documented bird predators on spawning aggregations of eulachon in various river systems are summarized in Table A-10.

Ormseth et al. (2008, their Table 2) listed the estimates of eulachon contribution to seabird diets (percent weight of eulachon in the predator's diet) based on a mass-balance ecosystem model derived from predator diet data in the Gulf of Alaska for the following birds: kittiwakes (*Rissa* spp.) (4.3%), murres (*Uria* spp.) (3.0%), puffins (*Fratercula* spp.) (6.1%), cormorants (*Phalacrocorax* spp.) (3.0%), gulls (*Larus* spp.) (8.2%), shearwaters (*Puffinus* spp.) (5.0%), and albatross/jaeger (3.5%).

Fish

Numerous fish species have been recorded as consuming eulachon, including spiny dogfish (*Squalus acanthias*) (Chatwin and Forrester 1953, Jones and Geen 1977), green sturgeon (*Acipenser medirostris*) (Fry 1979), Pacific cod (*Gadus macrocephalus*) (Hart 1949, Yang 1993, Yang and Nelson 2000, Yang et al. 2006), walleye pollock (Yang 1993, Yang and Nelson 2000, Yang et al. 2006), Pacific halibut (*Hippoglossus stenolepis*) (Scott and Crossman 1973, Yang 1993, Yang and Nelson 2000, Yang et al. 2006), sablefish (Yang 1993, Buckley et al. 1999, Yang and Nelson 2000, Yang et al. 2006), Pacific hake (Alton and Nelson 1970, Outram and Haegele 1972, Livingston 1983, McFarlane and Beamish 1985, Rexstad and Pikitch 1986, Buckley and Livingston 1997, Buckley et al. 1999), rougheye rockfish (*Sebastes aleutianus*) (Yang and Nelson 2000), and arrowtooth flounder (*Atheresthes stomias*) (Kabata and Forrester 1974, Yang 1993, Buckley et al. 1999, Yang and Nelson 2000, Yang et al. 2006).

Larval and juvenile eulachon have also been reported to be the occasional prey of Pacific herring, surf smelt, Pacific sand lance, kelp greenling (*Hexagrammos decagrammus*), threespine stickleback (*Gasterosteus aculeatus*), steelhead (*Oncorhynchus mykiss*), Chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*) salmon in the Strait of Georgia (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968b). Juvenile white sturgeon (*Acipenser transmontanus*) in the Columbia River are known to consume large quantities of eulachon eggs during spawning events (McCabe et al. 1993). Marston et al. (2002) reported that coho salmon and Dolly Varden (*Salvelinus malma*) may also feed on eulachon eggs and larvae. In addition, juvenile eulachon may occasionally consume larval eulachon (Barraclough 1967, p. 26).

Other predators

Marston et al. (2002) noted that terrestrial mammals such as bears (*Ursus* spp.), wolves (*Canis lupus*), river otters (*Lontra canadensis*), and mink (*Mustela vison*) likely prey on eulachon either during or after spawning events.

Parasites

Compilations of parasites and fish hosts in British Columbia (Margolis and Arthur 1979, Kabata 1988, McDonald and Margolis 1995, Gibson 1996) listed two trematodes (*Pronoprymna petrowi* and *Lecithaster gibbosus*), a cestode (*Phyllobothrium* sp.), a nematode (*Contracaecum* sp.), and a parasitic pennellid copepod (*Haemobaphes disphaerocephalus*) as known parasites on eulachon. The trematode *L. gibbosus* was found in stomachs of juvenile eulachon collected in the Strait of Georgia with 29–59 mm FL (Robinson et al. 1968a, 1968b, Barraclough 1967). Similarly, the trematode *P. petrowi* was found in the stomachs of juvenile eulachon collected in the Strait of Georgia with 32–38 mm FL (Barraclough 1967). Arai (1967, 1969) reported the trematode *L. gibbosus*, a larval cestode *Phyllobothrium* sp, and a larval nematode *Contracaecum* sp. in eulachon from Burke Channel, an inlet on the south mainland coast of British Columbia. Hoskins et al. (1976) reported the occurrence of the parasitic copepod *Haemobaphes diceraus* on a eulachon host, from Port Hardy on Vancouver Island, British Columbia. Kabata (1988) and McDonald and Margolis (1995) described another pennellid copepod (*H. disphaerocephalus*) as parasitic on eulachon from British Columbia. Kabata (1988) noted that the report of *H. diceraus* infecting eulachon by Hoskins et al. (1976) occurred before *H. disphaerocephalus* was described as a separate species. The pennellid copepods in the genus *Haemobaphes* attach themselves headfirst to the bulbous arteriosus of the host fish with the body protruding from the gill arch (McDonald and Margolis 1995).

Information Relating to the Species Question

Approaches to Addressing Discreteness and Significance

The BRT considered several kinds of information to delineate potential DPS structure in eulachon. To address the discreteness criteria, the BRT primarily considered patterns of genetic variation among eulachon sampled from various locations along the coast, patterns of variation in life history and morphology, and ecological and environmental differences between eulachon populations. Comparison of spawning distribution, spawn timing, meristic variation in vertebral counts, elemental analysis of otoliths, and genetic variation have also been cited as evidence for stock discrimination in eulachon (Hay and McCarter 2000, Beacham et al. 2005, Hay and Beacham 2005). For the significance criteria, the BRT focused primarily on ecological differences among populations and on whether loss of such populations would create a significant gap in the range of the species.

Life history and morphology

Isolation between populations may be reflected in several variables, including differences in life history variables (e.g., spawning timing, seasonal migrations), spawning location, parasite incidence, growth rates, morphological variability (e.g., morphometric and meristic traits), and demography (e.g., fecundity, age structure, length and age at maturity, mortality rates), among others. Although some of these traits may have a genetic basis, they are usually also strongly influenced by environmental factors over the lifetime of an individual or over a few generations. Differences can arise among populations in response to environmental variability among areas and can sometimes be used to infer the degree of independence among populations or subpopulations. Begg et al. (1999) have emphasized the necessity to examine the temporal stability of life history characteristics in order to determine whether differences between populations persist across generations.

Persistence of spawn location and spawn timing

Eulachon generally spawn in rivers that are glacier fed or have peak spring freshets. It has been argued that the rapid movement of eggs and larvae by these freshets to estuaries makes it likely that eulachon imprint and home to an estuary into which several rivers drain rather than to individual spawning rivers (McCarter and Hay 1999, Hay and McCarter 2000). Thus the estuary has been invoked as the likely geographic stock unit for eulachon (McCarter and Hay 1999, 2003, Hay and McCarter 2000, Hay 2002, Hay and Beacham 2005) (Table A-1).

Variation in spawn timing among rivers has been cited as indicative of local adaptation in eulachon (Hay and McCarter 2000), although the wide overlap in spawn timing and river entry timing among rivers makes it difficult to discern distinctive geographic patterns in this trait. In general, eulachon spawn earlier in southern portions of their range than in rivers to the north. River entry and spawning begins as early as December and January in the Columbia River system and as late as June in Southcentral Alaska (Table A-9, Figure 5, and Figure 6). However, they have been known to spawn as early as January in rivers on the Copper River delta of Alaska and as late as May in northern California. The general spawn timing pattern is reversed along the coast of British Columbia, where the earliest spawning occurs in the Nass River in the far north in February to early March and the latest spawning occurs in the Fraser River in April and May in the far south (Table A-9, Figure 5). There is also some evidence that different waves or runs of eulachon may occur in some basins, based on run-time separation (Table A-9).

These differences in spawn timing result in some populations spawning when water temperatures are as low as 0–2°C, and sometimes under ice (Nass River, Langer et al. 1977), whereas other populations experience spawning temperatures of 4–7°C (Cowlitz River, Smith and Saalfeld 1955) (Table A-11).

Morphology

Differences in the mean number of vertebrae in eulachon from northern and southern rivers in British Columbia have been cited as indicative of population separation (Hart and McHugh 1944, Hay and McCarter 2000), although no differences were evident in population means between the Fraser and Columbia rivers (Hay and McCarter 2000) (Figure 7). However, meristic differences such as these can vary with environmental conditions and it is impossible to determine the underlying causes of these differences from the available data. It has often been shown that the number of vertebrae formed during early development is subject to modification by temperature such that the average vertebral number in fish populations is greater in the northern versus the southern portion of the range and the mean vertebral number in a population may also vary from year to year within a population (McHugh 1954, Waldman 2005). In addition, morphometric and meristic differences between groups of fish are often subtle and relating such differences to a specific degree of isolation among populations can be difficult.

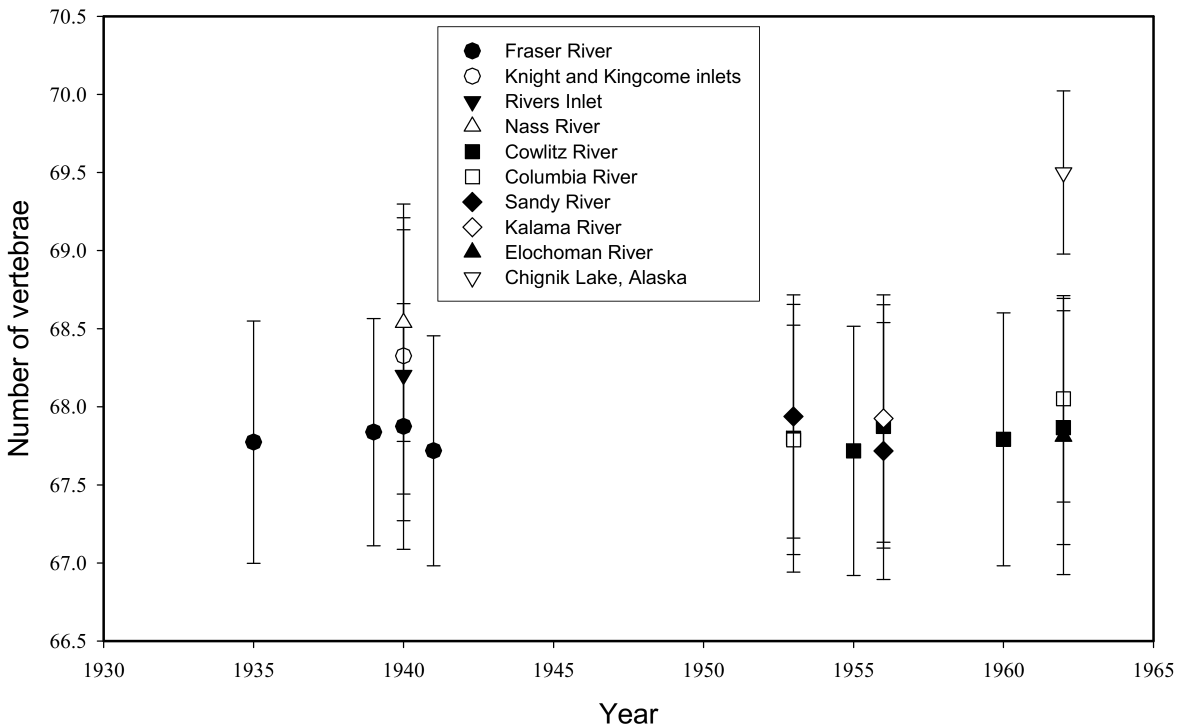

Figure 7. Comparison of mean and standard deviations of eulachon vertebral counts in various rivers. Data from DeLacy and Batts (1963) for the Columbia River, its tributaries, and Chignik Lake. Data from Hart and McHugh (1944) for rivers in British Columbia.

Coastwide, there appears to be an increase in both mean length and weight of eulachon at maturity with an increase in latitude (Table A-7, Table A-8, and Figure 8). Mean eulachon fork length and weight at maturity range from upwards of 215 mm and 70 g in the Twentymile River in Alaska to 175 mm and 37 g in the Columbia River. Although eulachon obtain a larger body size in the northern portion of their range compared to populations in the south, this relationship may be somewhat obscured by problems associated with the ageing of this species (Hay and McCarter 2000). Most Pacific herring also exhibit a latitudinal cline in mean size-at-age, such that Pacific herring in southern locations (e.g., California) exhibit small size and Pacific herring in the north (e.g., Bering Sea) obtain a far larger size at a similar age (Stout et al. 2001a, Gustafson et al. 2006). This pattern is typical of many vertebrate ectotherms where higher rearing temperatures result in reduced size at a given stage of development (Lindsey 1966, Atkinson 1994).

Otolith chemistry

Hay and McCarter (2000) and Hay and Beacham (2005) reported on attempts to use differences in the elemental makeup of eulachon otoliths (earbones) to detect stock structure among various rivers on the coast of British Columbia. Significant variation occurred in the elemental analysis associated with the date of the laboratory elemental analysis. Despite these sources of potential error, the results indicated that there were differences in the elemental

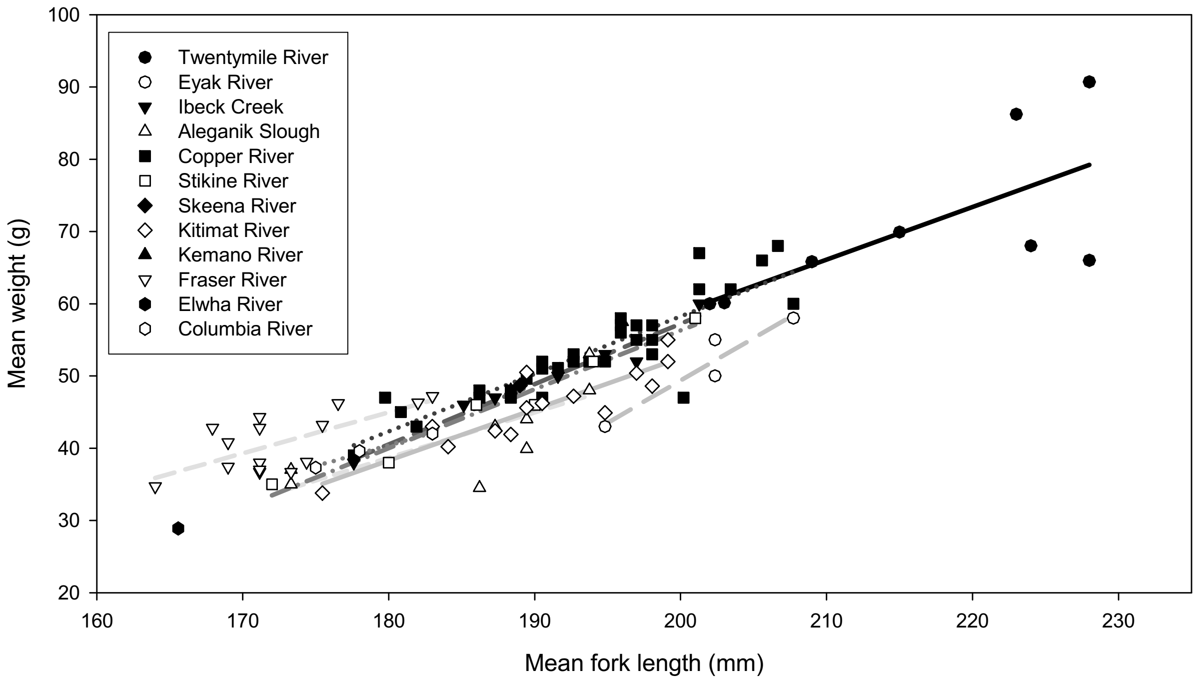

Figure 8. Length-weight relationship of eulachon from various rivers. Standard linear regressions fit the data to lines for each population that has multiple observations. Standard lengths and total lengths have been converted to fork length using equations published in Buchheister and Wilson (2005).

composition of eulachon otoliths over a broad geographic range, but that "elemental analysis was not useful to distinguish between closely adjacent stocks" (Hay and Beacham 2005, p. 10).

Age composition

Age determination of eulachon has been difficult to validate and estimates of age based on otolith or scale increments may not be accurate (Ricker et al. 1954, Hay and McCarter 2000). However, in general, studies using otolith aging techniques have concluded that some eulachon spawn at age 2 or age 5, but most are age 2 or age 3 at spawning (Willson et al. 2006). Recently, Clarke et al. (2007) pioneered a method to estimate eulachon age at spawning from analysis of variations in barium and calcium in the otoliths. This study indicated that age structure of spawners in the southern areas may be limited to one, or at most, two year classes (Clarke et al. 2007). According to Clarke et al. (2007):

> The number of Ba:Ca peaks measured in the eulachon populations varied; eulachon captured in Barkley Sound, located off the west coast of Vancouver Island (ocean), had 1.5 and 2.5 peaks, Fraser River eulachon were all characterized by 3 peaks, and Columbia River eulachon exhibited 2 or 3 peaks. All of the fish in the Kemano and Skeena rivers examined were characterized by 3 peaks in Ba:Ca with the exception of two Skeena River fish that had 4 peaks. Fish collected from the Copper River in Alaska had 3 or 4 peaks. The number of

peaks in Ba:Ca observed in eulachon otoliths increased with increasing latitude, suggesting that the age at maturity is older for northern populations.

Genetic differentiation

The analysis of the geographical distribution of genetic variation is a powerful method of identifying discrete populations. In addition, such analysis can sometimes be used to estimate historical dispersals, equilibrium levels of migration (gene flow), and past isolation. Commonly used molecular genetic markers include protein variants (allozymes), microsatellite loci (variable numbers of short tandem DNA repeats), and mtDNA.

One widely used method of population analysis is sequence or restriction fragment length polymorphism (RFLP) analysis of mtDNA, which codes for several genes that are not found in the cell nucleus. mtDNA differs from nuclear DNA (nDNA) in two ways. One way is that recombination is lacking in mtDNA, so that gene combinations (haplotypes) are passed unaltered from one generation to the next, except for new mutations. A second way is that mtDNA is inherited from only the maternal parent in most fishes, so that gene phylogenies correspond to female lineages. These characteristics permit phylogeographical analyses of mtDNA haplotypes, which can potentially indicate dispersal pathways for females and the extent of gene flow between populations (Avise et al. 1987). Although the lack of recombination allows for some types of analysis that are difficult to conduct with other markers (e.g., microsatellites), inferences of population structure (or lack thereof) from mtDNA are limited by the fact that the entire mitochondrial genome is inherited genetically as a single locus. Mitochondrial studies are therefore most useful for detecting deep patterns of population structure, and may not be very powerful for detecting structure among closely related populations.

Microsatellite DNA markers can potentially detect stock structure on finer spatial and temporal scales than can other DNA or protein markers, because of higher levels of polymorphism found in microsatellite DNA (reflecting a high mutation rate). Relatively high levels of variation can increase the statistical power to detect stock structure, particularly among closely related populations. In addition, microsatellite studies usually involve analysis of multiple genetic loci, which increases the power to detect differentiation among populations.

The BRT reviewed four published genetic studies of genetic population structure in eulachon. One of these studies (McLean et al. 1999) used RFLP analysis to examine variation in mtDNA. The other studies (McLean and Taylor 2001, Kaukinen et al. 2004, Beacham et al. 2005) analyzed microsatellite loci. Additional detail on two of these studies can be found in McLean (1999).

McLean et al. (1999) examined mtDNA variation in two fragments (each containing two genes NADH-5/NADH-6 and 12S/16S rRNA) in 285 eulachon samples collected at 11 freshwater sites ranging from the Columbia River to Cook Inlet, Alaska, and also in 29 ocean-caught fish captured in the Bering Sea. Samples were taken at two sites (Columbia and Cowlitz rivers) in two years and all other locations were sampled in single years. Overall, 37 mtDNA composite haplotypes were observed in the study. Two haplotypes were found in all sampling locations and together accounted for approximately 67% of the samples in the study. Eight additional haplotypes were present at multiple sites and the remaining 27 haplotypes were "private" (found only in one location).

An analysis of the nucleotide substitutions separating the 37 haplotypes revealed that the haplotypes were all closely related, with the number of substitutions ranging between 1 and 13. The mtDNA haplotypes clustered into two major groups and the frequencies of the two haplotype groups differed among sampling sites, particularly in the Alaska and Bering Sea collections compared to samples from further south, although these differences were not statistically significant. Approximately 97% of mtDNA variation occurs within populations and about 2% is found among regions (F_{ST} = 0.023). McLean et al. (1999) also found that genetic distance among sampling locations was correlated with geographic distance ($r^2 = 0.22$, P = 0.0001). Based on these results, McLean et al. (1999) concluded that there was little genetic differentiation among distinct freshwater locations throughout the eulachon range. However, McLean et al. (1999) noted that association of geographic distance and genetic differentiation among eulachon populations suggested an emerging population subdivision throughout the range of the species.

In a later study, McLean and Taylor (2001) used five microsatellite loci to examine variation in the same set of populations as McLean et al. (1999). The populations in the Columbia and Cowlitz rivers were represented by 2 years of samples with a total sample size of 60 fish from each river. However, several populations were represented by very few samples including just 5 fish from the 3 rivers in Gardner Canal and just 10 fish from the Fraser River. Results from a hierarchical analysis of molecular variance test were similar to that of the McLean et al. (1999) mtDNA study, with 0.85% of variation occurring among large regions and 3.75% among populations within regions.

Tests of differentiation were significant among several pairs of populations in the microsatellite study (27% of tests after correction for multiple comparisons), particularly comparisons that included populations in the Columbia and Cowlitz rivers and those with the Nass River sample and samples taken further south. F_{ST} (a commonly used metric to evaluate population subdivision) was estimated as 0.047 when sample sites were considered separately, and was significantly different from zero. In contrast to the mtDNA analysis, genetic distances among populations using these five microsatellite loci were not correlated with geographic distances. Overall, however, McLean and Taylor (2001) concluded that their microsatellite results were mostly consistent with the mtDNA findings of McLean et al. (1999) and that both studies indicated that eulachon have some degree of population structure.

The most extensive study of eulachon, in terms of sample size and number of loci examined, is that of Beacham et al. (2005). Beacham et al. (2005) examined microsatellite DNA variation in eulachon collected at 9 sites ranging from the Columbia River to Cook Inlet, Alaska, using the 14 loci developed by Kaukinen et al. (2004). Sample sizes per site ranged from 74 fish in the Columbia River to 421 from the Fraser River. Samples collected in multiple years were analyzed from populations in the Bella Coola and Kemano rivers (2 years of sampling) and also in the Nass River (3 years of sampling).

Beacham et al. (2005) observed much greater microsatellite diversity within populations than that reported by McLean and Taylor (2001) and all loci were highly polymorphic in all of the sampled populations. Significant genetic differentiation was observed among all comparisons of the nine populations in the study and F_{ST} values for pairs of populations ranged from 0.0014 to 0.0130. A cluster analysis of genetic distances showed genetic affinities among the populations in the Fraser, Columbia, and Cowlitz rivers and also among the Kemano, Klinaklini, and Bella Coola rivers along the central British Columbia coast. In particular, there was evidence of a genetic discontinuity north of the Fraser River, with Fraser and Columbia/Cowlitz samples being approximately 3–6 times more divergent from samples further to the north than they were to each other (Figure 9). Similar to the mtDNA study of McLean et al. (1999), Beacham et al. (2005) also found that genetic differentiation among populations (F_{ST}) was correlated with geographic distances (r = 0.34, $P < 0.05$).

Beacham et al. (2005) found stronger evidence of population structure than the earlier genetic studies, and concluded that their results indicated that management of eulachon would be appropriately based at the level of the river drainage. In particular, the microsatellite analysis showed that populations of eulachon in different rivers are genetically differentiated from each other at statistically significant levels. The authors suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish, but less than that observed in most salmon species.

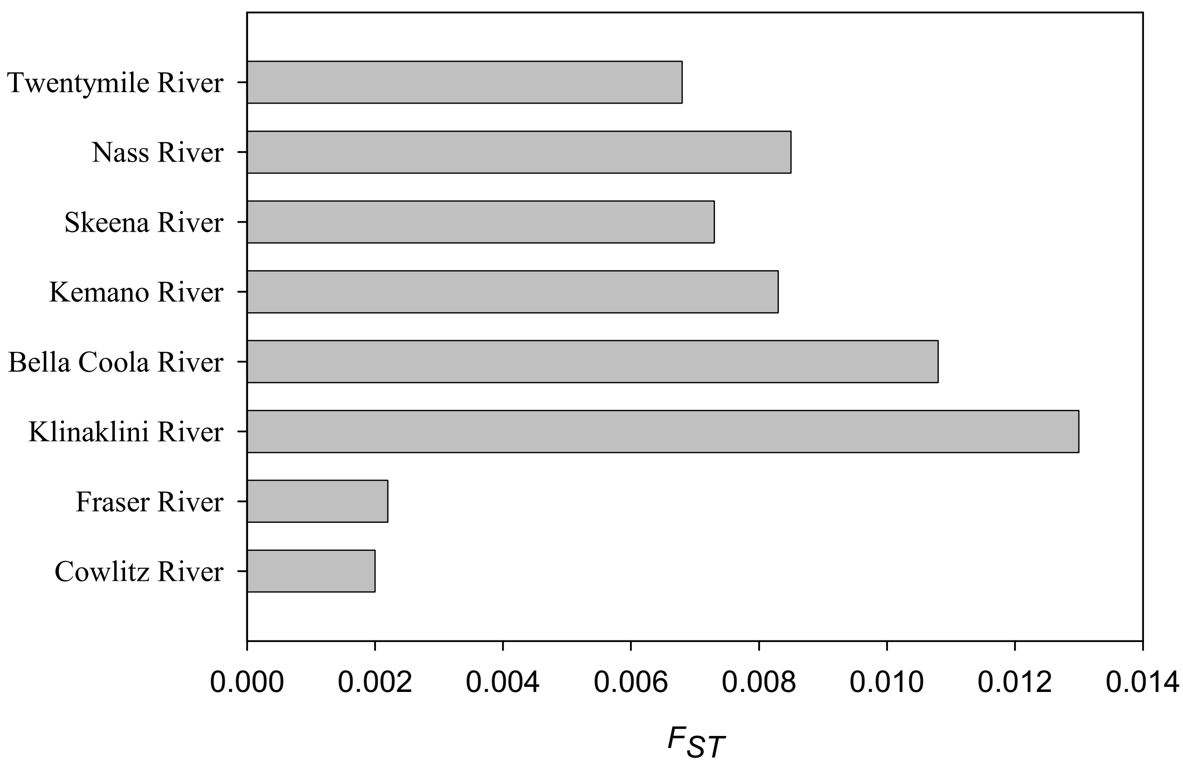

Figure 9. Comparison of F_{ST} (a measure of genetic distance) values of the Columbia River eulachon sample to other samples. Data are from Beacham et al. (2005, their Table 4). See Beacham et al. (2005, their Figure 1) for sampling locations.

Although Beacham et al. (2005) found clear evidence of genetic structure among eulachon populations, the authors also noted that important questions remained unresolved. The most important one in terms of identifying a DPS or DPSs for eulachon is the relationship between temporal and geographic patterns of genetic variation. In particular, Beacham et al. (2005) found that year-to-year genetic variation within three British Columbia coastal river systems was similar to the level of variation among the rivers, which suggests that patterns among rivers may not be temporally stable. However, in the comparisons involving the Columbia River samples, the variation between the Columbia samples and one north-of-Fraser sample from the same year was approximately five times greater than a comparison within the Columbia from two different years. Taken together, there appears to be little doubt that there is some genetic structure within eulachon and that the most obvious genetic break appears to occur in southern British Columbia north of the Fraser River. To fully characterize genetic relationships among eulachon populations, additional research will be needed to identify appropriate sampling and data collection strategies.

Ecological features

The analysis of ecological features or habitat characteristics may be informative in identifying population segments that occupy unusual or distinctive habitats, relative to the biological species as a whole. One of the criteria that may be useful for evaluating discreteness as articulated in the joint DPS policy (USFWS-NMFS 1996) relates to the population being "markedly separated from other populations of the same taxon as a consequence of … ecological … factors." In addition, the persistence of a discrete population segment in an ecological setting unusual or unique for the taxon is also a factor identified in the joint DPS policy that may provide evidence of the population's significance. Oceanographic and other ecological features may also contribute to demographic isolation between marine populations.

Freshwater (spawning) environment—The presumed fidelity with which eulachon return to their natal river, estuary, inlet, or area implies a close association between a specific stock and its freshwater or estuarine environment. Differences in life history strategies among eulachon populations or stocks may have arisen, in part, in response to selective pressures of different freshwater and estuarine environments. If the boundaries of distinct freshwater or estuarine habitats coincide with substantial differences in life histories, it would suggest a certain degree of local adaptation. Therefore, identifying distinct freshwater, terrestrial, and climatic regions may be useful in identifying eulachon DPSs.

The Environmental Protection Agency has established a system of ecoregion designations based on soil content, topography, climate, potential vegetation, and land use for the conterminous United States (Omernik 1987) and Alaska (Gallant et al. 1995). Historically, the distribution of eulachon in Washington, Oregon, and California corresponds closely with the Coastal Range Level III Ecoregions as defined in Omernik and Gallant (1986) and Omernik (1987). Similarly, Environment Canada (2008) has established a system of ecozones and ecoregions in Canada. Ecozones in Canada have been described as "areas of the earth's surface representative of large and very generalized ecological units characterized by interactive and adjusting abiotic and biotic factors." Each ecozone consists of numerous ecoregions that are described as "a part of a province characterized by distinctive regional ecological factors, including climatic, physiography, vegetation, soil, water, fauna, and land use" (Environment Canada 2008).

Coastal range ecoregions of the United States—Extending from the Olympic Peninsula through the Coast Range proper and down to the Klamath Mountains and the San Francisco Bay area, this region is influenced by medium to high rainfall levels due to the interaction between marine weather systems and the mountainous nature of the region. Topographically, the region averages about 500 m in elevation, with mountain tops under 1,200 m. These mountains are generally rugged with steep canyons. Between the ocean and the mountains lies a narrow coastal plain composed of sand, silt, and gravel. Tributary streams are short and have a steep gradient; therefore, surface runoff is rapid and water storage is relatively short term during periods of no recharge.

These rivers are especially prone to low flows during times of drought. Regional rainfall averages 200–240 cm per year, with generally lower levels along the southern Oregon coast. Average annual river flows for most rivers in this region are among the highest found on the West Coast when adjusted for watershed area. Peak flow of coastal rivers occurs during winter rain storms common in December and January. Snow melt adds to the surface runoff in the spring, providing a second flow peak (spring freshet), and there are long periods when the river flows are maintained at a level of at least 50% of peak flow. During July or August there is usually little or no precipitation; this period may expand to 2 or 3 months every few years. River flows are correspondingly at their lowest and temperatures at their highest during August and September, with the exception of glacier fed systems. The region is heavily forested primarily with Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). Forest undergrowth is composed of numerous types of shrubs and herbaceous plants.

Terrestrial ecozones and ecoregions of Canada—All rivers that support regular runs of eulachon in British Columbia are within the Pacific Maritime Ecozone, which consists of 14 ecoregions (Figure 10). The Lower Mainland, Pacific Ranges, and Coastal Gap ecoregions contain rivers supporting regular runs of eulachon as defined in Hay and McCarter (2000) and Hay (2002), and two rivers, the Nass and the Skeena, drain out of the Nass Basin Ecoregion (Environment Canada 2008).

The Lower Mainland Ecoregion (196 in Figure 10) is dominated by the Fraser River and occupies the Fraser River valley from Chilliwack and the Cascade Range foothills downstream to the Fraser River delta and northward from there to incorporate the Sunshine Coast. Mean summer and winter air temperatures in this region are 15°C and 3.5°C, respectively. At sea level, less than 10% of winter precipitation falls as snow, although maximum precipitation occurs in the winter. Mean annual precipitation in the Fraser River valley ranges from 200 cm in the Cascade foothills to 85 cm at the river's mouth. Douglas fir *(Pseudotsuga menziesii*) dominates native forest stands with an understory typically containing hollyleaved barberry, aka tall Oregon grape (*Mahonia aquifolium*), salal (*Gaultheria shallon*), and mosses. Disturbed sites are commonly dominated by stands of red alder (*Alnus rubra*). Drier natural sites consist of mixed stands of Pacific madrone (*Arbutus menziesii*), Douglas fir, western hemlock, and occasionally, Pacific dogwood (*Cornus nuttallii*). Wetter areas contain mixtures of western red cedar, Douglas fir, and western hemlock. Soils consist of unconsolidated clay-like and silty

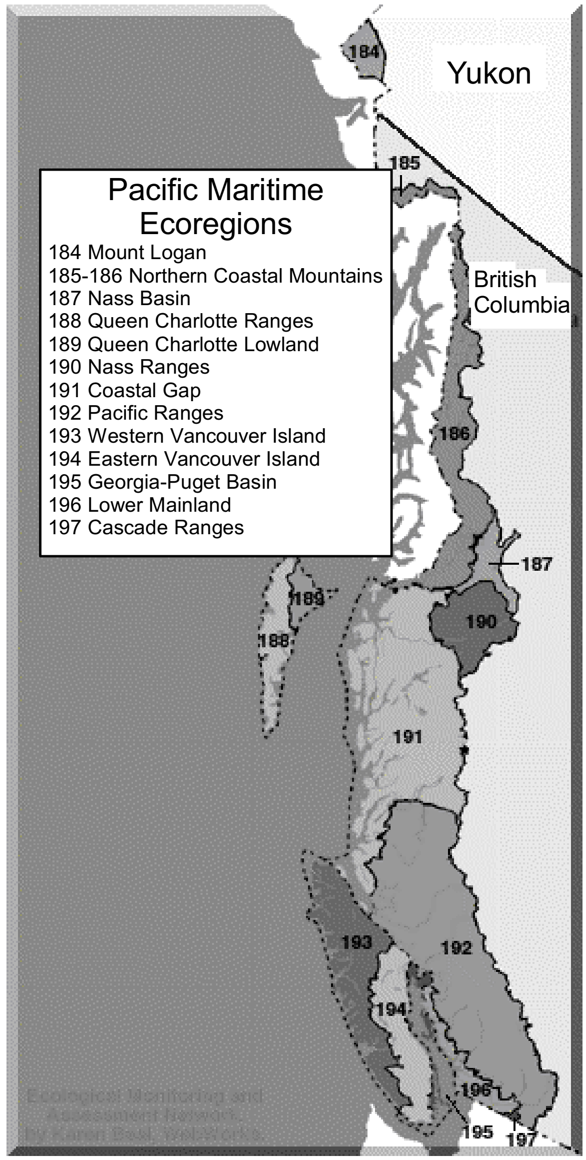

Figure 10. Ecoregions in the Pacific Maritime Ecozone of British Columbia. Map modified from online source: http://ecozones.ca/english/zone/PacificMaritime/ecoregions.html.

marine deposits, silty alluvium, glacial till, and glaciofluvial deposits. Eastern hills in the ecoregion up to 310 m in height are formed from bedrock outcrops of Mesozoic and Paleozoic age.

The Pacific Ranges Ecoregion (192 in Figure 10) extends from the southern extent of the steeply sloping irregular Coast Mountains at the U.S.-Canada border to Bella Coola in the north. These mountains range from sea level to as high as 4,000 m and are made up of granite and crystalline gneisses. Many rivers in this region originate in expansive ice fields, and numerous glaciers extend into the lowlands. Many steep-sided, transverse valleys bisect these mountains and terminate in inlets or fjords. Mean summer and winter air temperatures in this region are

13.5°C and –1°C, respectively. Mean annual precipitation in this ecoregion ranges from 340 cm at high elevations to 150 cm at sea level. This ecoregion consists of three main regions distinguished by altitude: an alpine zone above 1,800 m, a subalpine zone between 900 and 1,800 m, and a coastal forest zone below 900 m. The coastal forest zone is dominated by stands of western red cedar, western hemlock, and Pacific silver fir (*Abies amabilis*) and in drier sites by Douglas fir and western hemlock.

The Coastal Gap Ecoregion (191 in Figure 10) extends from Dean Channel north to the border between British Columbia and Alaska and is bounded by the taller Pacific Ranges to the south and the Boundary Ranges to the north. The low-relief mountains in this ecoregion consist of the Kitimat Ranges, which rarely reach higher than 2,400 m and are made up of granitic rocks and crystalline gneisses. Although many inlets and fjords bisect this mountainous coastline and terminate in steep-sided, transverse valleys, glaciers are less common and smaller than in areas to the south and north of this ecoregion. Mean summer and winter air temperatures are 13°C and –0.5°C, respectively. This ecoregion has the highest mean annual precipitation in British Columbia, ranging from 200 cm on the coast to more than 450 cm at high elevations. At sea level, the forests are dominated by western red cedar, yellow cedar (*Chamaecyparis nootkatensis*), and western hemlock. Some Sitka spruce and shore pine (*Pinus contorta* var. *contorta*) are also present with red alder being common on disturbed sites. Low-lying bogs and stream fens are common types of wetlands. Forests in upland areas are dominated by western red cedar and western hemlock, whereas Pacific silver fir and western hemlock are found in areas with poorer drainage.

The Nass Basin Ecoregion (187 in Figure 10) lies between the interior and coastal portions of the Coast Mountains in west-central British Columbia and is an area of low relief composed of folded Jurassic and Cretaceous sediments that is almost encircled by mountains. The Nass Basin is drained by the Nass and Skeena rivers to the ocean through large gaps in the Coast Mountains and consists of a gently rolling landscape generally below 750 m in altitude. Mean summer and winter air temperatures in this region are 11.5°C and –9.5°C, respectively. Mean annual precipitation ranges up to 250 cm at higher elevations to 150 cm in the lowlands. The moist montane zone is dominated by western red cedar and western hemlock, whereas forests in the subalpine zone contain subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta* var. *latifolia*), and Engelmann spruce (*Picea engelmannii*).

Oceanic environment—Ware and McFarlane (1989) built on previous descriptions of oceanic domains in the northeast Pacific Ocean by Dodimead et al. (1963) and Thomson (1981) to identify three principal fish production domains: 1) a southern Coastal Upwelling Domain, 2) a northern Coastal Downwelling Domain, and 3) a central Subarctic Domain (aka the Alaskan Gyre) (Figure 11). The boundary between the Coastal Upwelling Domain and Coastal Downwelling Domain occurs where the eastward flowing Subarctic Current (aka the North Pacific Current) bifurcates to form the north-flowing Alaska Current and the south-flowing California Current in the vicinity of a transitional zone between the northern tip of Vancouver Island and the northern extent of the Queen Charlotte Islands (Figure 11). Similarly, Longhurst (2006) identifies an Alaska Downwelling Coastal Province and a California Current Province within the Pacific Coastal Biome.

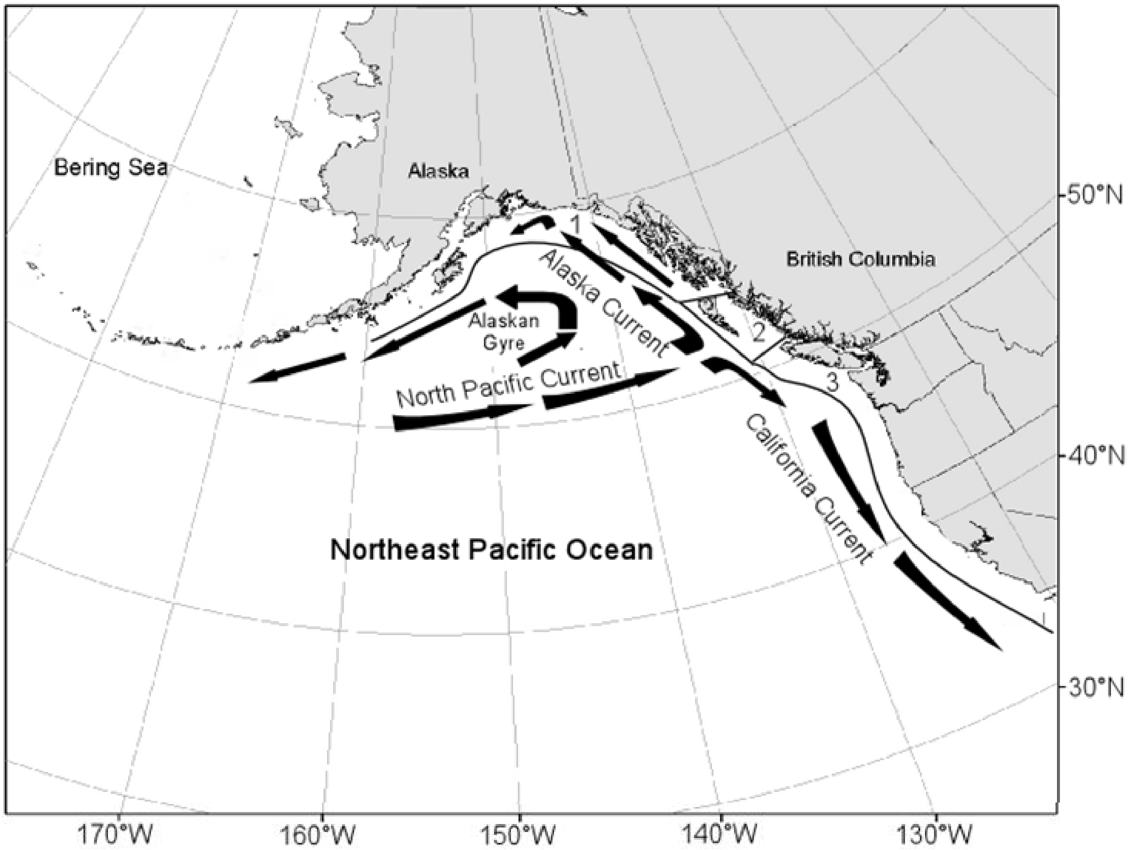

Figure 11. Approximate locations of oceanographic currents, oceanic domains (Ware and McFarlane 1989), and coastal provinces (Longhurst 2006) in the Northeast Pacific Ocean. 1–Alaska Coastal Downwelling Province (aka Coastal Downwelling Domain), 2–Transition Zone, and 3–California Current Province (aka Coastal Upwelling Domain).

Longhurst's (2006) work provides a worldwide ecological geography of the sea that identifies 4 primary oceanic biomes and 51 biogeochemical provinces based mainly on differences in regional physical processes that act on regional patterns of phytoplankton growth that are partially defined by "the interaction between light, nutrients, mixing, and stability in the upper part of the water column." This scheme to partition the ocean into provinces differs from previous attempts by relying on oceanographic features that drive phytoplankton ecology rather than on biogeography of species or water current patterns alone (Longhurst 2006). The steps taken and data analyzed to define biogeochemical provinces in the ocean are detailed in Longhurst (2006).

Within Longhurst's (2006) Pacific Coastal Biome, ocean distribution of eulachon spans the Alaska Downwelling Coastal Province and the northern portion of the California Current Province (Figure 11). Longhurst (2006) places the boundary between the Alaska Coastal Downwelling Province and the California Current Province between the Queen Charlotte Islands at 53°N latitude and the northern end of Vancouver Island at 47–48°N latitude, where the eastward flowing North Pacific Current encounters the North American continent and bifurcates to form the north-flowing Alaska Current and south-flowing California Current. Different modes of physical forcing and nutrient enrichment characterize these provinces.

The Alaska Coastal Downwelling Province spans the coastal boundary region from the Aleutian Islands east and south to the Queen Charlotte Islands (Haida Gwai'i) at about 53°N latitude and extends seaward to the Alaska Current velocity maximum (Longhurst 2006). The continental shelf in this region is dominated by nearly year-round onshore downwelling winds. Large amounts of precipitation and runoff from melting glaciers along the mountainous Alaska coast is another feature of this province. In summer and fall, when runoff is at maximum, waters in the fjord-like coastline and in the Alaska Coastal Current are usually highly stratified in both temperature and salinity. Following the spring phytoplankton bloom, stratification in the top layers of the water column limits nutrient availability and leads to subsequent nutrient depletion. Occasional wind events lead to temporary local upwelling of nutrients and subsequent phytoplankton blooms.

The northern extent of the California Current Province (aka California Upwelling Coastal Province) begins where the eastward flowing North Pacific Current splits near Vancouver Island near 47–48°N latitude, creating the southward flowing California Current and northward flowing Alaska Coastal Current (Longhurst 2006). The southern boundary of this province occurs off the southwest tip of Baja California, where the North Equatorial Current begins. Seasonal wind-driven upwelling is a dominate feature of this province, especially in the northern portion of the province. This process carries nutrients onshore where they are upwelled along the coast, leading to high primary production that lasts through much of the spring and summer. Nearshore upwelling also results in higher salinities and lower temperatures compared to offshore locations.

A widely recognized Transition Pacific Zone (Ware and McFarlane 1989, BC Ministry of Sustainable Resource Management 2002) occurs between the Alaska Coastal Downwelling and California Current provinces whose "northern boundary is indistinct and approximately coincident with the southern limit of the Alaskan Current" (BC Ministry of Sustainable Resource Management 2002, p. 35). This zone is characterized as a mixing area between boreal plankton communities to the north and temperate plankton communities to the south, and incorporates the waters of Queen Charlotte Sound and Hecate Strait (i.e., north of Vancouver Island and inshore of the Queen Charlotte Islands). In the summer, the California Current may affect the southern portion of this transition zone with the inshore Davidson Current flowing south in the summer and north in the winter (BC Ministry of Sustainable Resource Management 2002).

Marine zoogeographic provinces

Marine zoogeography attempts to identify regional geographic patterns in marine species' distribution and delineate faunal provinces or regions based largely on the occurrence of endemic species and of unique species' assemblages (Ekman 1953, Hedgpeth 1957, Briggs 1974, Allen and Smith 1988). These province boundaries are usually coincident with changes in the physical environment such as temperature and major oceanographic currents. Similar to the above ecological features category, boundaries between zoogeographic provinces may indicate changes in the physical environment that are shared with the species under review.

Ekman (1953), Hedgpeth (1957), and Briggs (1974) summarized the distribution patterns of coastal marine fishes and invertebrates and defined major worldwide marine zoogeographic zones or provinces. Along the coastline of the boreal eastern Pacific, which extends roughly from Point Conception, California, to the eastern Bering Sea, numerous schemes have been proposed for grouping the faunas into zones or provinces. A number of authors (Ekman 1953, Hedgpeth 1957, Briggs 1974, Allen and Smith 1988) have recognized a zoogeographic zone within the lower boreal eastern Pacific that has been termed the Oregonian Province.

Another zone in the upper boreal eastern Pacific has been termed the Aleutian Province (Briggs 1974). However, exact boundaries of zoogeographic provinces in the eastern boreal Pacific are in dispute (Allen and Smith 1988). Briggs (1974) and Allen and Smith (1988) reviewed previous literature from a variety of taxa and from fishes, respectively, and found the coastal region from Puget Sound to Sitka, Alaska, to be a gray zone or transition zone that could be classified as part of either of two provinces: Aleutian or Oregonian (Figure 12). The southern boundary of the Oregonian Province is generally recognized as Point Conception, California, and the northern boundary of the Aleutian Province is similarly recognized as Nunivak in the Bering Sea or perhaps the Aleutian Islands (Allen and Smith 1988).

Briggs (1974) placed the boundary between the Oregonian and Aleutian provinces at Dixon Entrance, based on the well-studied distribution of mollusks, but indicated that distributions of fishes, echinoderms, and marine algae gave evidence for placement of this

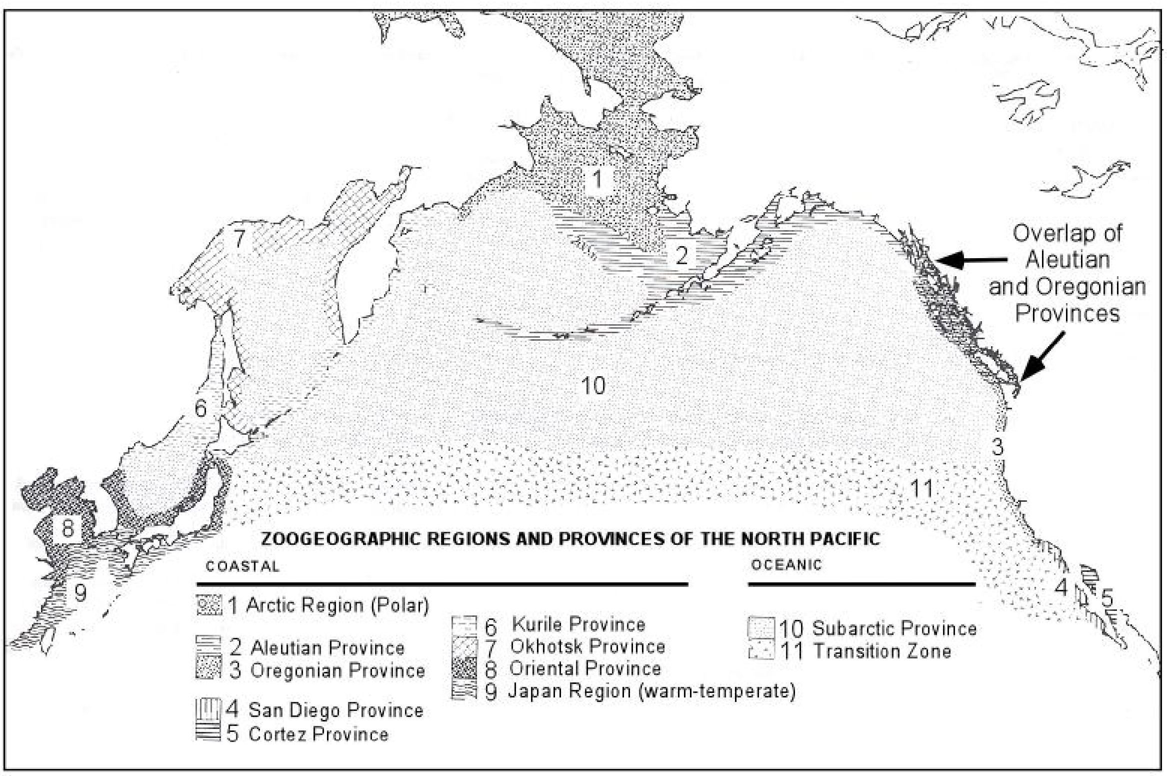

Figure 12. Marine zoogeographic provinces of the North Pacific Ocean. Modified after Allen and Smith (1988).

boundary in the vicinity of Sitka, Alaska. Briggs (1974) placed strong emphasis on the distribution of littoral mollusks (due to the more thorough treatment this group has received) in placing a major faunal break at Dixon Entrance. The authoritative work by Valentine (1966) on distribution of marine mollusks of the northeastern Pacific shelf showed that the Oregonian molluscan assemblage extended to Dixon Entrance with the Aleutian fauna extending northward from that area. Valentine (1966) erected the term Columbian Subprovince to define the zone from Puget Sound to Dixon Entrance.

Several lines of evidence suggest that an important zoogeographic break for marine fishes occurs in the vicinity of Southeast Alaska. Peden and Wilson (1976) investigated the distributions of inshore fishes in British Columbia and found Dixon Entrance to be of minor importance as a barrier to fish distribution. A more likely boundary between these fish faunas was variously suggested to occur near Sitka, Alaska, off northern Vancouver Island, or off Cape Flattery, Washington (Peden and Wilson 1976, Allen and Smith 1988). Chen (1971) found that of the more than 50 or more rockfish species belonging to the genus Sebastes occurring in northern California, more than two-thirds do not extend north of British Columbia or Southeast Alaska. Briggs (1974, p. 278) stated that "about 50 percent of the entire shore fish fauna of western Canada does not extend north of the Alaskan Panhandle." In addition, many marine fish species common to the Bering Sea extend southward into the Gulf of Alaska, but apparently occur no further south (Briggs 1974). Allen and Smith (1988, p. 144) noted that "the relative abundance of some geographically displacing [marine fish] species suggest that the boundary between these provinces [Aleutian and Oregonian] occurs off northern Vancouver Island."

Blaylock et al. (1998) examined the distribution of more than 25 species of parasites in 432 juvenile and adult Pacific halibut sampled over much of its North American range and found evidence of three zoogeographic zones as determined by parasite clustering; northern, central, and southern. Similar to studies with other invertebrates, Blaylock et al. (1998, p. 2,269) found a breakpoint between zoogeographic zones in the vicinity of the Queen Charlotte Islands.

Other marine fish DPS designations

It is also useful to briefly review the size and complexity of other designated DPSs of marine fish that have undergone the status review process and have thus been considered both discrete and significant to their respective biological species. DPSs have been designated for portions of the range of Pacific herring (NMFS 2000, 2005, 2008b), Pacific hake, Pacific cod, walleye pollock (NMFS 2000), copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*), brown rockfish (*S. auriculatus*) (NMFS 2001), bocaccio (*S. paucispinis*) (NMFS 2002), and smalltooth sawfish (*Pristis pectinata*) (NMFS 2003).

Several marine fish DPSs cover large geographic areas (e.g., Pacific cod and walleye pollock DPSs extend from Puget Sound to Southeast Alaska, two West Coast DPSs of bocaccio rockfish were designated off Washington and Oregon [the northern DPS] and off California and Mexico [the southern DPS], and all smalltooth sawfish in U.S. waters were designated a separate DPS). At slightly smaller geographic scales, a Southeast Alaska Pacific herring DPS (Carls et al. 2008) and DPSs of Pacific hake and Pacific herring in Georgia Basin (Puget Sound and the straits of Georgia and Juan de Fuca) were established as separate from coastal hake and herring (Gustafson et al. 2000, Stout et al. 2001a) (Figure 13). Three DPSs each of copper and quillback rockfish (Puget Sound Proper DPS, Northern Puget Sound DPS, and Coastal DPS) and two of brown rockfish (Puget Sound Proper DPS and Coastal DPS) have also been delineated (Stout et al. 2001b). Many of these marine fish DPSs include a number of identifiable subpopulations with numerous isolated spawning locations and a substantial level of life history and ecological diversity (Gustafson et al. 2000, 2006, Stout et al. 2001a, Carls et al. 2008).

Evaluation of Discreteness and Significance for Eulachon

In past evaluations of distinct population boundaries for marine fish (Gustafson et al. 2000, 2006, Stout et al. 2001a), spawn timing, spawning distribution, tagging, biogeography, ecological factors, seasonal migration patterns, parasite incidence, genetic population structure, morphometrics, meristics, and demographic data (growth rate, fecundity, etc.) have been evaluated for evidence of DPS discreteness and significance. The BRT examined similar evidence for eulachon and found evidence that was informative included genetic data, differences in spawning temperatures and length-at-maturity and weight-at-maturity of eulachon between northern and southern rivers, ecological features of both the oceanic and terrestrial environments occupied by eulachon, and biogeography.

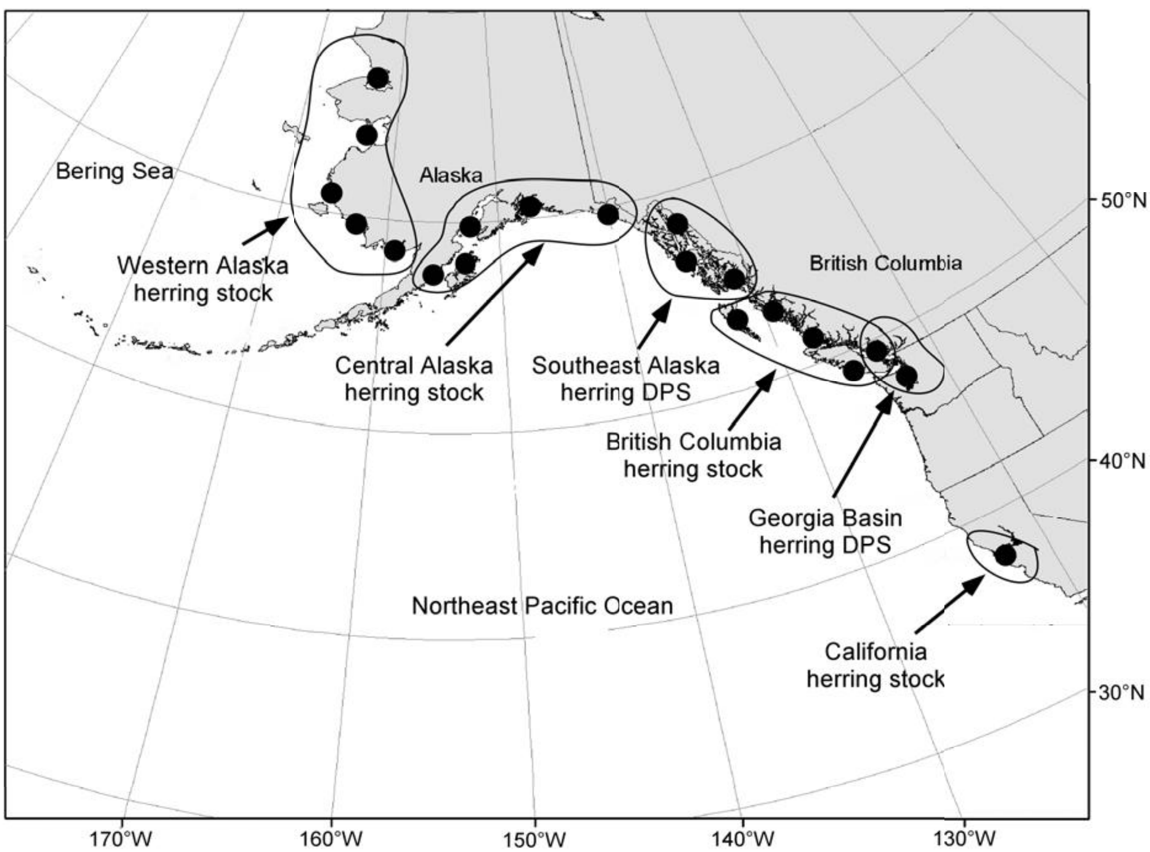

Figure 13. Major stocks of Pacific herring in the Northeast Pacific in relation to the Georgia Basin Pacific herring DPS (Stout et al. 2001a, Gustafson et al. 2006) and the Southeast Alaska Pacific herring DPS (Carls et al. 2008).

To allow for expressions of the level of uncertainty in identifying the boundaries of a discrete and significant eulachon population, the BRT adopted a likelihood point method, often referred to as the FEMAT method, because it is a variation of a method used by scientific teams evaluating options under the Forest Plan (Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team, or FEMAT) (FEMAT 1993). This method was previously used in the DPS decisions for Southern Resident killer whales (Krahn et al. 2004) and Pacific herring (Gustafson et al. 2006). In this approach, each BRT member distributes 10 "likelihood" points among a number of proposed DPSs, reflecting their opinion of how likely that proposal correctly reflects the true DPS boundary. Thus if a member were certain that the DPS that contains eulachon from California, Oregon, and Washington included all spawning aggregations from the Fraser to the south, he or she could assign all 10 points to that proposal. A member with less certainty about DPS boundaries could split the points among two, three, or even more DPS proposals (Table 1).

The BRT ultimately considered six possible DPS configurations or scenarios that might conceivably incorporate eulachon that spawn in Washington, Oregon, and California rivers. Each BRT member distributed his or her 10 likelihood points amongst these six scenarios. Other possible geographic configurations that incorporated the petitioned unit were contemplated but not seriously considered by the BRT. The BRT did not attempt to divide the entire species into DPSs, but rather focused on evaluating whether a DPS could be identified that contains eulachon that spawn in Washington, Oregon, and California. The geographic boundaries (Figure 14) of possible DPSs considered in this evaluation were:

1. The entire biological species is the ESA species (i.e., there is no apparent DPS structure)
2. One DPS inclusive of eulachon in Southeast Alaska to northern California
3. One DPS south of the Nass River/Dixon Entrance
4. One DPS inclusive of eulachon in the Fraser River to California
5. One DPS south of the Fraser River (i.e., one DPS in Washington, Oregon, and California)
6. Multiple DPSs of eulachon in Washington, Oregon, and California

The distribution of likelihood points among these six scenarios is presented in Table 1. Scenario 1 (no DPS structure) received about 12% of the total likelihood points. Scenarios 2 (one DPS inclusive of eulachon in Southeast Alaska to northern California) and 5 (one DPS south of the Fraser River) received no support on the BRT. There was also very little support on the BRT for multiple DPSs of eulachon in the conterminous United States; only about 4% of the likelihood points were placed in scenario 6 (multiple DPSs of eulachon in Washington, Oregon, and California).

All remaining likelihood points (84%) were distributed among scenarios supporting a DPS at a level larger than the petitioned unit of Washington, Oregon, and California. Scenario 3 (one DPS south of the Nass River/Dixon Entrance) received about 57% of the total likelihood points and all but one BRT member placed between 5 and 10 points in this DPS scenario. Scenario 4 (one DPS inclusive of eulachon in the Fraser River to California) received significant

Table 1. Worksheet for evaluating potential of DPS or DPSs of eulachon (*Thaleichthys pacificus*) that incorporate spawning populations in California, Oregon, and Washington using the "likelihood point" method (FEMAT 1993).

	Likelihood points	
Scenario	**Number**[a]	**Percentage**[b]
1) Entire species (no DPS structure)	11	12.2
2) One DPS south of Yakutat Forelands	—	—
3) One DPS south of Nass River and Dixon Entrance	51	56.7
4) One DPS, Fraser River and south	24	26.7
5) One DPS south of Fraser River	—	—
6) Multiple DPSs in Washington, Oregon, and California	4	4.4

[a]Each BRT member distributes 10 likelihood points among the 6 DPS scenarios. Placement of all 10 points in a given scenario reflects 100% certainty that this is the DPS configuration that incorporates eulachon from Washington, Oregon, and California. Distributing points between scenarios reflects uncertainty in whether a given scenario reflects the true DPS delineation.
[b]Nine of 10 BRT members in attendance.

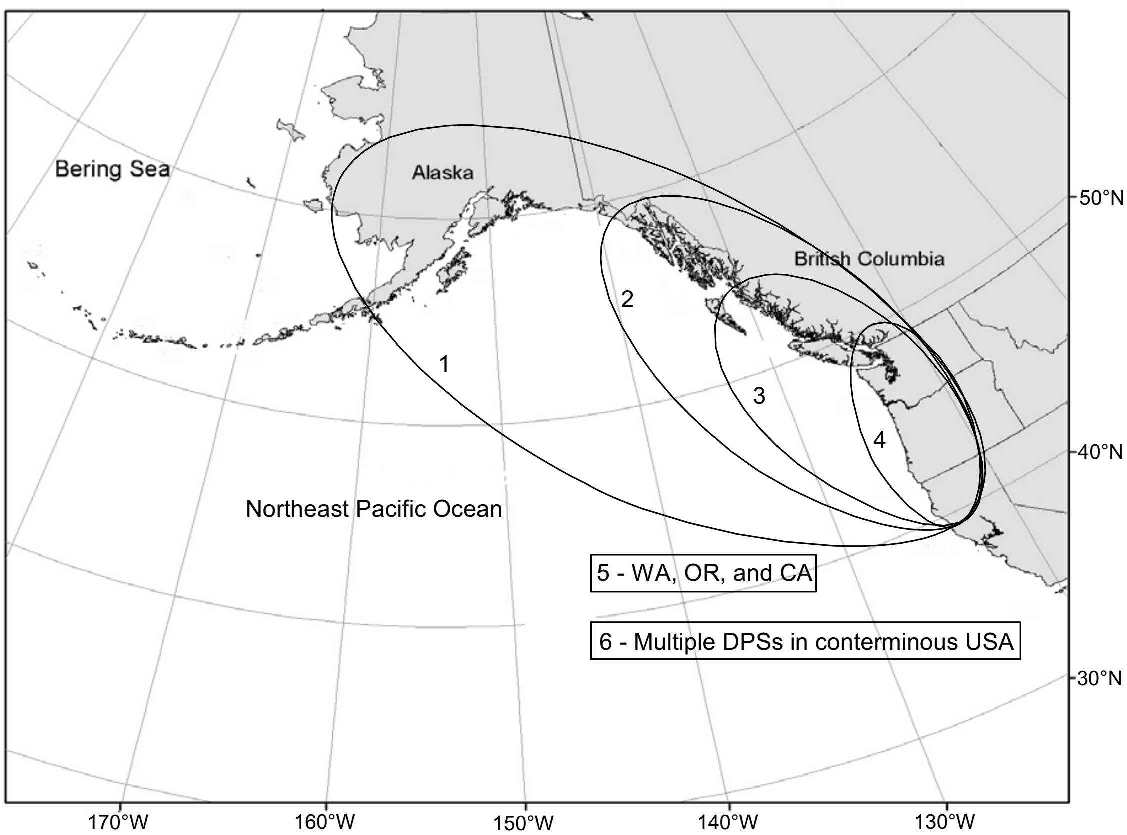

Figure 14. Geographic boundaries of possible eulachon DPSs considered by the BRT: 1) the entire biological species is one DPS, 2) one DPS south of the Yakutat Forelands (Southeast Alaska to northern California), 3) one DPS south of the Nass River (i.e., south of Dixon Entrance), 4) one DPS that includes the Fraser River and south, 5) one DPS south of the Fraser River (i.e., one DPS in Washington, Oregon, and California), and 6) multiple DPSs of eulachon in Washington, Oregon, and California.

support with about 27% of all points placed in this scenario and all but two members placed from 2 to 5 of their likelihood points in this DPS scenario. In discussing the evidence for these alternative scenarios, the BRT focused on the following factors.

In considering the discreteness and significance criteria (USFWS-NMFS 1996), the BRT concluded that the weight of the available evidence indicated that there are multiple discrete populations of eulachon. In particular, the most comprehensive genetic study of eulachon that has been published to date (Beacham et al. 2005) found reasonably strong evidence of a genetic break between eulachon spawning in the Fraser and Columbia rivers compared to those spawning in rivers further north in British Columbia and Alaska, and also found that nearly all sampled populations were differentiated statistically from each other. Earlier genetic studies (McLean et al. 1999, McLean and Taylor 2001) also found some evidence of population structure, although the evidence was less compelling than that reported by Beacham et al. (2005). However, these earlier studies were characterized by fewer loci and smaller sample sizes than the later study and therefore likely had less power to detect population structure. Overall, the BRT believed the results to be largely consistent among the studies, when differences in sample size and power are taken into account. The BRT did note, however, that there was some uncertainty about the genetic population structure due to the small number of temporally replicated samples in all of the studies, and this uncertainty is reflected in the proportion of the likelihood points that were placed in the no DPS structure category (Table 1).

In addition to the genetic data, the BRT considered the strong ecological and environmental break that occurs between the California Current and Alaska Current oceanic domains as contributing evidence for discreteness, a factor that was also important for identifying DPS structure in Pacific cod (Gustafson et al. 2000), killer whales (Krahn et al. 2004), and Southeast Alaska Pacific herring (Carls et al. 2008). The BRT also considered, but did not weigh heavily, the latitudinal differences in spawn timing, body size, and vertebral counts among samples from different rivers. Similar latitudinal patterns in life history characters were considered but did not weigh heavily in DPS decisions for Pacific cod, walleye pollock (Gustafson et al. 2000), and Pacific herring (Stout et al. 2001a). Overall, the BRT believed the genetic and ecological data provided strong evidence that eulachon south of the Nass River were discrete from those in the Nass River and northward, but that there was also evidence (from the genetic data) suggesting that Fraser and Columbia River groups may be discrete from more northern groups.

In evaluating the significance criteria, the BRT focused primarily on criteria 1 (ecological setting), criteria 2 (evidence that loss would result in a significant gap in the range of the species), and criteria 4 (markedly differs in genetic characteristics). After carefully discussing all of the available data, the BRT concluded that there was evidence supporting the significance criteria under either scenario 3 (one DPS south of the Nass River/Dixon Entrance) or scenario 4 (one DPS inclusive of eulachon in the Fraser River to California). In particular, there is evidence under either scenario for a significant break in ecological setting, and loss of a putative DPS defined by either boundary would without question result in a significant gap (or reduction) in the range of the overall species. The BRT also considered whether the available genetic data provided any evidence for "markedly different" populations, but concluded that although the genetic data provides evidence for discreteness (lack of gene flow) there was little evidence to support the existence of deep intraspecific phylogenetic breaks that the BRT believed were necessary to be considered "marked."

In summary, the BRT believed the evidence most strongly supported scenario 3, but that there was also some evidence for scenarios 4 and 1. The factors supporting each of the top three scenarios are summarized below.

Scenario 3

This scenario designated one DPS south of the Nass River/Dixon Entrance (57% support). Supporting factors were:

1. Beacham et al. (2005) found strong evidence that populations of eulachon in different rivers are genetically differentiated from each other at statistically significant levels and the authors suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish but less than that observed in most Pacific salmon species.
2. A major ecological break occurs in the coastal ocean biome between the Coastal Downwelling Province (Ware and McFarlane 1989, Longhurst 2006) to the north and the California Current Province (Ware and McFarlane 1989, Longhurst 2006) to the south. The northern boundary of the transition zone that separates these provinces occurs in the vicinity of the Dixon Entrance at the northern end of the Queen Charlotte Islands. The coastal distribution of eulachon south of the Dixon Entrance occupies an ecologically discrete area that is a combination of this transition zone and the northern California Current Province (Longhurst 2006).
3. Dixon Entrance is also the approximate northern boundary that separates two major marine zoogeographic provinces (Oregonian and Aleutian Provinces) (Briggs 1974), further supporting the ecological discreteness of marine waters south of Dixon Entrance.
4. Stocks of eulachon from the Columbia River to the Klinaklini River in British Columbia experienced a nearly simultaneous collapse in 1994 (Hay and McCarter 2000, Hay 2002), stayed at low levels throughout the 1990s, experienced a rebound in 2001–2003, and subsequently declined to near record low levels of abundance (Hay 2002, JCRMS 2007). The nearly synchronous demographic responses of all eulachon stocks south of the Nass River to what are likely coast-wide changes in ocean condition, strongly suggest that these stocks occupy a common ocean rearing environment. Stocks of eulachon from the Nass River and north remained relatively healthy throughout this period of decline of more southern stocks. Not until 2003 did eulachon stocks in southern Southeast Alaska begin to show serious declines. These demographic patterns are similar to those seen in Pacific salmon stock abundance that fluctuates in opposite directions in the Alaska and California Current domains (Hare et al. 1999), which has been correlated with the Pacific Decadal Oscillation (PDO) (Mantua and Hare 2002).
5. A major break in terrestrial ecoregions also occurs along the north coast of British Columbia in the vicinity of the Nass River, with both the Nass and Skeena rivers draining the interior Nass Basin Ecoregion (Environment Canada 2008). Evidence of a natural biological boundary coinciding with the international boundary separating Southeast Alaska and British Columbia (Dixon Entrance/Nass River) also supported delineation of

- Different biological zones are apparent along the coast, probably a result of both thermal (north-south) and salinity (east-west) gradients.
- A thermal gradient is clearly evident through British Columbia and Southeast Alaska.
    - o Temperatures in Southeast Alaska are colder than in British Columbia.
    - o Southeast Alaska has tidewater glaciers, British Columbia does not, chilling the water and increasing turbidity and possibly nutrients.
    - o Southeast Alaska mainland topography is heavily influenced by snowfields and glaciers; this is less prevalent in British Columbia.

6. Eulachon spawning in rivers on the north coast of British Columbia (e.g., Nass River) experience significantly colder temperatures at spawning (often spawning under ice) than eulachon spawning to the south, particularly in the Klinaklini, Fraser, and Columbia rivers (Hay and McCarter 2000) (Table A-11). Hochachka and Somero (2002, p. 292, 317) emphasized that habitat temperature plays a "strong and frequently dominant role … in governing the distribution patterns of organisms" and that "temperature differences of a few degrees Celsius have sufficient effects on proteins to favor adaptive change." The dominant role that temperature plays on ectothermic organisms, affecting "essentially every aspect of an organism's physiology" (Hochachka and Somero 2002, p. 290), suggests that these 2–4°C temperature differences experienced by adult eulachon and their gametes during spawning (Table A-11) are a strong indicator of potential physiological differences between eulachon south of the Nass River and those in the Nass River and northward.

Items 2–5 above support a discrete and significant eulachon population south of the Nass River/Dixon Entrance on the basis of being "markedly separated on the basis of ecological features" and Item 6 supports a discrete eulachon population south of the Nass River/Dixon Entrance on the basis of being "markedly separated on the basis of physiological features."

Scenario 4

This scenario designated one DPS inclusive of eulachon in the Fraser River to California (27% support). Supporting factors were:

1. The available genetic data indicate that a substantial genetic break occurs between eulachon populations from the Fraser River and those from rivers further to the north (see Genetic Differentiation subsection, p. 61). In particular, the largest genetic discontinuity appears to be in southern British Columbia rather than northern British Columbia.
2. In contrast to systems to the north of the Fraser River, the Columbia, Fraser, and Klamath rivers have many physiographic and habitat features in common; all three are large rivers with wide valleys, drain extensive interior basins, are fed by spring snow melt, and do not drain off extensive ice sheets.

Average length-at-maturity and weight-at-maturity in eulachon from the Columbia and Fraser rivers and southern rivers in general are smaller than eulachon from more northern rivers (Figure 8). However, this pattern is typical in many vertebrate poikilotherms (ectotherms), where higher temperatures lead to reduced size at a given stage of development (Atkinson 1994, Lindsey 1966), so the BRT did not weight this evidence very heavily.

Scenario 1

This scenario designated no DPS structure (12% support). Supporting factors were:

1. There was a lack of apparent discrete differences in many eulachon life history traits (Hay and McCarter 2000, Hay and Beacham 2005); however, similar uniformity in life history characters over large geographic distances was evident in previous marine fish reviews of Pacific cod, walleye pollock (Gustafson et al. 2000), and Pacific herring (Stout et al. 2001a).
2. Another reason BRT members put some support in this scenario was uncertainty about how strongly to weight the genetic study of Beacham et al. (2005). In particular, although the BRT concluded that the study as a whole clearly supported the existence of discrete genetic populations of eulachon, the BRT was also somewhat concerned about the limited temporal replication in the study.

Given the previous DPS structure established for marine fishes, such as Pacific herring, Pacific cod, Pacific hake, and walleye pollock (Gustafson et al. 2000, 2006, Stout et al. 2001a), it seems unlikely that there would be an absence of DPS structure across the more than 2,800 km range of eulachon, an anadromous species with similar among-population genetic differentiation, as these purely marine fishes. Pacific herring, which exhibit genetic variation similar to eulachon when compared over the same geographic range (Beacham et al. 2002, 2005, Small et al. 2005), have had DPSs delineated at the geographic level of the Georgia Basin (Stout et al. 2001a) and Southeast Alaska (Carls et al. 2008), based to a large degree on marked differences in ecological features of their habitats. For example, the estimated mean F_{ST} value for Pacific herring over 13 microsatellite DNA loci and 83 sampling sites ranging from California to Southeast Alaska was 0.0032 (Beacham et al. 2002), whereas a similar estimated mean F_{ST} value over 14 loci and 9 eulachon sampling sites ranging from the Columbia River to Southcentral Alaska was 0.0046 (Beacham et al. 2005).

Although nowhere near the same quantity or quality of data exists for eulachon as for the economically more valuable Pacific herring, it is likely that if data comparable to that for Pacific herring were available, an even finer DPS structure for the anadromous eulachon might become apparent. In addition, the biological heterogeneity of eulachon as seen in “the geographical discontinuity of different spawning runs, different spawning times, and the apparent homing of each run to individual rivers” (Hay and McCarter 2000, p. 36) strongly argues against the lack of DPS structure.

BRT DPS Determination

In conclusion, it was the majority opinion of the BRT that eulachon from Washington, Oregon, and California are part of a DPS that extends beyond the conterminous United States and that the northern boundary of the DPS occurs in northern British Columbia south of the Nass River (most likely) or in southern British Columbia north of the Fraser River (less likely). The BRT proposes that this DPS be termed the southern DPS of eulachon. Although it was not the

BRT's objective to subdivide the entire biological species of eulachon into DPSs throughout their range, the identification of a southern DPS of eulachon indicates that at least one, and possibly more than one, additional DPS or DPSs of eulachon occur north of the Skeena River on the north coast of British Columbia and in Alaska.

Although the BRT could not with any certainty identify multiple populations or DPSs of eulachon within the region south of Dixon Entrance/Nass River, it acknowledged the possibility that significant stock structuring does exist within this region and that a finer DPS structure might be revealed by further information on the behavior, ecology, and genetic population structure of eulachon. The BRT also recognized that the DPS that includes eulachon from California, Oregon, and Washington may represent fish that are uniquely adapted to survive at the southern end of the species' range.

The Extinction Risk Question

Information considered in evaluating the status of a DPS can generally be grouped into two categories: 1) demographic information reflecting the past and present condition of subpopulations (e.g., data on population abundance or density, population trends and growth rates, number and distribution of populations, exchange rates of individuals among populations, and ecological, life history, or genetic diversity among populations) and 2) information on past factors for decline as well as threats faced by the DPS (e.g., habitat loss and degradation, overutilization, disease, climate change). The demographic risk data reviewed by the BRT are summarized in this document. This document also contains a narrative summary of threats faced by the DPS.

Evaluating extinction risk of a species includes considering the available information concerning the abundance, growth rate and productivity, spatial structure and connectivity, and diversity of a species and assessing whether these demographic criteria indicate that it is at high risk of extinction, at moderate risk, or neither. A species at very low levels of abundance and with few populations will be less tolerant to environmental variation, catastrophic events, genetic processes, demographic stochasticity, ecological interactions, and other processes (e.g., Gilpin and Soulé 1986, Meffe and Carroll 1994, Caughley and Gunn 1996). A rate of productivity that is unstable or declining over a long period of time may reflect a variety of causes, but indicates poor resiliency to future environmental variability or change (e.g., Lande 1993, Foley 1997, Middleton and Nisbet 1997).

For species at low levels of abundance, in particular, declining or highly variable productivity confers a high level of extinction risk. A species that is not widely distributed across a variety of well-connected habitats will have a diminished capacity for recolonizing locally extirpated populations and is at increased risk of extinction due to environmental perturbations and catastrophic events (Schlosser and Angermeier 1995, Hanski and Gilpin 1997, Tilman and Lehman 1997, Cooper and Mangel 1999). A species that has lost locally adapted genetic and life history diversity may lack the characteristics necessary to endure short-term and long-term environmental changes (e.g., Hilborn et al. 2003, Wood et al. 2008).

The demographic risk criteria described above are evaluated based on the present species status in the context of historical information, if available. However, there may be threats or other relevant biological factors that might alter the determination of the species' overall level of extinction risk. These threats or other risk factors are not yet reflected in the available demographic data because of the time lags involved, but are nonetheless critical considerations in evaluating a species' extinction risk (Wainwright and Kope 1999).

Forecasting the effects of threats and other risk factors into the foreseeable future is rarely straightforward, and usually necessitates qualitative evaluations and the application of informed professional judgment. This evaluation highlights those factors that may exacerbate or ameliorate demographic risks so that all relevant information may be integrated into the determination of overall extinction risk for the species. Examples of such threats or other relevant factors may include climatic regime shifts that portend favorable temperature and marine productivity conditions, an El Niño event that is anticipated to result in reduced food quantity or quality, or recent or anticipated increases in the range or abundance of predator populations.

In considering the status of eulachon, we evaluated both qualitative and quantitative information. Qualitative evaluations included aspects of several of the risk considerations outlined above, as well as recent, published assessments of the status of eulachon populations by agencies, reviewed below. Additional information presented by the petitioners was considered, as discussed under the Introduction: Summary of Information Presented by the Petitioner section above.

Abundance and Carrying Capacity

Absolute Numbers

The absolute number of individuals in a population is important in assessing two aspects of extinction risk. For small populations that are stable or increasing, population size can be an indicator of whether the population can sustain itself into the future in the face of environmental fluctuations and small-population stochasticity; this aspect is related to the concept of minimum viable populations (MVP) (Gilpin and Soulé 1986, Thompson 1991). For a declining population, present abundance is an indicator of the expected time until the population reaches critically low numbers; this aspect is related to the concept of "driven extinction" (Caughley 1994). In addition to total numbers, the spatial and temporal distribution of adults is important in assessing risk to a species or DPS.

Several aspects of eulachon biology indicate that large aggregations of adult eulachon are necessary for maintenance of normal reproductive output. Eulachon are a short-lived, high-fecundity, high-mortality forage fish, and such species typically have extremely large population sizes. Research from other marine fishes (Sadovy 2001) suggests that there is likely a biological requirement for a critical threshold density of eulachon during spawning to ensure adequate synchronization of spawning, mate choice, gonadal sterol levels, and fertilization success. Since eulachon sperm may remain viable for only a short time, perhaps only minutes, sexes must synchronize spawning activities closely, unlike other fish such as Pacific herring (Hay and McCarter 2000, Willson et al. 2006).

In most samples of spawning eulachon, males greatly outnumber females (although many factors may contribute to these observations) (Willson et al. 2006), and in some instances congregations of males have been observed simultaneously spawning upstream of females that laid eggs as milt drifted downstream (Langer et al. 1977). Sadovy (2001, p. 100) noted that "the idea that, if a population drops below some critical density, the intrinsic rate of population increase may not be realized because breeding activity may cease, cannot be readily dismissed and a number of possible Allee effects have been noted" in marine fishes. Sadovy (2001, p. 101) further noted that "aggregating behaviour presumably reflects some biological imperative for sociality during the reproductive season."

In addition, the genetically effective population size of eulachon may be much lower than the census size. Although eulachon exhibit high fecundity (7,000–60,000 eggs; mean ≈30,000), survival from egg to larva may vary widely (3–5% in the Kemano River to approximately 1% in the Wahoo River [Willson et al. 2006]) and may be less than 1% in large egg masses. Larvae are small (4–8 mm long), are rapidly carried by currents to the sea, and rear in the pelagic zone similarly to many marine pelagic fish larvae where the extent of mortality during the transition phase from larva to juvenile is high. In marine species, under conditions of high fecundity and high mortality associated with pelagic larval development, local environmental conditions may lead to random "sweepstake recruitment" events where only a small minority of spawning individuals contribute to subsequent generations (Hedgecock 1994). Hauser and Carvalho (2008) report that "data available so far suggest that the scope for sweepstake recruitment may be higher in larger populations, as the N_e/N [ratio of effective size to census size] is lower in larger populations."

Large spawning aggregations of adult eulachon may also be necessary to withstand predation pressure associated with large congregations of predators that target returning adults, and to produce enough eggs and pelagic larvae to swamp out predation in the ocean (Bailey and Houde 1989). Multiple species of predators (sea lions, harbor seals, gulls, bald eagles, ducks, sturgeon, porpoises, killer whales, etc.) commonly congregate at eulachon spawning runs and "local observers often judge arrival of fish by the conspicuous arrival of many predators" (Willson et al. 2006).

Historical Abundance and Carrying Capacity

Knowing the relationship of present abundance to present carrying capacity is important for evaluating the health of populations, but the fact that a population is near its current capacity does not necessarily signify full health. A population near capacity implies that short-term management may not be able to increase fish abundance.

The relationship of current abundance and habitat capacity to historical levels is an important consideration in evaluating risk. Knowledge of historical population conditions provides a perspective for understanding the conditions under which present populations evolved. Historical abundance also provides the basis for scaling long-term trends in populations. Comparison of present and past habitat capacity can also indicate long-term population trends and problems of population fragmentation. For eulachon, current and historical abundance data and information was available in the form of spawner biomass (pounds or metric tons) or total spawner counts (numbers of adult fish), offshore juvenile eulachon biomass estimates (metric tons), mean eulachon larval density, CPUE, commercial-recreational-subsistence fisheries landings, ethnographic studies, and anecdotal qualitative information.

Trends in Abundance

Short-term and long-term trends in abundance are primary indicators of risk. Trends may be calculated from a variety of quantitative data, which are discussed in detail in specific subsections below. Interpretation of trends in terms of population sustainability is difficult for several reasons. First, eulachon are harvested in fisheries and shifting harvest goals or market conditions directly affect trends in spawning abundance and catch. Second, environmental fluctuations on short timescales affect trend estimates, especially for shorter trends.

Recent Events

A variety of factors, both natural and human-induced, affect the degree of risk facing eulachon populations. Because of time lags in these effects and variability in populations, recent changes in any of these factors may affect current risk without any apparent change in available population statistics. Thus consideration of these effects must go beyond examination of recent abundance and trends, but forecasting future effects is rarely straightforward and usually involves qualitative evaluations based on informed professional judgment. Events affecting populations may include natural changes in the environment or human-induced changes, either beneficial or detrimental. Possible future effects of recent or proposed conservation measures have not been taken into account in this analysis, but we have considered documented changes in the natural environment. A key question regarding the role of recent events is: Given our uncertainty regarding the future, how do we evaluate the risk that a population may not persist?

It is generally accepted that important shifts in ocean-atmosphere conditions occurred about 1977 and again in 1998 that affected North Pacific marine ecosystems. Several studies have described decadal-scale oscillations in North Pacific climatic and oceanic conditions (Mantua and Hare 2002). These changes have been associated with recruitment patterns of several groundfish species and Pacific herring (McFarlane et al. 2000). As discussed in this report, increases in eulachon in the Columbia, Fraser, and Klinaklini rivers in 2001–2002 may be largely a result of the more favorable ocean conditions for eulachon survival during the transition from larvae to juvenile when these broods entered the ocean in 1998–2000.

One indicator of the ocean-atmosphere variation for the North Pacific is the PDO index; Figure 15 shows that from fall 2007 to mid-summer 2009 (time period E on the graph) monthly PDO values were negative, whereas PDO values were mostly positive in time period D from 2002 to fall of 2007 and during most of the previous two decades (time period B). One exception is time period C, which corresponds with 1998–2000 when good ocean conditions for survival of larval eulachon led to the increased run strength noted in 2001–2002. PDO values were generally negative for a long period from the 1950s to the late 1980s (time period A). Recently negative PDO values are associated with relatively cool ocean temperatures off the Pacific Northwest and positive values are associated with warmer, less productive conditions (Mantua and Hare 2002).

Coupled changes in climate and ocean conditions have occurred on several different time scales and have influenced the geographical distributions, and hence local abundance, of marine fishes. On time scales of hundreds of millennia, periodic cooling produced several glaciations in the Pleistocene Epoch (Imbrie et al. 1984, Bond et al. 1993). Since the end of this major period of cooling, several population oscillations of pelagic fishes, such as anchovies (*Engraulis mordax*) and sardines (*Sardinops sagax*), have been noted on the west coast of North America (Baumgartner et al. 1992). These oscillations, with periods of about 100 years, have presumably occurred in response to climatic variability. On decadal time scales, climatic variability in the North Pacific and North Atlantic oceans has influenced the abundances and distributions of widespread species, including several species of Pacific salmon (*Oncorhynchus* spp.) (Francis et

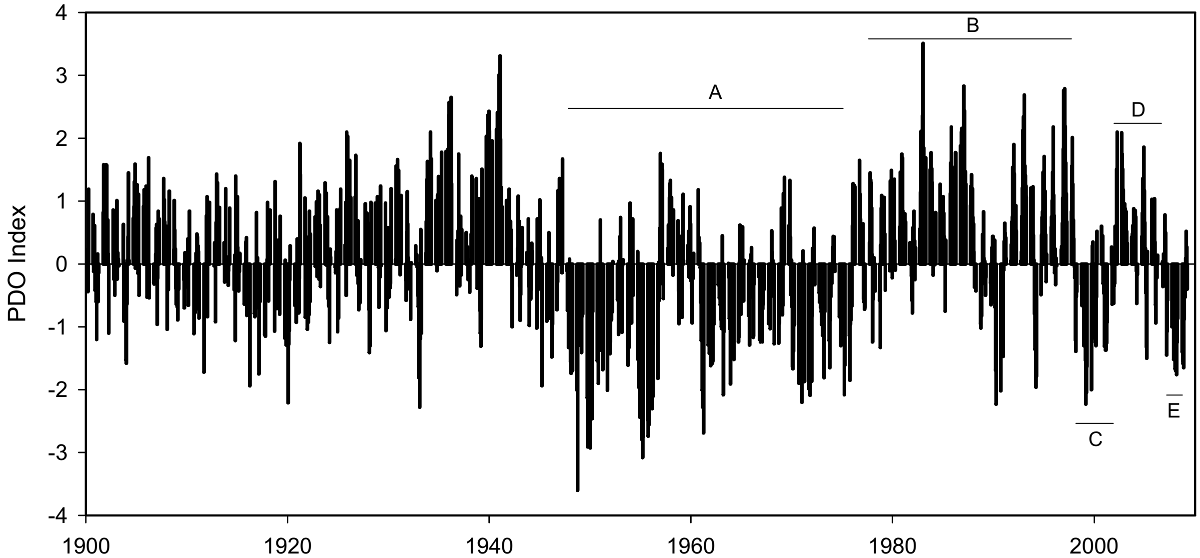

Figure 15. Monthly values for the PDO index, which is based on sea surface temperatures in the North Pacific Ocean, poleward of 20º N. A through E are time periods discussed in the text. Data source: online at http://jisao.washington.edu/pdo/PDO.latest.

al. 1998, Mantua et al. 1997) in the North Pacific, and Atlantic herring (*Clupea harengus*) (Alheit and Hagen 1997) and Atlantic cod (*Gadus morhua*) (Swain 1999) in the North Atlantic. At this time, we do not know whether recent shifts in climate and ocean conditions represent a long-term shift in conditions that will continue affecting stocks into the future or short-term environmental fluctuations that can be expected to be reversed in the near future. Although recent conditions appear to be within the range of historic conditions under which eulachon populations have evolved, the risks associated with poor climate conditions may be exacerbated by human influence on these populations (Lawson 1993).

None of the elements of risk outlined above are easy to evaluate, particularly in light of the great variety in quantity and quality of information available for various populations. Two major types of information were considered: previous assessments that provided integrated reviews of the status of eulachon in our region and data regarding individual elements of population status, such as abundance, trend, and habitat conditions.

A major problem in evaluations of risk for eulachon is combining information on a variety of risk factors into a single overall assessment of risk facing a population. Conducting an overall assessment of extinction risk involves the consideration of a wide variety of qualitative and quantitative information concerning the threats and demographic risks affecting a species' persistence. Moreover, the type and spatial-temporal coverage of the information available often varies within and among populations. This presents a substantial challenge of integrating disparate types of information into an assessment of a species' overall level of extinction risk. Usually such assessments necessitate qualitative evaluations based on informed professional judgment. In this review, we have used a risk-matrix approach through which the BRT members applied their best scientific judgment to combine qualitative and quantitative evidence regarding multiple risks into an overall assessment.

Status Assessments

Official Status in California, Oregon, and Washington

In California eulachon are classified on the Fish Species of Special Concern List as a Class 3 Watch List species (see http://www.dfg.ca.gov/wildlife/nongame/ssc/fish.html). This list was most recently updated in 1995. Class 3 Watch List species are defined as:

> taxa occupying much of their native range, but were formerly more widespread or abundant within that range. … The populations of such species need to be assessed periodically (i.e., every 5 years) and included in long-term plans for protected waterways (e.g., ADMAs [aquatic diversity management areas]).

In Oregon, eulachon are not listed as a state threatened, endangered, or candidate species, nor are they on the state sensitive species list. However, eulachon are on the list of Strategy Species in Oregon's Nearshore Strategy (ODFW 2006, p. 26). These species are defined in the following manner:

> Strategy species are nearshore species that were identified by the Nearshore Team to be in greatest need of management attention. Identification as a strategy species does not necessarily mean the species is in trouble. Rather, those identified as a strategy species have some significant nearshore management/conservation issue connected to that species that is of interest to managers.

ODFW (2006, p. 28) further refers to eulachon under the category of Notes on Conservation Needs as:

> Forage fish. Vulnerable freshwater spawning and nursery grounds. Columbia River population has declined. Other distinct population segments (DPS) may have experienced similar declines.

In Washington, eulachon are classified by the WDFW (online at http://wdfw.wa.gov/wlm/diversty/soc/candidat.htm) as a State Candidate Species, which are defined as:

> fish and wildlife species that the department will review for possible listing as State Endangered, Threatened, or Sensitive. A species will be considered for designation as a State Candidate if sufficient evidence suggests that its status may meet the listing criteria defined for State Endangered, Threatened, or Sensitive.

Status in Canada

The Province of British Columbia examined the conservation status of eulachon in 2000 and again in 2004 and in both instances assigned eulachon to its blue list. According to the British Columbia Conservation Data Centre (2008, online at http://www.env.gov.bc.ca/atrisk/red-blue.html) the blue list:

> Includes any indigenous species or subspecies considered to be of Special Concern (formerly Vulnerable) in British Columbia. Taxa of Special Concern have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered, or Threatened.

Eulachon are also considered a Group 1 high priority candidate species for review in British Columbia by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). According to the COSEWIC Web site (http://www.cosewic.gc.ca/eng/sct0/assessment_process_e.cfm), "Group 1 contains species of highest priority for COSEWIC assessment. Wildlife species suspected to be extirpated from Canada would also be included in this group." A recent bid to conduct a COSEWIC review has been awarded in Canada and a final product is due in November 2010 (see information online at http://www.cosewic.gc.ca/eng/sct2/sct2_4_e.cfm).

Pickard and Marmorek (2007) reported out the results of a DFO workshop whose purpose was to determine research priorities and recovery strategies for eulachon in the wake of the recent coastwide decline. They stated that:

> Recent information indicates that eulachon are declining in many parts of the west coast of North America, though the reasons for this decline and possible remedies are not well understood. In 1994 the Columbia, Fraser, and Klinaklini rivers suffered sudden drastic declines (Hay 1996). Since then First Nations have reported that fish are absent or at very low levels in many other British Columbia eulachon spawning rivers including: the Kemano, Kitimat, Wannock, Bella Coola, Nass, Skeena, Chilcoot, Unuk, Kitlope, and Stikine (Moody 2007, Hay 2007).

According to Schweigert et al. (2007, p. 13):

> In recent years, particularly since 1994, eulachon abundance has declined synchronously in many rivers and virtually disappeared in California. This decrease has been noticeable in the PNCIMA [Pacific North Coast Integrated Management Area] region, with very poor runs in Douglas Channel, Gardner Canal, Dean/Burke channels, and Rivers Inlet areas in the past 5 years. It is suspected that these declines may be related to large-scale climate change. Recent studies suggest rivers that normally experience spring freshet events may gradually be changing to summer and fall freshets that may impair eulachon spawning runs.

Other Status Assessments

Musick et al. (2000, p. 11) assessed the status of eulachon following American Fisheries Society criteria to define extinction risk in marine fishes (Musick 1999), and classified eulachon in the Columbia River as threatened based on "commercial landings [that] have declined from average of 2.1 million lb annually from 1938 to 1989 to 5,000 lb in 1999, a decline > 0.99." In addition, Musick et al. (2000, p. 11) stated that "other DPSs from British Columbia to northern California may have declines similar to that observed in the Columbia River."

Hay and McCarter (2000) conducted a review of the status of eulachon for the Canadian Stock Assessment Secretariat of Fisheries and Oceans Canada and concluded at that time that "the widespread decline in the southern part of the range warrants a COSEWIC classification of 'threatened' in Canadian waters." This conclusion was based on:

> Available evidence [which] suggests that several rivers in the central coast of British Columbia may be extirpated, while others have declined severely. Only the Nass maintains normal or near-normal runs, although the Fraser, while markedly lower in recent decades and especially since 1994, still has regular, but diminished runs. The Columbia River, with the world's largest eulachon run, declined sharply in 1993, and has remained low since. Apparently all runs in California have declined and several runs that once were large have not been seen in more than 20 years.

General Demographic Indicators

Within the range of the DPS, the BRT examined abundance related information in the published literature; data provided by DFO, WDFW, and ODFW; analyses of available abundance data both past and present summarized in Moody (2008); and information and presentations provided by eulachon experts from DFO, WDFW, ODFW, the Cowlitz Indian Tribe, and the Yurok Indian Tribe assembled during a scientific technical meeting at the NWFSC in June 2008. Information on eulachon abundance fell into the general categories of 1) fisheries-independent scientific surveys of adults, offshore juveniles, and outmigrant larvae; 2) commercial fisheries-dependent landings; 3) recreational fisheries-dependent landings; 4) First Nations subsistence fisheries landings; 5) ethnographic studies; 6) anecdotal qualitative information; and 7) traditional ecological knowledge.

In addition, the BRT reviewed the results of a fuzzy logic expert system developed by Moody (2008) to estimate a past and present relative abundance status index for eulachon in several areas of the southern DPS of eulachon. Moody's (2008) expert system uses catch data to determine the exploitation status of a fishery and combines this with other data sources such as spawning stock biomass estimates, CPUE data, test fishery catches, larval survey data, or anecdotal comments on run size to estimate the relative abundance status index. This index was produced using designed heuristic rules and by adjusting weighting parameters (Moody 2008).

Although humans have exploited eulachon populations for centuries, the perceived abundance of the resource and its low commercial value has resulted in limited regulation of past commercial and recreational fisheries, limited recording of past catches, and until recently a lack of assessment surveys of spawning abundance. The BRT recognized that the lack of direct estimates of eulachon abundance based on fishery-independent surveys (spawning stock biomass estimates or escapement counts) prior to 1993 makes it very difficult to quantify trends in eulachon abundance. Since the mid-1990s, monitoring of this resource has improved and a handful of data sets are now available that track eulachon spawning stock abundance and offshore juvenile abundance or provide an indication of run strength in several subareas of the DPS.

Data Availability

Fisheries-independent scientific surveys

There are few direct estimates of spawning biomass of eulachon from rivers within the DPS, although all of these data sets began to be collected after the perceived decline in run sizes occurred in the early 1990s. Spawner biomass (pounds or metric tons) or total spawner counts (numbers of adult fish) are available for the Fraser River (1996–2009), Klinaklini River (1995), Kingcome River (1997), Wannock/Kilbella rivers (2005–2006), Bella Coola River (2001–2004), Kitimat River (1993–1996, 1998–2005), and Skeena River (1997). Even though the results of most of these studies are only available in gray literature reports, they were regarded by the BRT as constituting the best scientific and commercial data available for recent eulachon abundance in the DPS and were heavily weighted in the BRT's risk analysis. The BRT was cognizant of the fact that abundance estimates always contain observational error. These factors were taken into account when evaluating the data sets.

Offshore juvenile eulachon biomass estimates were available for Queen Charlotte Sound (1998–2009), West Coast Vancouver Island (1973, 1975–1983, 1985, 1987–2009), and the U.S. West Coast (1995, 1998, 2001). Data for Queen Charlotte Sound and West Coast Vancouver Island were collected by DFO as part of offshore shrimp biomass assessments. Eulachon juvenile biomass data for the U.S. West Coast were available from AFSC triennial groundfish bottom trawl surveys on the continental shelf (55–500 m) in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

CPUE data for eulachon were also available off the U.S. West Coast in AFSC triennial groundfish bottom trawl surveys over the continental shelf in depths of 55–366 m (1989, 1992) or 55–500 m (1995, 1998, 2001) and in certain INPFC statistical areas in AFSC groundfish bottom trawl surveys over the continental slope in depths of 183–1,280 m (1989–1999). However, as mentioned previously, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon.

Mean eulachon larval density data were available in the mainstem Columbia River (1996–2009), Cowlitz River (1986, 1994–2004, 2006–2009), Grays River (1998–2001, 2004–2006, 2008, 2009), Elochoman River (1997–2001, 2003, 2008), Kalama River (1995–2002), Lewis River (1997–2003, 2007–2009), and Sandy River (1998–2000, 2003).

Data from a Fraser River test fishery were available for the years 1995–1998 and 2000–2005 and are reported as number of fish caught. CPUE data were available from the Columbia River (1988–2008), Kemano River (1988–2006), and Kitimat River (1994–2006).

Commercial fisheries–dependent landings

Commercial fisheries landings in pounds or metric tons of eulachon were available for the Klamath River (1963), Umpqua River (1967), Columbia River (1888–1892, 1894–1913, 1915–2009), Fraser River (1881–1996), Kitimat River (1969–1971), and Skeena River (1900–1916, 1919, 1924, 1926–1927, 1929–1932, 1935, 1941).

In some areas of the southern DPS of eulachon where escapement counts or estimates of spawning stock biomass are unavailable, catch statistics provide the only available quantitative data source that defines the relative abundance of eulachon occurrence that may be otherwise evident only by simple run-strength observation. However, inferring population status or even trends from yearly changes in catch statistics requires assumptions that are seldom met, including similar fishing effort and efficiency, assumptions about the relationship of the harvested portion to the total portion of the stock, and statistical assumptions such as random sampling.

First Nations and Indian tribal subsistence fisheries landings

First Nations subsistence fisheries landings in pounds or metric tons of eulachon were available for a number of rivers in British Columbia including the Fraser River (1975–1987, 1991), Klinaklini River (1947, 1949, 1950, 1952, 1959–1973, 1977), Kingcome River (1950, 1957, 1960, 1961, 1963, 1966), Wannock River (1967, 1968, 1971), Bella Coola River (1945, 1946, 1948–1989, 1995, 1998), Kemano River (1969–1973, 1988–2006), and Kitimat River (1969–1972).

Recreational fisheries–dependent landings

Recreational fisheries for eulachon are even more poorly documented that those for commercial and subsistence purposes. A popular recreational dip net fishery for eulachon has a long history on the Columbia River, particularly in tributary rivers such as the Cowlitz and on occasion the Sandy River. Catch records are not maintained for this fishery, although it has been estimated at times to equal the commercial catch (WDFW and ODFW 2001). A similar recreational dip net fishery occurred in the past on the Fraser River, and landings data exist for a portion of this fishery in the vicinity of Mission, British Columbia, for the years 1956, 1963–1967, and 1970–1980 (Moody 2008, p. 49, her Figure 2.22).

Ethnographic studies

Numerous ethnographic studies emphasize the nutritional and cultural importance of eulachon to coastal mainland Indian tribes and First Nations. The BRT examined ethnographic sources that describe historical distributions and relative abundance of eulachon fisheries within the boundaries of the DPS. Many of the statements in these sources as to the historical distribution and abundance of eulachon consisted of traditional ecological knowledge or were anecdotal in nature.

Anecdotal qualitative information

Anecdotal information is defined in the present context as information based on personal observation, case study reports, or random investigations rather than systematic scientific evaluation. This category includes memoirs of pioneers, fur trappers, and explorers; newspaper articles; and interviews with local fishers.

The BRT examined a variety of primary sources (e.g., accounts of early explorers, surveyors, fur trappers, and settlers and newspaper articles) and secondary sourced (e.g., agency fisheries reports and journal articles that cite personal communications) that describe historical distributions and relative abundance of eulachon within the boundaries of the DPS. The BRT also examined documents (e.g., Larson and Belchik 1998, Hay and McCarter 2000, Moody 2008) that cited interviews with local fishers or personal communications from local fisheries managers in their attempt to qualitatively characterize eulachon run strength. Many statements in these sources as to the historical distribution of eulachon were largely anecdotal in nature.

Traditional ecological knowledge

Although there is a largely untapped store of knowledge on eulachon residing in the culture and traditions of Native American Indian Tribes and First Nations in Canada, the BRT did not separately consider traditional ecological knowledge sources in its deliberations; however, the BRT did examine secondary sources that presented information on eulachon presence and run size that was gathered from interviews with traditional local fishers.

Summary of Regional Demographic Data

To facilitate evaluation of eulachon distribution and abundance, the BRT analyzed the available demographic information on a subpopulation basis, arranged geographically into separate major estuaries, which have been postulated to be the smallest area that likely supports a biological stock (McCarter and Hay 1999, Hay and McCarter 2000, Hay 2002). These major areas are 1) Klamath River, 2) Columbia River (Cowlitz, Grays, Lewis, Kalama, Sandy rivers, etc.) in the United States, 3) Fraser River, 4) Knight Inlet (Klinaklini River), 5) Kingcome Inlet (Kingcome River), 6) Rivers Inlet (Wannock and Kilbella/Chuckwalla rivers), 7) Dean Channel (Bella Coola and Kimsquit rivers), 8) Gardner Canal (Kemano, Kowesas, and Kitlope rivers), 9) Douglas Channel (Kitimat and Kildala rivers), and 10) Skeena River in British Columbia.

Eulachon are periodically noted in small numbers in several rivers and creeks on the Washington and Oregon coast. Documentation of these irregular occurrences of eulachon is usually anecdotal and it is uncertain how these fish are related demographically to eulachon in rivers such as the Fraser and Columbia where consistent annual runs occur. Occasionally large runs are noticed, usually by the abundance of predatory birds and marine mammals that accompany these runs, in coastal rivers such as the Queets and Quinault. Usually these large run events are separated in time by periods greater than the generation time of eulachon. We do not know enough about the biology of eulachon to know if these eulachon run events represent self-sustaining populations or are simply stray individuals from larger eulachon systems. It is possible that these populations may exist at levels of abundance that would not be detected by the casual observer, only to become noticed in years of high abundance. Further research on the source and sustainability of eulachon that occasionally appear in these coastal creeks and rivers is needed to fully assess the status of these eulachon aggregations.

Offshore juvenile abundance estimates

Four fisheries-independent indices of juvenile offshore biomass are available that indicate status of stock mixtures: 1) a West Coast Vancouver Island eulachon biomass index (Figure 16); 2) a Queen Charlotte Sound eulachon biomass index (Figure 17); 3) estimates of CPUE, biomass, or number of eulachon reported in a series of groundfish bottom trawl surveys conducted on the continental shelf and slope of the U.S. West Coast by NMFS's NWAFC and

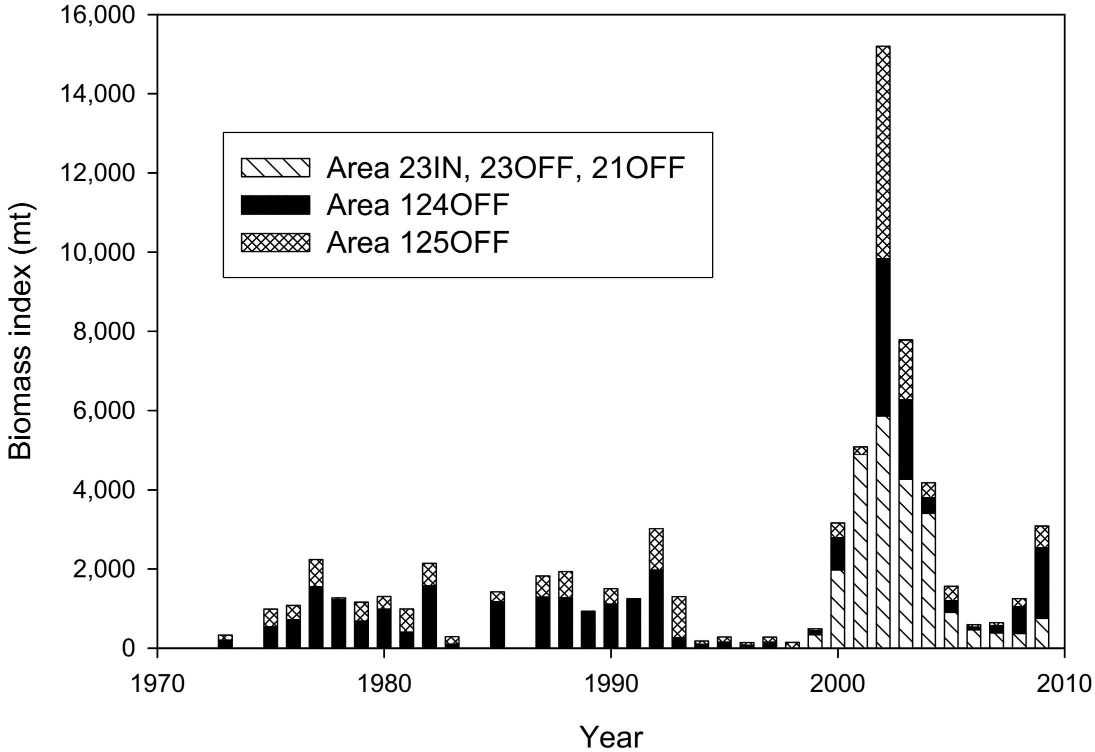

Figure 16. West coast Vancouver Island offshore eulachon biomass index. See Figure 21 for geographic locations of DFO shrimp management areas 23IN, 23OFF, 21OFF, 124OFF, and 125OFF. Data from Hay et al. (2003) and DFO west coast Vancouver Island shrimp survey bulletins (2000–2009), online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm?

AFSC and more recently by NWFSC (Table 2 through Table 5, Figure 18, and Figure 19); and 4) the AFSC Gulf of Alaska bottom trawl biomass estimates for eulachon (Figure 20). The latter two groundfish surveys were designed to sample bottom-dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon. In addition, none of these four indices provides information on spawning stock biomass and each incorporates juvenile biomass derived from 2 to 4 broodyears; however, these indices are useful predictors for potential future run sizes.

DFO (2008a, p. 11) describes the west coast Vancouver Island eulachon biomass index as follows (Figure 16):

> The offshore biomass index is based on an annual trawl survey conducted in late April or early May by Fisheries and Oceans Canada, Science Branch. The survey initially was designed to index shrimp abundance but since eulachon also are caught by this survey, a eulachon index is possible. It is important to note that this is a biomass index and not a biomass estimate and that eulachon caught in this survey include stocks from both the Fraser River, and the Columbia River, and possibly other areas. This survey has been conducted since 1973 and provides an annual index of offshore abundance for the lower west coast Vancouver Island (areas 121, 23, 123, 124, and 125) [Figure 21].

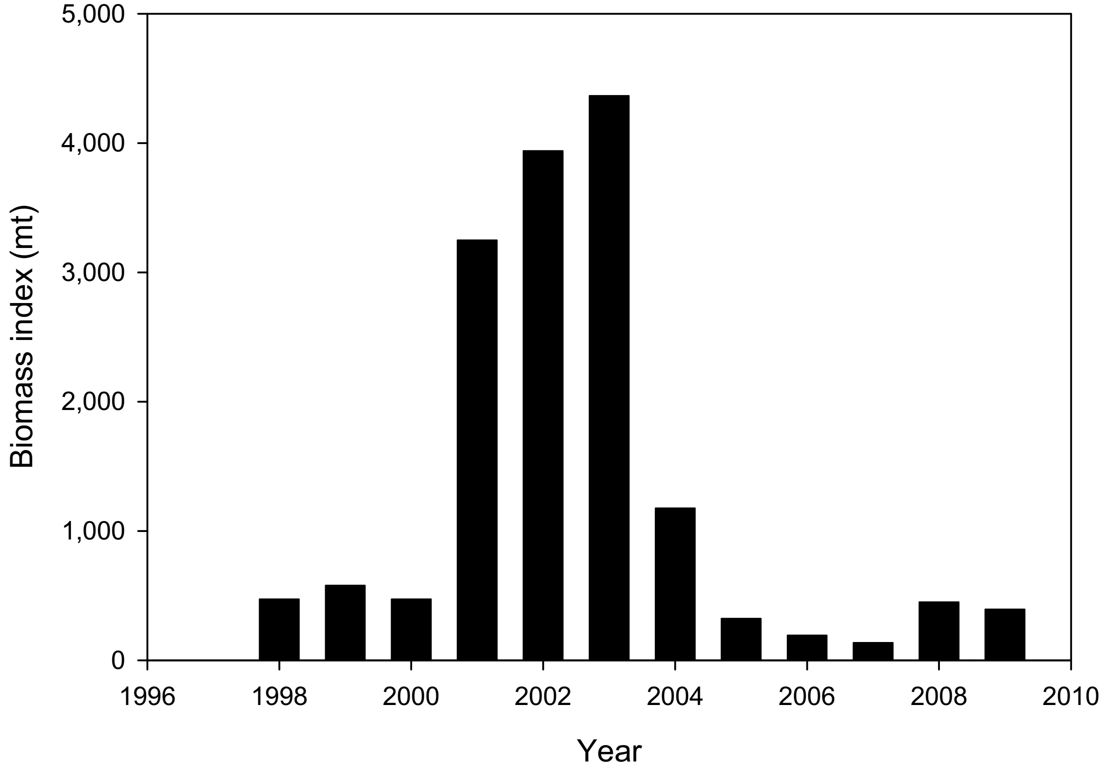

Figure 17. Queen Charlotte Sound offshore eulachon biomass index. Data from DFO Queen Charlotte Sound shrimp survey bulletins (2000–2009), online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm?

DFO (2009a, p. 3) stated that "the eulachon biomass indices for 2009 increased in all SMAs [shrimp management areas] surveyed [off west coast Vancouver Island] compared to 2008 indices" (Figure 16). Biomass increased "from 353.7 t in 2008 to 720.8 t in 2009" in SMAs 23OFF+21OFF, "from 697.8 t in 2008 to 1810.1 t in 2009" in SMA 124OFF, and "from 184.9 t in 2008 to 520.0 t in 2009" in SMA 125OFF (DFO 2009a, p. 3) (Figure 21).

In a similar manner, a Queen Charlotte Sound eulachon biomass index (Figure 17) is derived from eulachon caught in the fishery-independent shrimp survey that is conducted in May of each year in SMA Queen Charlotte Sound. Data indicate that "the 2008 estimate of 451.5 t is a significant increase from the record low 137.1 t in 2007" (DFO 2008b, p. 2); however, "eulachon biomass on the shrimp grounds decreased slightly to 394.8 t in 2009 from 451.5 t in 2008" (DFO 2009b, p. 2). As reported in DFO (2009b, p. 3) "the shrimp trawl fishery in SMA Queen Charlotte Sound will remain closed due to eulachon conservation concerns in central British Columbia rivers" (Figure 21).

The history and location of groundfish trawl surveys conducted by the NWAFC, AFSC, and NWFSC in Alaska and off the U.S. West Coast were described in the above Marine Distribution subsection. Mean CPUE (kg/ha) data for eulachon in select INPFC statistical areas (Table 2) were published in various AFSC groundfish bottom trawl surveys conducted between

Table 2. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC groundfish bottom trawl surveys on the continental slope in depths of 183 to 1,280 m. ND (for no data) indicates that no survey occurred in a certain area and a dash indicates a survey occurred but no eulachon were reported.

Year	Canadian Vancouver	U.S. Vancouver	Total Vancouver	Columbia	Eureka	Monterey	Conception	U.S. total	Total
1989[a]	ND	ND	ND	2.296	ND	ND	ND	ND	ND
1990[a]	ND	ND	ND	ND	0.487	ND	ND	ND	ND
1991[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1992[a] (183–366 m)	ND	0.003	ND	0.032	ND	ND	ND	ND	ND
1992[a] (367–549)	ND	0.004	ND	0.002	ND	ND	ND	ND	ND
1993[a] (183–366 m)	ND	ND	ND	0.001	ND	ND	ND	ND	ND
1993[a] (367–549 m)	ND	ND	ND	0.001	ND	ND	ND	ND	ND
1996[b] (183–366 m)	ND	—	ND	—	ND	ND	ND	ND	ND
1996[b] (367–549 m)	ND	—	ND	0.002	ND	ND	ND	ND	ND
1997[c] (183–366 m)	ND	—	ND	0.002	—	—	—	0.001	ND
1997[c] (367–549 m)	ND	—	ND	0.003	—	—	—	0.001	ND
1999[d] (183–366 m)	ND	—	ND	0.006	0.007	—	—	0.003	ND

[a] Lauth et al. 1997
[b] Lauth 1997b
[c] Lauth 1999
[d] Lauth 2000

Table 3. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 366 m (1989 and 1992) or 55 to 500 m (1995–2001). A dash indicates a survey occurred but no eulachon were reported.

Year	Canadian Vancouver	U.S. Vancouver	Total Vancouver	Columbia	Eureka	Monterey	Conception	U.S. total	Total
1989[a]	0.723	0.259	0.557	0.438	0.458	0.014	0.169	0.295	0.368
1992[b]	3.115	0.010	1.933	0.188	0.226	—	—	0.114	0.604
1995[c]	1.118	0.094	0.761	0.027	0.001	—	—	0.019	0.169
1998[d]	0.127	0.007	0.077	0.009	Trace	—	—	0.004	0.018
2001[e]	13.251	0.362	6.888	0.253	0.013	—	—	0.135	1.172

[a] Weinberg et al. 1994, [b] Zimmerman 1994, [c] Wilkins 1998, [d] Wilkins and Shaw 2000, [e] Wilkins and Weinberg 2002

Table 4. Estimated biomass (mt) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 500 m. A dash indicates a survey occurred but no eulachon were reported.

Year	Canadian Vancouver	U.S. Vancouver	Total Vancouver	Columbia	Eureka	Monterey	Conception	U.S. total	Total
1995[a]	1,137	85	1,221	59	1	—	—	145	1,281
1998[b]	123	9	132	20	—	—	—	30	153
2001[c]	12,186	717	12,903	558	9	—	—	1,284	13,470

[a] Wilkins 1998, [b] Wilkins and Shaw 2000, [c] Wilkins and Weinberg 2002

Table 5. Estimated number of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 500 m. A dash indicates a survey occurred but no eulachon were reported.

Year	Canadian Vancouver	U.S. Vancouver	Total Vancouver	Columbia	Eureka	Monterey	Conception	U.S. total	Total
1995[a]	39,912,489	2,475,680	42,579,382	1,552,718	16,787	—	—	4,045,185	44,148,887
1998[b]	7,811,913	595,554	8,407,466	1,150,452	5,297	—	—	1,751,303	9,653,216
2001[c]	340,794,386	22,481,691	363,276,077	22,146,832	808,073	—	—	45,436,595	386,230,981

[a] Wilkins 1998, [b] Wilkins and Shaw 2000, [c] Wilkins and Weinberg 2002

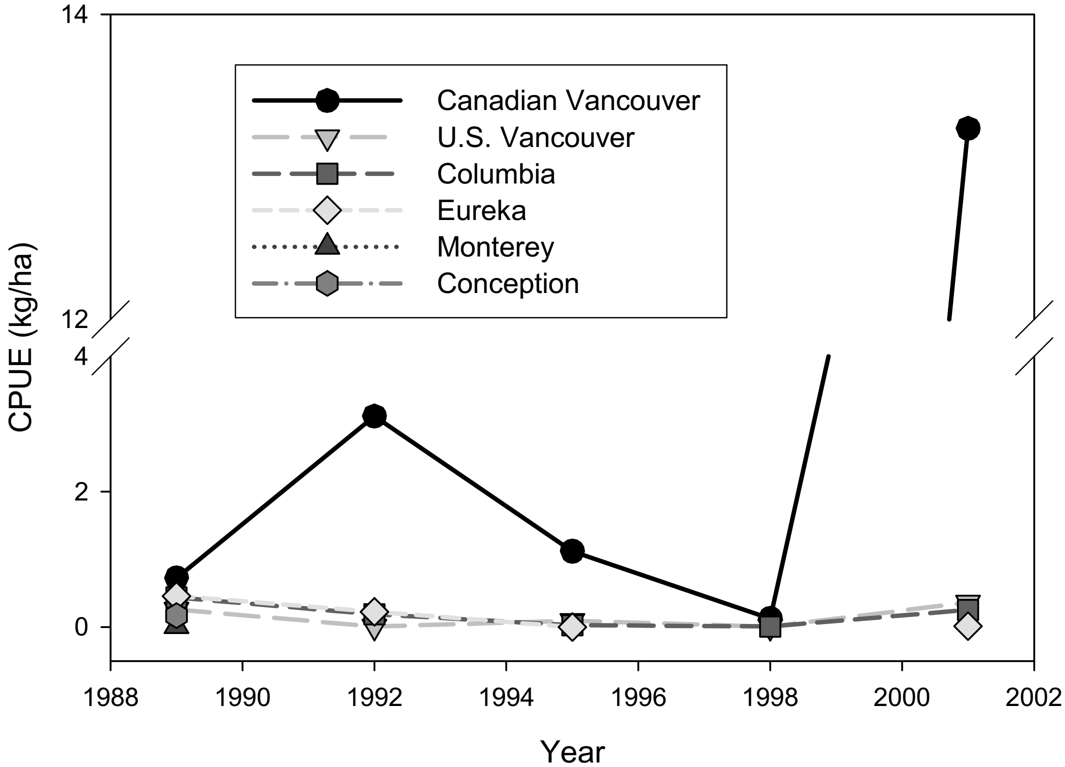

Figure 18. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) off the U.S. West Coast, as reported in AFSC triennial groundfish bottom trawl surveys on the continental shelf in depths of 55–366 m (1989 and 1992) or 55–500 m (1995–2001) in 1989 (Weinberg et al. 1994), 1992 (Zimmermann 1994), 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

1989 and 1999 on the U.S. West Coast continental slope between depths of 183 and 1,280 m (Lauth et al. 1997, Lauth 1997b, 1999, 2000).

As mentioned previously, this depth range is deeper than preferred by eulachon and it is likely that these continental slope surveys missed the vast majority of eulachon in the area. The 1977 triennial groundfish survey recorded eulachon in six of nine assemblages on the continental shelf off the Washington and Oregon coasts, being most abundant within the Nestucca Intermediate Assemblage (90–145 m), where they constituted 3.5% of the total biomass and had a mean CPUE of 28.6 lb/haul (13 kg/haul) (Gabriel and Tyler 1980). In 1980 eulachon were recorded as the 15th most common fish encountered (0.69 kg/ km trawled) in the shallow stratum (55–183 m) in the INPFC Eureka area, but were not recorded within the top 20 species encountered in the INPFC Vancouver, Columbia, or Monterey areas (Coleman 1986). Triennial surveys conducted in 1989–2001 provided mean CPUE (kg/ha) data for eulachon (Table 3, Figure 18) in INPFC statistical areas off the U.S. West Coast (Weinberg et al. 1994b, Zimmermann 1994, Wilkins 1998, Wilkins and Shaw 2000, Wilkins and Weinberg 2002).

Biomass and total number of fish (Table 5) estimates for eulachon were published for surveys conducted in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins

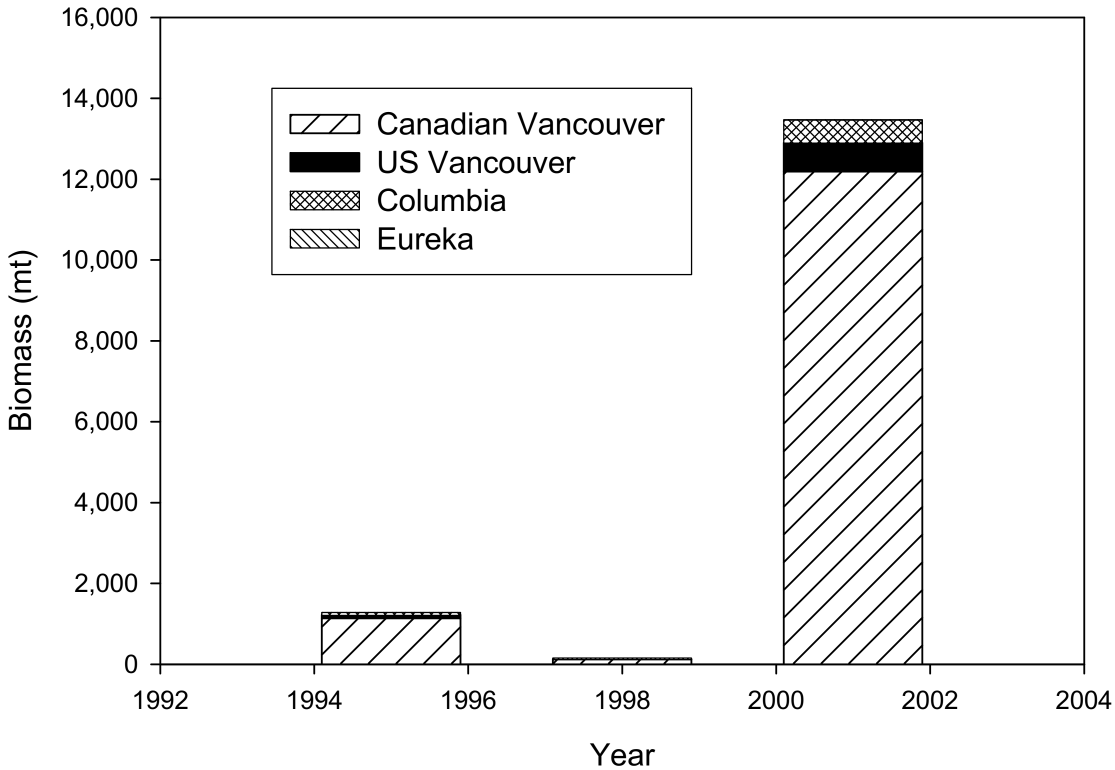

Figure 19. Estimated biomass (mt) of eulachon in INPFC statistical areas (Figure 4) off the U.S. West Coast as reported in AFSC triennial groundfish bottom trawl surveys on the continental shelf in depths of 55–500 m in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

and Weinberg 2002). Between 80% and 90% of the eulachon biomass in these surveys occurred in the Canadian portion of the Vancouver INPFC area (Table 4, Figure 19). As stated previously, these groundfish surveys were designed to sample bottom-dwelling species and only capture a small and erratic portion of the pelagic distribution of eulachon.

Although unlikely to include eulachon from the southern DPS, the AFSC Gulf of Alaska bottom trawl estimates for eulachon (Figure 20) are a useful indicator of fluctuations in abundance in the Alaska Current for comparison with conditions in the California Current.

Oregon marine recreational fisheries survey data

ODFW (Williams 2009) (Table 6) provided a:

> summary for catches of eulachon in the marine sport fishery. The Oregon Recreational Boat Survey (ORBS) is our ocean boat sampling project. The survey is responsible for sampling sport catches from boats, focusing on ocean catches. Estimates of harvest are produced based on this sampling and are used for in-season management of quota species. Sampling takes place at a lesser extent in estuaries and that information is catalogued, but not used routinely. The

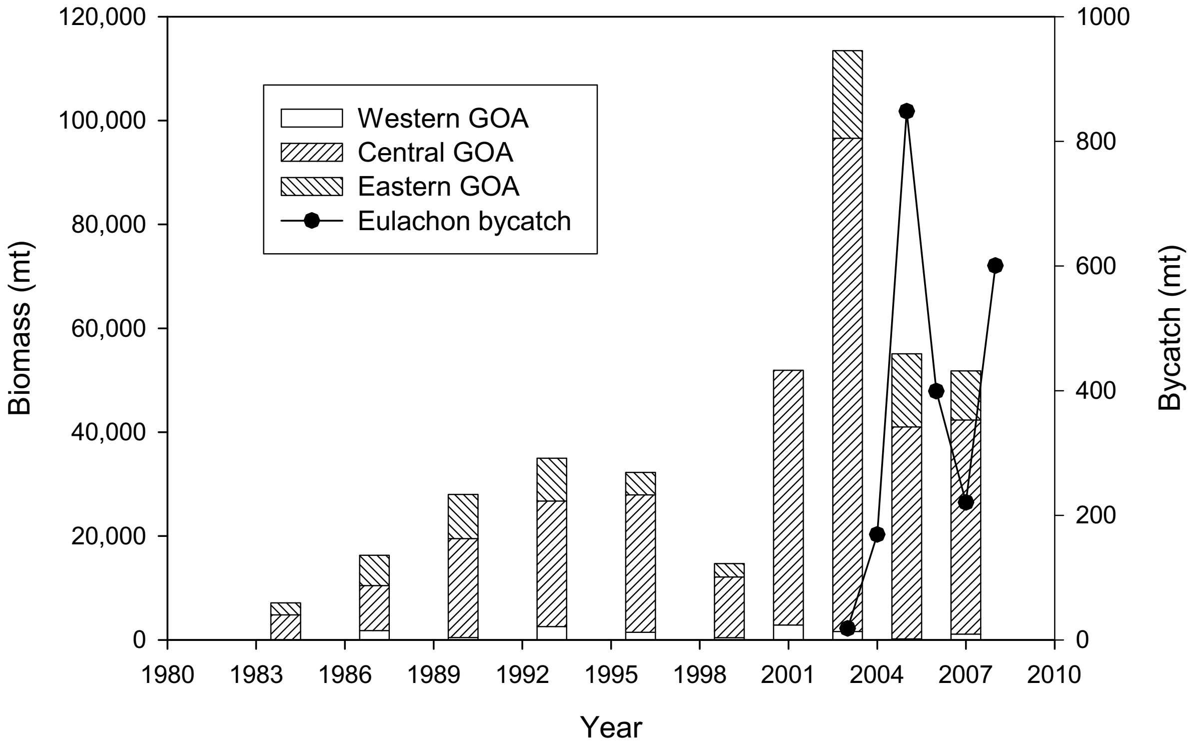

Figure 20. AFSC bottom trawl survey biomass estimates for eulachon and fishery incidental catch (bycatch) of eulachon in the Gulf of Alaska. Data from Ormseth and Vollenweider (2007) and Ormseth et al. (2008).

> Marine Recreational Finfish Statistical Survey (MRFSS) was formed by NMFS and operated by the Pacific States Marine Fisheries Commission. This survey was conducted at all saltwater access points including beaches, estuaries, man-made structures (e.g., jetties), and docks. It was a comprehensive survey that was intended to produce harvest trends over a number of years. … Beginning in 1994, ORBS estimates for ocean boats superseded those generated by the old MRFSS program because ORBS methodology generates more accurate estimates. In particular, MRFSS is weak in capturing pulse, or short-term, fisheries like smelt (the PSE [proportional statistical error] for the annual eulachon estimates range from 73 to 100). Hence, the summary is best regarded as an indicator of eulachon presence in the sport fishery, not absolute numbers.

Northern California

There has been no long-term monitoring program for eulachon in California, making the assessment of historical abundance and abundance trends difficult. Within California, large spawning aggregations of eulachon were reported to have once regularly occurred in the Klamath River (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Moyle 2002, Hamilton et al. 2005) and on occasion in the Mad River (Moyle et al. 1995, Moyle 2002) and Redwood Creek (Moyle et al. 1995) (Table A-1, Figure 2). In addition, Moyle et al. (1995) and Moyle (2002) stated that small numbers of eulachon have been reported from the Smith River

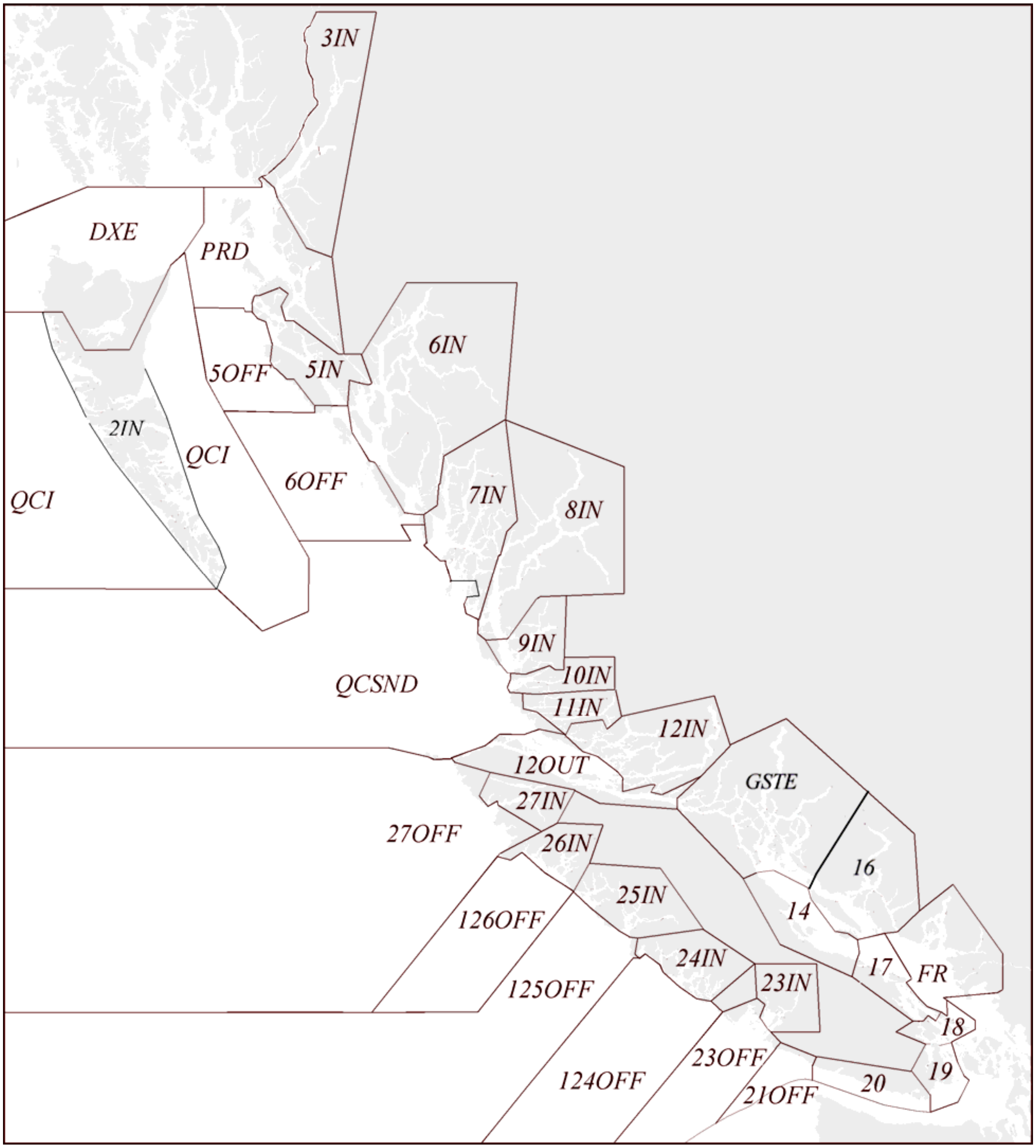

Figure 21. Map of major shrimp management areas on the coast of British Columbia. Map modified from DFO (2009c).

Table 6. Marine Recreational Finfish Statistical Survey (MRFSS) and Shore and Estuary Boat Survey (SEBS) eulachon catch data provided by Williams (2009) for Oregon between 1980 and June 2005. All eulachon were caught from piers or docks in bays. CPUE is fish caught per fisher interviewed.

	South Beach			Winchester Bay			Bandon		
	No. fish	**No. fishers**	**CPUE**	**No. fish**	**No. fishers**	**CPUE**	**No. fish**	**No. fishers**	**CPUE**
1983									
1987									
1993	53	11	4.8	8	4	2.0			
1994									
1995				18	1	18.0			
1999							66	6	11.0
Total	53	11	4.8	26	5	5.2	66	6	11.0

Table 6 continued horizontally. MRFSS and SEBS eulachon catch data provided by Williams (2009) for Oregon between 1980 and June 2005. All eulachon were caught from piers or docks in bays. CPUE is fish caught per fisher interviewed.

	Charleston			Brookings			Total		
	No. fish	**No. fishers**	**CPUE**	**No. fish**	**No. fishers**	**CPUE**	**No. fish**	**No. fishers**	**CPUE**
1983	1	2	0.5				1	2	0.5
1987	2	3	0.7				2	3	0.7
1993							61	15	4.1
1994				4	2	2.0	4	2	2.0
1995							18	1	18.0
1999							66	6	11.0
Total	3	5	0.6	4	2	2.0	152	29	5.5

(Table A-1). CDFG's Status Report on Living Marine Resources (Sweetnam et al. 2001, p. 477–478) stated that "The principal spawning run [of eulachon] in California is in the Klamath River, but runs have also been recorded in the Mad and Smith rivers and Redwood Creek." Allen et al. (2006) indicated that eulachon usually spawn no further south than the lower Klamath River and Humboldt Bay tributaries.

Eulachon were of great cultural and subsistence importance to the Yurok Tribe on the lower Klamath River (Trihey and Associates 1996) and the Yurok people consider eulachon to be a Tribal Trust Species along with spring and fall Chinook salmon, coho salmon, steelhead, Pacific lamprey (*Lampetra tridentata*) , and green sturgeon (*Acipenser medirostris*) (Trihey and Associates 1996, Larson and Belchik 1998). Eulachon once supported popular recreational fisheries in northern California rivers, but were never commercially important in California. The only reported commercial catch of eulachon in northern California occurred in 1963 when a combined total of 56,000 lb (25 mt) was landed from the Klamath River, the Mad River, and Redwood Creek. According to Larson and Belchik (1998, p. 4):

> Literature regarding … [eulachon] specific to the Klamath River Basin is limited to accounts of mere presence and qualitative descriptions of the species. Though integral components of Yurok culture, eulachon … have not been of commercial importance in the Klamath and are … totally unstudied as to their run strengths.

Larson and Belchik (1998, p. 6) also reported that according to accounts of Yurok tribal elders:

> The last noticeable runs of eulachon were observed [in the Klamath River] in 1988 and 1989 by tribal fishers. Most fishers interviewed perceived a decline in the mid to late 1970s, while about a fifth thought it was in the 1980s. A minority of those interviewed noticed declines in the 1950s and 1960s.

Larson and Belchik (1998, p. 7) further stated that:

> In December 1988 and May 1989, a total of 44 eulachon were identified in outmigrant salmonid seining operations in and above the Klamath River estuary (CDFG unpublished seining data). Though only selected sites are seined and salmonids are the targeted species, no eulachon have been positively identified since at least 1991 (M. Wallace, CDFG, pers. commun.).

As detailed in Larson and Belchik (1998), the Yurok Tribal Fisheries Program spent more than 119 hours of staff time from February 5 to May 6, 1996, sampling for eulachon in the lower Klamath River at 5 different sites where eulachon had been noted in the past without encountering a single eulachon. However, one eulachon was captured by a Yurok tribal member near the mouth of the Klamath River in 1996 (Larson and Belchik 1998). Sweetnam et al. (2001, p. 478), in the CDFG Status Report on Living Marine Resources, stated that "In recent years, eulachon numbers seem to have declined drastically, so they are now rare or absent from the Mad River and Redwood Creek and scarce in the Klamath River." CDFG (Sweetnam et al. 2001, p. 478) also stated that "the eulachon and its fishery have been largely ignored in the past" in California, and perhaps the perceived lack of eulachon in the Klamath River, currently and in the recent past, represent a low point in a natural cycle. In January 2007 six eulachon were reportedly caught by tribal fishermen on the Klamath River.[12]

The BRT was concerned that there are almost no scientifically obtained abundance data available for eulachon in the Klamath River or any other basin in northern California. Ethnographic studies, pioneer diaries, interviews with local fishers, personal communications from managers, and newspaper accounts are therefore the best information available that provide documentation of eulachon occurrence in the Klamath River and other rivers on the northern California coast.

The BRT discussed several possible interpretations of the available information. In particular, the BRT discussed the possibility that historically runs of eulachon in the Klamath River were episodic and perhaps only occasionally large enough to be noticed. The BRT also considered the possibility that eulachon still occur in low but viable numbers in northern California rivers but are not frequently observed because of the absence of a formal monitoring program. The BRT also discussed the possibility that some eulachon may spawn in estuarine environments and are not observed in the riverine environment.

The BRT concluded, however, that explanations that posit the absence of sustained Klamath River eulachon runs historically are less consistent with the available information than the hypothesis that Klamath River eulachon runs used to be regular and large enough to be readily noticeable and now are at most small and sporadic. In particular, various accounts written by CDFG personnel (Fry 1979, Sweetnam et al. 2001, CDFG 2008), Yurok Tribal Fisheries Department personnel (Larson and Belchik 1998), the National Resource Council's Committee on Endangered and Threatened Fishes in the Klamath River Basin (NRC 2004), or available academic literature (Moyle et al. 1995, Moyle 2002, Hamilton et al. 2005) universally describe accounts of the past occurrence of eulachon in the Klamath River and their subsequent decline. Based on the available information, the BRT was therefore unable to estimate the historical abundance of eulachon in northern California, but the BRT found no reason to discount the veracity of these anecdotal sources, which span a period of approximately 100 years and are nearly universal in their description of noticeable runs of eulachon having once ascended the Klamath River.

Likewise, although the BRT was concerned about the absence of a contemporary monitoring program for eulachon, the information available strongly indicated that noticeable runs of eulachon are not currently spawning in Klamath River or other northern California rivers. In particular, the BRT thought it likely that if eulachon were returning in any substantial numbers, it would be reported by residents or those engaged in recreation, research, or management on rivers in northern California. The BRT noted that large eulachon runs tend to attract the attention of fishermen, and the previous runs on the Klamath River were readily noticeable (e.g., "the fish moved up in huge swarms, followed by large flocks of feeding seabirds" [Moyle 2002, p. 240]). The BRT therefore concluded that the available information was most readily interpreted as indicating that noticeable, regularly returning runs of eulachon used to be present in the Klamath River, but have been rare or sporadic for a period of several decades.

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[12] D. Hillemeier, Yurok Tribal Fisheries Department, Klamath, CA. Pers. commun., 23 June 2008.

Although the BRT was reasonably confident that eulachon have declined substantially in northern California, it is also clear that they have not been totally absent from this area in recent years. In particular, recent reports from Yurok tribal fisheries biologists of a few eulachon being caught incidentally in other fisheries on the Klamath in 2007 indicates eulachon still on occasion enter the Klamath River in low numbers.

Columbia River

The Columbia River and its tributaries support the largest eulachon run in the world (Hay et al. 2002). Despite its size and the importance of the fishery (Appendix B and Appendix D), estimates of adult spawning stock abundance are unavailable and the primary information sources on trends in Columbia River eulachon abundance are catch records. In addition to regular returns to mainstem spawning locations in the Columbia River and on the Cowlitz River (most years), eulachon are known to spawn in the following lower Columbia River tributaries: Grays River (common use), Skamokawa Creek (infrequent use), Elochoman River (periodic use), Kalama River (common use), Lewis River (common use), and Sandy River (common use in large run years) (Table A-1, Figure 2) (WDFW and ODFW 2008).

Commercial fishery records begin in 1888 (Table 7 through Table 9, Figure 22) and local newspapers record catches in the Columbia River as early as 1867 (see Appendix B). A large recreational dip net fishery for which catch records are unavailable has existed in concert with commercial fisheries, and the importance of the eulachon run to local Indian tribes was documented as early as the Lewis and Clark Expedition (Burroughs 1961, WDFW and ODFW 2001). The Joint Columbia River Management Staff (JCRMS 2007) stated that “limited past creel census information suggest that the recreational catch may equal the commercial landings in some years when smelt are abundant for a long period of time.”

The BRT did not have confidence in the fishery landings, particularly prior to 2001 in the Columbia River as an accurate index of the actual abundance of the species. Landings are influenced by market conditions, fishing effort, weather, and many other factors other than actual fish abundance (WDFW and ODFW 2008). After implementation in 2000 of the interim Joint State Eulachon Management Plan (WDFW and ODFW 2001), the commercial fishery landings have become a relatively accurate index of the trend in the run size of eulachon returning to the Columbia River. For instance, eulachon returns increased during 2001–2003, dropped slightly in 2004, then dropped dramatically in 2005, which is reflected in both the commercial landings and CPUE data collected during 2001–2007. This pattern was also essentially identical to that seen in offshore eulachon abundance indices (Figure 16 and Figure 17) and in abundance and catch records in several other rivers (e.g., Fraser and Klinaklini rivers) in the DPS. JCRMS (2007) has concluded that recent commercial landings “do provide a useful measure of the relative annual run strength.” In particular, state fisheries managers of Columbia River eulachon use commercial landings to judge whether population trends are upward, neutral, or downward (JCRMS 2007).

Although not useful for estimating an accurate trend, the long-term landings data do indicate that commercial catch levels were consistently high (>500 mt and often >1,000 mt) for the three-quarters of a century period from about 1915 to 1992 (Table 9, Figure 22). Catches

Table 7. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

Year	Columbia River	Grays River	Cowlitz River	Kalama River	Lewis River	Sandy River	Oregon only[a]	Washington only	Total	Source
1888							150,000		150,000	Collins 1892 (p. 231)
1889							60,000		60,000	Reed et al. 1891 (p. 39)
1890								1,000	1,000	Crawford 1890 (p. 8)
1891							150,000		150,000	Reed et al. 1892 (p. 9)
1892							125,000	500,000	625,000	Reed et al. 1892 (p. 42), Crawford 1892 (p. 9–10)
1893									Unknown[b]	
1894								300,000[c]	300,000	Crawford 1894 (p.5)
1895	31,125		20,625		230,500				282,250	Wilcox 1898 (p. 604, 607, 629)
1896							338,675	338,675	677,350	McGuire 1896 (p. 77), Crawford 1896 (p. 9)
1897							677,480	344,000	1,021,480	McGuire 1898 (p. 35), Little 1898 (p. 88)
1898							450,000	287,000	737,000	McGuire 1898 (p. 118), Little 1898 (p. 15)
1899							280,500	280,420	560,920	Reed 1900 (p. 19), Little 1901 (p. 72)
1900							260,200	227,400	487,600	Reed 1900 (p. 69), Little 1901 (p. 82)
1901							265,380		265,380	Van Dusen 1903 (p. 52)
1902							122,454	450,000	572,454	Van Dusen 1903 (p. 135), Kershaw 1902 (p. 82)
1903							102,000	300,000	402,000	Van Dusen 1904 (p. 69), Kershaw 1904 (p. 81)
1904							15,138	425,322	440,460	Wilcox 1907 (p. 33–34, p. 45)
1905							143,015	340,000	483,015	Van Dusen 1907 (p. 111), Riseland 1907 (p. 81)
1906							163,000	340,000	503,000	Van Dusen 1907 (p. 190), Riseland 1907 (p. 56)
1907							169,804		169,804	Van Dusen and McCallister 1908 (p. 110)
1908							262,022	340,000	602,022	Van Dusen and McCallister 1906 (p. 150), Riseland 1909 (p. 25)
1909							209,608	340,000	549,608	Van Dusen and McCallister 1911 (p. 36), Riseland 1909 (p. 37)

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

Year	Columbia River	Grays River	Cowlitz River	Kalama River	Lewis River	Sandy River	Oregon only[a]	Washington only	Total	Source
1910							272,478	350,000	622,478	McCallister and Clanton 1911 (p. 44), Riseland 1911 (p. 46)
1911							174,639	175,000	349,639	Clanton 1913 (p. 112), Riseland 1911 (p. 58)
1912							320,336	175,000	495,336	Clanton 1913 (p. 112), Riseland 1911 (p. 48)
1913								200,000	200,000	Riseland 1913 (p. 63)
1914									Unknown[b]	
1915			1,609,500						1,609,500	Radcliffe 1920 (p. 64–65)
1916								641,595	641,595	Darwin 1917 (p. 103)
1917								2,806,129	2,806,129	Darwin 1917 (p. 173)
1918								1,633,700	1,633,700	Darwin 1920 (p. 64)
1919								2,405,360	2,405,360	Darwin 1920 (p. 121)
1920								977,084	977,084	Darwin 1920 (p. 162)
1921								1,051,283	1,051,283	Darwin 1921 (p. 236)
1922							215,000	1,156,180	1,371,180	Sette 1926 (p. 306), Brennan 1936 (p. 100)
1923							277,195	752,223	1,029,418	Sette 1926 (p. 346–347), Brennan 1936 (p. 100)
1924							226,800	779,422	1,006,222	Sette 1928 (p. 409), Pollock 1925 (p. 44)
1925							308,676	1,092,028	1,400,704	Sette 1928 (p. 445), Pollock 1925 (p. 97)
1926							72,900	1,194,314	1,267,214	Sette and Fiedler 1929 (p. 514), Pollock 1928 (p. 104)
1927							411,732	881,314	1,293,046	Fiedler 1930 (p. 570), Pollock 1928 (p. 168)
1928							19,148	1,149,670	1,168,818	Maybury 1930 (p. 33), Cleaver 1951 (p. 80)
1929							50,061	1,158,419	1,208,480	Maybury 1930 (p. 84), Cleaver 1951 (p. 80)
1930							194,172	1,260,314	1,454,486	Pollock 1932 (p. 14, 49), Cleaver 1951 (p. 80)
1931							435,306	1,521,966	1,957,272	Pollock 1932 (p. 14, 103), Cleaver 1951 (p. 80)

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

Year	Columbia River	Grays River	Cowlitz River	Kalama River	Lewis River	Sandy River	Oregon only[a]	Washington only	Total	Source
1932							233,993	1,349,955	1,583,948	Brennan 1936 (p. 100), Cleaver 1951 (p. 80)
1933							520,418	872,172	1,392,590	Brennan 1936 (p. 100), Cleaver 1951 (p. 80)
1934							536,036	957,120	1,520,156	Brennan 1936 (p. 100), Cleaver 1951 (p. 80)
1935							132,773	2,199,185	2,331,958	Brennan 1936 (p. 100), Cleaver 1951 (p. 80)
1936	194,705	27,200	2,583,525	0	144,325	134,102			3,083,857	Cleaver 1951 (p. 154)
1937	432,063	7,350	1,999,030	0	0	0			2,438,443	Cleaver 1951 (p. 154)
1938	866,700	2,100	33,100	76,600	63,100	0			1,041,600	WDFW and ODFW 2002
1939	721,600	35,700	996,400	0	1,342,700	0			3,096,400	WDFW and ODFW 2002
1940	820,200	53,700	736,800	3,000	1,341,300	127,500			3,082,500	WDFW and ODFW 2002
1941	193,200	0	1,793,000	0	377,000	168,600			2,531,800	WDFW and ODFW 2002
1942	318,600	51,800	1,555,300	0	0	760,300			2,686,000	WDFW and ODFW 2002
1943	643,000	3,700	2,972,500	0	273,200	84,900			3,977,300	WDFW and ODFW 2002
1944	572,700	10,900	1,126,400	44,300	514,200	0			2,268,500	WDFW and ODFW 2002
1945	633,300	59,200	2,048,400	32,500	1,552,800	1,393,100			5,719,300	WDFW and ODFW 2002
1946	253,200	300	2,674,000	0	0	348,500			3,276,000	WDFW and ODFW 2002
1947	352,300	0	1,192,600	0	0	0			1,544,900	WDFW and ODFW 2002
1948	1,015,800	0	2,197,800	0	547,600	212,900			3,974,100	WDFW and ODFW 2002
1949	919,100	300	800	0	1,940,900	472,500			3,333,600	WDFW and ODFW 2002
1950	912,700	11,600	0	1,000	557,200	0			1,482,500	WDFW and ODFW 2002
1951	1,337,600	0	0	0	0	179,300			1,516,900	WDFW and ODFW 2002
1952	867,100	0	380,600	17,800	8,100	1,300			1,274,900	WDFW and ODFW 2002
1953	439,300	15,600	795,400	2,800	0	457,900			1,711,000	WDFW and ODFW 2002
1954	673,900	0	792,900	16,200	360,900	40,400			1,884,300	WDFW and ODFW 2002
1955	887,500	0	1,349,600	0	0	0			2,237,100	WDFW and ODFW 2002
1956	877,400	0	575,100	32,600	0	198,800			1,683,900	WDFW and ODFW 2002
1957	377,500	2,200	987,800	0	0	211,500			1,579,000	WDFW and ODFW 2002
1958	373,300	0	2,243,100	0	0	0			2,616,400	WDFW and ODFW 2002
1959	760,000	0	62,300	44,100	889,700	0			1,756,100	WDFW and ODFW 2002
1960	185,700	700	985,800	0	0	0			1,172,200	WDFW and ODFW 2002
1961	466,400	0	585,900	0	0	0			1,052,300	WDFW and ODFW 2002
1962	690,300	0	783,300	0	0	0			1,473,600	WDFW and ODFW 2002

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

Year	Columbia River	Grays River	Cowlitz River	Kalama River	Lewis River	Sandy River	Oregon only[a]	Washington only	Total	Source
1963	222,300	21,300	833,500	0	0	0			1,077,100	WDFW and ODFW 2002
1964	452,900	0	388,900	0	0	0			841,800	WDFW and ODFW 2002
1965	828,700	0	0	0	82,000	0			910,700	WDFW and ODFW 2002
1966	712,200	0	316,100	0	0	0			1,028,300	WDFW and ODFW 2002
1967	357,100	23,200	620,500	0	0	0			1,000,800	WDFW and ODFW 2002
1968	133,300	1,200	813,000	0	0	0			947,500	WDFW and ODFW 2002
1969	113,700	52,800	917,200	0	0	0			1,083,700	WDFW and ODFW 2002
1970	238,200	4,500	559,700	55,900	325,600	0			1,183,900	WDFW and ODFW 2002
1971	364,500	0	509,400	0	902,800	0			1,776,700	WDFW and ODFW 2002
1972	304,100	0	1,339,400	0	0	0			1,643,500	WDFW and ODFW 2002
1973	132,000	0	2,302,400	0	0	0			2,434,400	WDFW and ODFW 2002
1974	868,400	6,200	1,474,700	0	500	12,000			2,361,800	WDFW and ODFW 2002
1975	28,300	0	2,049,300	0	0	0			2,077,600	WDFW and ODFW 2002
1976	9,400	0	3,055,300	0	0	10,400			3,075,100	WDFW and ODFW 2002
1977	662,700	0	0	326,200	0	764,100			1,753,000	WDFW and ODFW 2002
1978	16,600	0	2,642,700	0	21,000	0			2,680,300	WDFW and ODFW 2002
1979	313,600	0	18,200	0	233,300	591,600			1,156,700	WDFW and ODFW 2002
1980	160,100	8,800	116,500	700	2,651,600	273,800			3,211,500	WDFW and ODFW 2002
1981	158,200	0	932,500	0	567,100	14,500			1,672,300	WDFW and ODFW 2002
1982	304,200	0	1,343,200	8,200	554,400	0			2,210,000	WDFW and ODFW 2002
1983	58,700	0	1,307,300	0	1,364,400	0			2,730,400	WDFW and ODFW 2002
1984	120,400	0	377,600	0	0	0			498,000	WDFW and ODFW 2002
1985	537,800	34,900	1,160,800	0	0	304,500			2,038,000	WDFW and ODFW 2002
1986	53,000	0	3,736,100	0	49,700	0			3,838,800	WDFW and ODFW 2002
1987	73,600	0	1,321,000	700	500,400	0			1,895,700	WDFW and ODFW 2002
1988	72,800	0	2,244,300	0	549,600	1,000			2,867,700	WDFW and ODFW 2002
1989	65,200	0	3,001,600	0	0	0			3,066,800	WDFW and ODFW 2002
1990	6,400	0	2,756,200	0	21,600	0			2,784,200	JCRMS 2007
1991	5,800	0	2,944,600	0	0	0			2,950,400	JCRMS 2007
1992	800	0	3,673,000	0	0	0			3,673,800	JCRMS 2007
1993	33,200	0	413,900	66,800	0	0			513,900	JCRMS 2007
1994	200	0	43,200	0	0	0			43,400	JCRMS 2007
1995	7,700	0	431,400	900	0	0			440,000	JCRMS 2007
1996	7,100	0	2,000	0	0	0			9,100	JCRMS 2007
1997	37,100	0	21,500	0	0	0			58,600	JCRMS 2007

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

Year	Columbia River	Grays River	Cowlitz River	Kalama River	Lewis River	Sandy River	Oregon only[a]	Washington only	Total	Source
1998	11,900	0	200	0	0	0			12,100	JCRMS 2007
1999	20,900	0	0	0	0	0			20,900	JCRMS 2007
2000	31,000	0	0	0	0	0			31,000	JCRMS 2007
2001	158,800	0	154,300	0	0	0			313,100	JCRMS 2007
2002	58,000	0	169,600	0	493,600	0			721,200	JCRMS 2007
2003	66,900	0	464,400	0	529,100	23,000			1,083,400	JCRMS 2007
2004	15,400	0	216,200	0	0	0			231,600	JCRMS 2007
2005	100	0	100	0	0	0			200	JCRMS 2007
2006	13,100	0	0	0	0	0			13,100	JCRMS 2007
2007	7,100	0	1,200	0	0	0			8,300	JCRMS 2007
2008	11,400	0	5,900	0	0	0			17,300	JCRMS 2008
2009	5,551	0	12,093	0	0	0			17,644	WDFW 2009

[a]Some Oregon commercial smelt catch values may be statewide smelt catch and may include an unknown number of noneulachon smelt caught in coastal streams.
[b]Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.
[c]Crawford (1894, p. 5) reported landings that equated to a monetary value of $3,000. At an average of one cent per pound, this equates to approximately 300,000 pounds of eulachon.

Table 8. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

Year	Total landings (pounds)	Number of fish at 10.8 per pound	Number of fish at 12.3 per pound
1888	150,000	1,620,000	1,845,000
1889	60,000	648,000	738,000
1890	1,000	10,800	12,300
1891	150,000	1,620,000	1,845,000
1892	625,000	6,750,000	7,687,500
1893	Unknown*	—	—
1894	300,000	3,240,000	3,690,000
1895	313,375	3,384,450	3,854,513
1896	677,350	7,315,380	8,331,405
1897	1,021,480	11,031,984	12,564,204
1898	737,000	7,959,600	9,065,100
1899	560,920	6,057,936	6,899,316
1900	487,600	5,266,080	5,997,480
1901	265,380	2,866,104	3,264,174
1902	572,454	6,182,503	7,041,184
1903	402,000	4,341,600	4,944,600
1904	440,460	4,756,968	5,417,658
1905	483,015	5,216,562	5,941,085
1906	503,000	5,432,400	6,186,900
1907	169,804	1,833,883	2,088,589
1908	602,022	6,501,838	7,404,871
1909	549,608	5,935,766	6,760,178
1910	622,478	6,722,762	7,656,479
1911	349,639	3,776,101	4,300,560
1912	495,336	5,349,629	6,092,633
1913	200,000	2,160,000	2,460,000
1914	Unknown*	—	—
1915	1,609,500	17,382,600	19,796,850
1916	641,595	6,929,226	7,891,619
1917	2,806,129	30,306,193	34,515,387
1918	1,633,700	17,643,960	20,094,510
1919	2,405,360	25,977,888	29,585,928
1920	977,084	10,552,507	12,018,133
1921	1,051,283	11,353,856	12,930,781
1922	1,371,180	14,808,744	16,865,514
1923	1,029,418	11,117,714	12,661,841
1924	1,006,222	10,867,198	12,376,531
1925	1,400,704	15,127,603	17,228,659
1926	1,267,214	13,685,911	15,586,732
1927	1,293,046	13,964,897	15,904,466
1928	1,168,818	12,623,234	14,376,461
1929	1,208,480	13,051,584	14,864,304
1930	1,454,486	15,708,449	17,890,178

Table 8 continued. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

Year	Total landings (pounds)	Number of fish at 10.8 per pound	Number of fish at 12.3 per pound
1931	1,957,272	21,138,538	24,074,446
1932	1,583,948	17,106,638	19,482,560
1933	1,392,590	15,039,972	17,128,857
1934	1,520,156	16,417,685	18,697,919
1935	2,331,958	25,185,146	28,683,083
1936	3,083,857	33,305,656	37,931,441
1937	2,438,443	26,335,184	29,992,849
1938	1,041,600	11,249,280	12,811,680
1939	3,096,400	33,441,120	38,085,720
1940	3,082,500	33,291,000	37,914,750
1941	2,531,800	27,343,440	31,141,140
1942	2,686,000	29,008,800	33,037,800
1943	3,977,300	42,954,840	48,920,790
1944	2,268,500	24,499,800	27,902,550
1945	5,719,300	61,768,440	70,347,390
1946	3,276,000	35,380,800	40,294,800
1947	1,544,900	16,684,920	19,002,270
1948	3,974,100	42,920,280	48,881,430
1949	3,333,600	36,002,880	41,003,280
1950	1,482,500	16,011,000	18,234,750
1951	1,516,900	16,382,520	18,657,870
1952	1,274,900	13,768,920	15,681,270
1953	1,711,000	18,478,800	21,045,300
1954	1,884,300	20,350,440	23,176,890
1955	2,237,100	24,160,680	27,516,330
1956	1,683,900	18,186,120	20,711,970
1957	1,579,000	17,053,200	19,421,700
1958	2,616,400	28,257,120	32,181,720
1959	1,756,100	18,965,880	21,600,030
1960	1,172,200	12,659,760	14,418,060
1961	1,052,300	11,364,840	12,943,290
1962	1,473,600	15,914,880	18,125,280
1963	1,077,100	11,632,680	13,248,330
1964	841,800	9,091,440	10,354,140
1965	910,700	9,835,560	11,201,610
1966	1,028,300	11,105,640	12,648,090
1967	1,000,800	10,808,640	12,309,840
1968	947,500	10,233,000	11,654,250
1969	1,083,700	11,703,960	13,329,510
1970	1,183,900	12,786,120	14,561,970
1971	1,776,700	19,188,360	21,853,410
1972	1,643,500	17,749,800	20,215,050
1973	2,434,400	26,291,520	29,943,120

Table 8 continued. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

Year	Total landings (pounds)	Number of fish at 10.8 per pound	Number of fish at 12.3 per pound
1974	2,361,800	25,507,440	29,050,140
1975	2,077,600	22,438,080	25,554,480
1976	3,075,100	33,211,080	37,823,730
1977	1,753,000	18,932,400	21,561,900
1978	2,680,300	28,947,240	32,967,690
1979	1,156,700	12,492,360	14,227,410
1980	3,211,500	34,684,200	39,501,450
1981	1,672,300	18,060,840	20,569,290
1982	2,210,000	23,868,000	27,183,000
1983	2,730,400	29,488,320	33,583,920
1984	498,000	5,378,400	6,125,400
1985	2,038,000	22,010,400	25,067,400
1986	3,838,800	41,459,040	47,217,240
1987	1,895,700	20,473,560	23,317,110
1988	2,867,700	30,971,160	35,272,710
1989	3,066,800	33,121,440	37,721,640
1990	2,784,200	30,069,360	34,245,660
1991	2,950,400	31,864,320	36,289,920
1992	3,673,800	39,677,040	45,187,740
1993	513,900	5,550,120	6,320,970
1994	43,400	468,720	533,820
1995	440,000	4,752,000	5,412,000
1996	9,100	98,280	111,930
1997	58,600	632,880	720,780
1998	12,100	130,680	148,830
1999	20,900	225,720	257,070
2000	31,000	334,800	381,300
2001	313,100	3,381,480	3,851,130
2002	721,200	7,788,960	8,870,760
2003	1,083,400	11,700,720	13,325,820
2004	231,600	2,501,280	2,848,680
2005	200	2,160	2,460
2006	13,100	141,480	161,130
2007	8,310	89,748	102,213
2008	17,300	186,840	212,790
2009	17,644	190,555	217,021

*Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.

Table 9. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

Year	Columbia River	Fraser River	Knight Inlet (Klinaklini River)	Bella Coola River	Kemano River	Skeena River
1888	68.04					
1889	27.22					
1890	0.45					
1891	68.04					
1892	283.50					
1893	Unknown[a]					
1894	136.08					
1895	142.14					
1896	307.24					
1897	463.34					
1898	334.30					
1899	254.43					
1900	221.17	113.40				27.2
1901	120.37	108.86				27.2
1902	259.66	90.72				22.7
1903	182.34	128.97				22.7
1904	199.79	129.27				18.1
1905	219.09	22.68				4.5
1906	228.16	13.61				5.4
1907	77.02	6.80				4.5
1908	273.07	10.21				4.1
1909	249.30	31.75				4.5
1910	282.35	42.50				136.1
1911	158.59	32.66				113.4
1912	224.68	36.29				90.7
1913	90.72	10.52				68.0
1914	Unknown[a]	6.44				54.4
1915	730.06	12.34				45.4
1916	291.02	12.52				45.4
1917	1,272.84	17.28				
1918	741.03	15.20				
1919	1,091.05	5.94				1.9
1920	443.20	5.22				
1921	476.85	8.53				
1922	621.96	7.98				
1923	466.94	19.87				
1924	456.41	36.51				15.4
1925	635.35	16.19				

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

Year	**Columbia River**	**Fraser River**	**Knight Inlet (Klinaklini River)**	**Bella Coola River**	**Kemano River**	**Skeena River**
1926	574.80	17.24				1.1
1927	586.52	12.97				9.1
1928	530.17	18.73				
1929	548.16	9.71				6.6
1930	659.74	35.33				5.4
1931	887.80	6.30				2.7
1932	718.47	5.03				3.3
1933	631.67	6.94				
1934	689.53	10.25				
1935	1,057.76	15.47				0.9
1936	1,398.81	10.07				
1937	1,106.06	4.08				
1938	472.46	7.67				
1939	1,404.50	20.59				
1940	1,398.20	34.16				
1941	1,148.41	50.1				1.0
1942	1,218.35	152.7				
1943	1,804.07	154.8				
1944	1,028.97	65.7		Unknown[b]		
1945	2,594.23	73.87		8.0		
1946	1,485.97	115.7		10.0		
1947	700.75	231.1	135.0	Unknown[b]		
1948	1,802.62	112.8		20.0		
1949	1,512.10	102.7	70.0	8.5		
1950	672.45	36.2	100.0	44.0		
1951	688.05	189.3	20.0	10.0		
1952	578.28	421.0	27.5	12.3		
1953	776.10	158.6		41.7		
1954	854.70	151.6		69.4		
1955	1,014.73	238.8		7.6		
1956	763.80	235.5		6.2		
1957	716.22	33.2		5.6		
1958	1,186.78	92.1		8.4		
1959	796.55	132.0	45.0	7.0		
1960	531.70	84.0	60.0	0.3		
1961	477.32	216.9		2.0		
1962	668.41	178.2	70.0	2.8		
1963	488.56	159.3		8.4		
1964	381.83	105.5		22.4		

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

Year	Columbia River	Fraser River	Knight Inlet (Klinaklini River)	Bella Coola River	Kemano River	Skeena River
1965	413.09	87.8	100.0	11.8		
1966	466.43	101.9		9.2		
1967	453.96	86.8	100.0	11.5		
1968	429.78	46.0	100.0	10.6		
1969	491.56	29.8	80.0	7.8		
1970	537.01	71.7	40.0	9.2		
1971	805.90	34.5	20.0	16.8		
1972	745.48	53.2	50.0	6.7		
1973	1,104.23	53.1	40.0	12.3		
1974	1,071.29	75.3		10.6		
1975	942.38	27.7		12.0		
1976	1,394.84	36.7		50.0		
1977	795.15	32.2	50.0	35.0		
1978	1,215.76	38.6		25.0		
1979	524.67	22.3		19.8		
1980	1,456.71	24.4		33.0		
1981	758.54	21.2		38.5		
1982	1,002.44	13.7		22.0		
1983	1,238.49	10.8		30.5		
1984	225.89	11.8		30.0		
1985	924.42	29.2		Unknown[b]		
1986	1,741.25	49.6		Unknown[b]		
1987	859.88	19.3		Unknown[b]		
1988	1,300.77	39.5		Unknown[b]	43.2	
1989	1,391.08	18.7		Unknown[b]	50.2	
1990	1,262.89	19.9		Unknown[b]	44.1	
1991	1,338.28	12.3		Unknown[b]	57.2	
1992	1,666.41	19.6		Unknown[b]	65.4	
1993	233.10	8.7		Unknown[b]	93.0	
1994	19.69	6.1		20.0	20.6	
1995	199.58	15.5		22.0	69.2	
1996	4.13	63.2		Unknown[b]	81.0	
1997	26.58	Closed		Unknown[b]	41.9	
1998	5.49	Closed		Unknown[b]	61.7	
1999	9.48	Closed		0.0		
2000	14.06	Closed		0.0		
2001	142.02	Closed				
2002	327.13	5.8				
2003	491.42	Closed				

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

Year	Columbia River	Fraser River	Knight Inlet (Klinaklini River)	Bella Coola River	Kemano River	Skeena River
2004	105.05	0.4				
2005	0.09	Closed				
2006	5.94	Closed				
2007	3.77	Closed				
2008	7.85	Closed				
2009	8.00	Closed				

[a]Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.
[b]Landings of unknown size occurred but data were not recorded (Hay 2002).

declined greatly to 233 mt in 1993 and to an average of less than 40 mt between 1994 and 2000. From 2001 to 2004, the catches increased to an average of 266 mt, before falling to less than 5 mt from 2005 to 2008. Fishing restrictions were instituted in 1995, so the low catches after that time are in part due to these restrictions (Figure 23 and Figure 24). Nonetheless, the steep decline in 1993 and subsequent low abundance as indexed by the fishery is generally accepted by fishery managers as indicating a marked decline in the abundance of the stock (Bargmann et al. 2005). The WDFW and ODFW Joint Columbia River Management Staff (JCRMS 2007) concluded that "run sizes [of Columbia River eulachon], as indexed by commercial landings, remained relatively stable for several decades until landings dropped suddenly in 1993 and remained low for several years thereafter." Following this period of time, "Due to reduced seasons during 1995–2000, landings are not completely comparable with previous years; however, it is apparent that the abundance of smelt in the Columbia River Basin was much reduced during 1993–2000" (JCRMS 2005) (Table 7, Figure 22 through Figure 25).

A previous petition (Wright 1999) and NMFS finding on this petition (NMFS 1999) mentioned years where zero catches were reported for eulachon in the Columbia River. The present status review uncovered additional published Columbia River commercial fishery landings data in annual reports of state and federal fisheries agencies that fill in most of these gaps in the catch record (Table 7, Figure 22), with the exception of 1893 and 1914. In both cases, a survey of periodicals (Appendix D) and available online digital newspaper resources (see Appendix B) found articles describing the presence of eulachon in the Columbia River in those years.

The Columbia River eulachon commercial fishery has been managed according to the Joint State Eulachon Management Plan since 2001 (with an interim plan in effect in 2000), which provides for three levels of fishing based on parental run strength, juvenile production, and ocean productivity (WDFW and ODFW 2001, Bargmann et al. 2005). Effort in this fishery

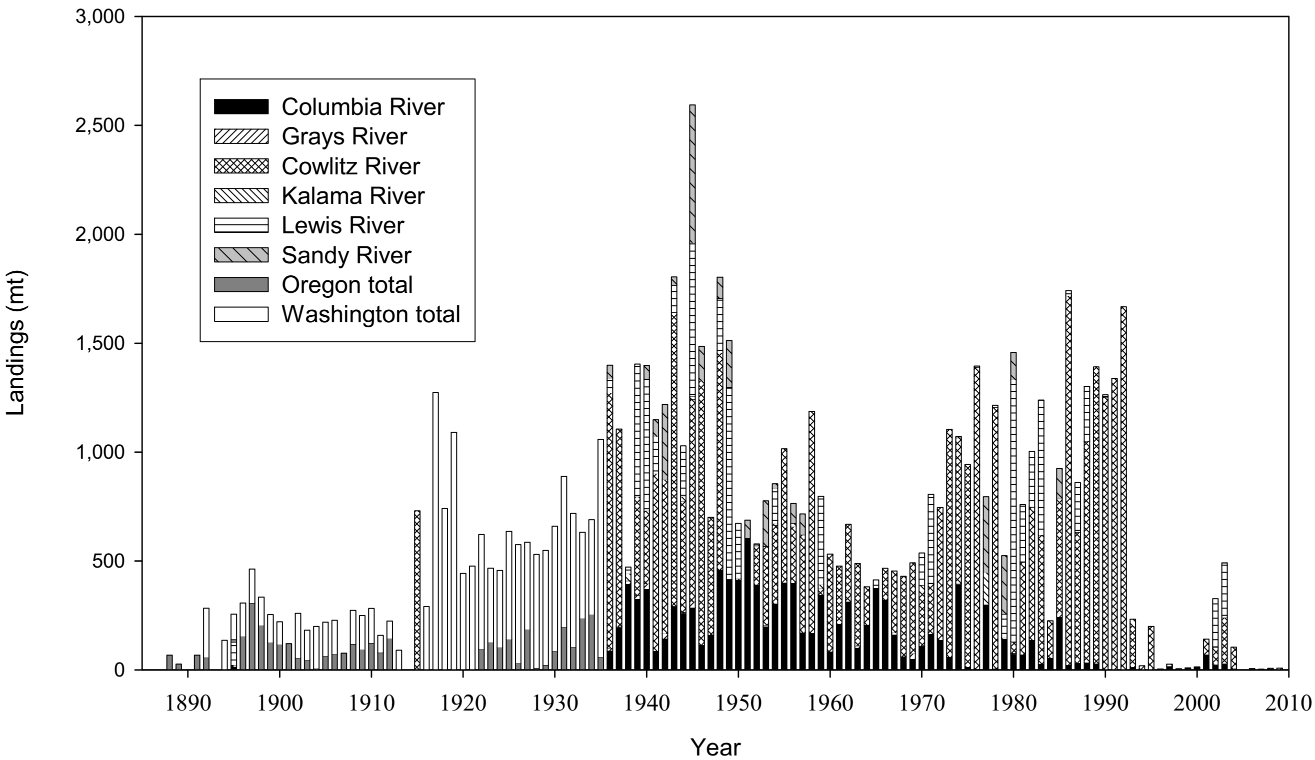

Figure 22. Commercial eulachon fishery landings in the Columbia River and tributaries from 1888 to 2009. Landings occurred in 1890 and in the Grays and Kalama rivers in many years; however, values are too small to be evident on the graph. Landings occurred in 1893 and 1914, based on newspaper and periodical sources (see Appendix B and Appendix D), but official records have not been located. Data sources listed in Table 7.

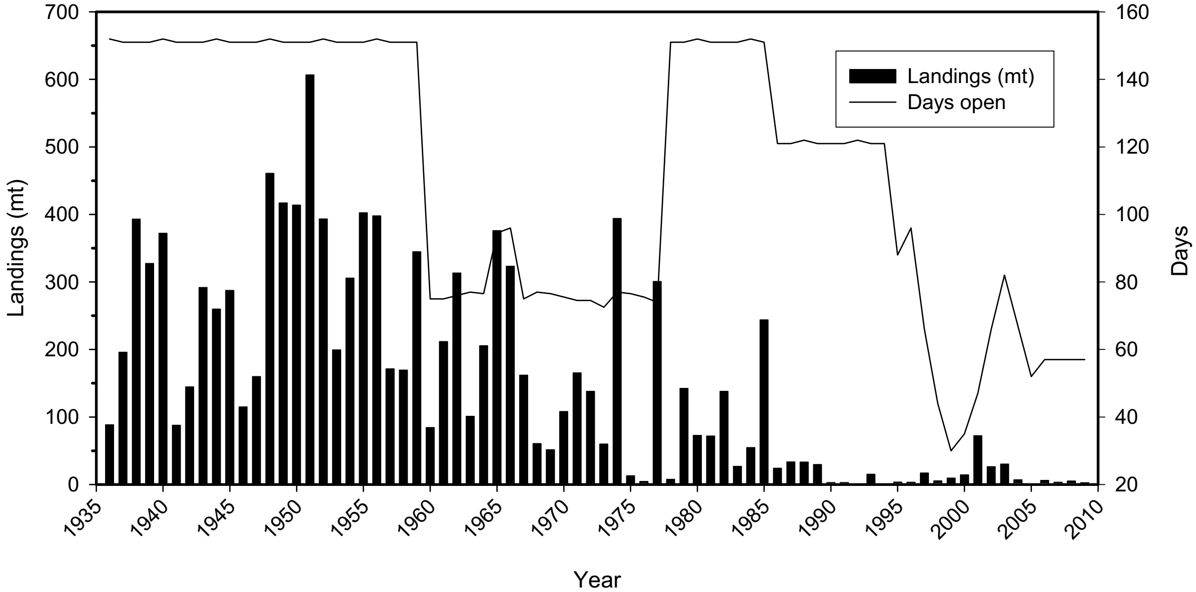

Figure 23. Commercial landings of eulachon and estimated total number of days the fishery was open in the Columbia River from 1935 to 2009.

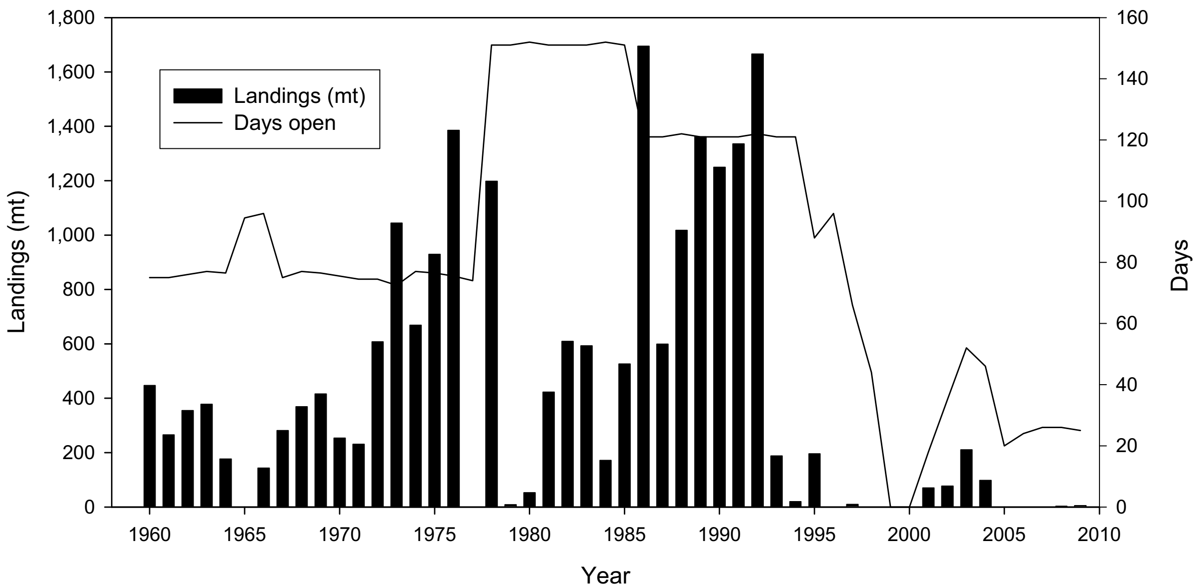

Figure 24. Commercial landings of eulachon and estimated total number of days the fishery was open in the Cowlitz River from 1960 to 2009.

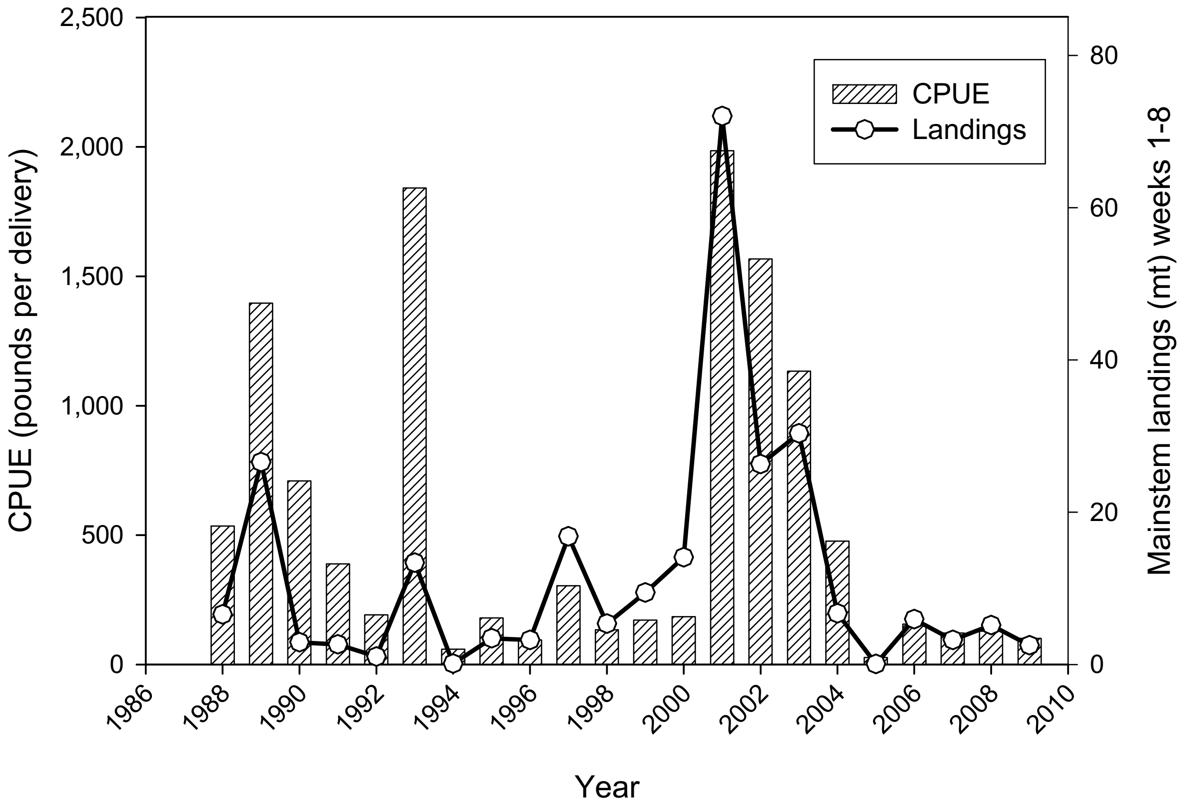

Figure 25. Columbia River commercial eulachon landings (season total may include landings during the previous December) and CPUE as pounds per delivery. Data from JCRMS (2009, their Table 17).

typically involves fewer than 10 vessels. WDFW and ODFW (2008) described these three levels of fishing: 1) Level One fisheries are the most conservative (commercial and recreational openings of 12–24 hours per week for Columbia and Cowlitz rivers) and are designed to act as a test fishery when there are indications of a poor return or great uncertainty in potential run strength, 2) Level Two fisheries (commercial and recreational openings of 2–3 days per week and potential of expansion to other tributaries) are indicated when fishery data suggest a moderate or strong run size, and 3) Level Three fisheries (commercial openings up to 4 days per week in all areas and all tributaries open to recreational fishing 4–7 days per week) may occur when abundance and productivity indicators are very strong.

The Columbia River eulachon fishery operated as a Level One test fishery in 2001; began as a Level Two fishery in 2002, switching to Level Three on February 1; operated at Level Three in 2003; started off as Level Three in 2004, with some later tributary commercial fishery restrictions; operated at Level Two in 2005 until February 23 when it was reduced to a Level One fishery; and has operated as a Level One test fishery in 2006 through 2009 (JCRMS 2005, 2006, 2007, 2008, 2009). The ability to adjust in-season fishery levels based on observed returns to the fishery, and its accurate tracking of past fluctuations in run strength, illustrates the utility of the Columbia River eulachon fishery statistics as an index of relative annual abundance (JCRMS 2007) (Figure 23 and Figure 24).

There is some information indicating that there have been periods of relatively low eulachon abundance in the past in the Columbia River. In particular, several anecdotal sources reported on a decline in the 1830s to 1860s (Suckley 1860, Lord 1866, Anderson 1872, 1877, Crawford 1878, Huntington 1963, Hinrichsen 1998, Martin 2008). Eulachon were once again seen in large numbers in the early to mid 1860s (Anderson 1872, 1877, Huntington 1963, Summers 1982, Urrutia 1998, Hinrichsen 1998, Martin 2008). Based on the available information, the BRT concluded that this information was probably accurate and likely indicated that a true and severe decline in eulachon returns and subsequent recovery occurred during that time period.

Subsequent to the decline in 1993, state and tribal fishery agencies have instituted additional monitoring efforts for Columbia River eulachon. For example, Figure 26 presents data from a larval sampling program that measures larval densities (averaged across stations and depths at selected index sites) that was initiated in 1994 for the Cowlitz River and expanded to include the Kalama River in 1995, the mainstem Columbia River in 1996, Elochoman and Lewis rivers in 1997, and Grays and Sandy rivers in 1998 (JCRMS 2005). Interannual comparison of larval densities prior to about 2003 is unreliable because "larval sampling techniques … did not include repeat sampling of the same area over the duration of the out migration period" (JCRMS 2007, p. 23), but since that time multiple surveys have been conducted each season at mainstem Columbia River sites that sample downstream of all the potential spawning locations, with the exception of Grays River. Notably, the larval densities show a peak in 2001–2002 that corresponds to a similar peak in catches (Figure 22) and offshore juvenile abundance (Figure 16 and Figure 17). Although spawning stock abundance has not been estimated using these larval surveys, the combination of data from the larval density survey and commercial and recreational landings "provides an indication of the relative run strength of eulachon in the Columbia River" (JCRMS 2007, p. 23).

The BRT had concerns about the absence of fishery-independent abundance data for Columbia River eulachon prior to the mid-1990s. The BRT agreed with state fishery managers, however, that the available catch and effort information indicate an abrupt decline in abundance in the early 1990s, and there is no evidence that the population has returned to its former level. The decline in the early 1990s appeared to coincide with a decline of eulachon in British Columbia, suggesting that a common cause, such as changing ocean conditions, was responsible for declines in both areas.

Fraser River

Eulachon return on a regular basis to the Fraser River and on an irregular basis to the Squamish River in Howe Sound to the north (Table A-1, Figure 3) (Hay and McCarter 2000, Moody 2008). Eulachon usually begin to ascend the Fraser River at the end of March and spawning occurs in April until the middle of May. Eulachon are no longer seen spawning in some areas of the Fraser River where they used to occur. Historically, spawning occurred "primarily between Chilliwack and Mission in areas of coarse sand but also in localized areas of the North and South Arms as well as in the vicinity of the Pitt and Alouette rivers" (Higgins et al. 1987). Currently spawning is confined to areas downstream of Mission.

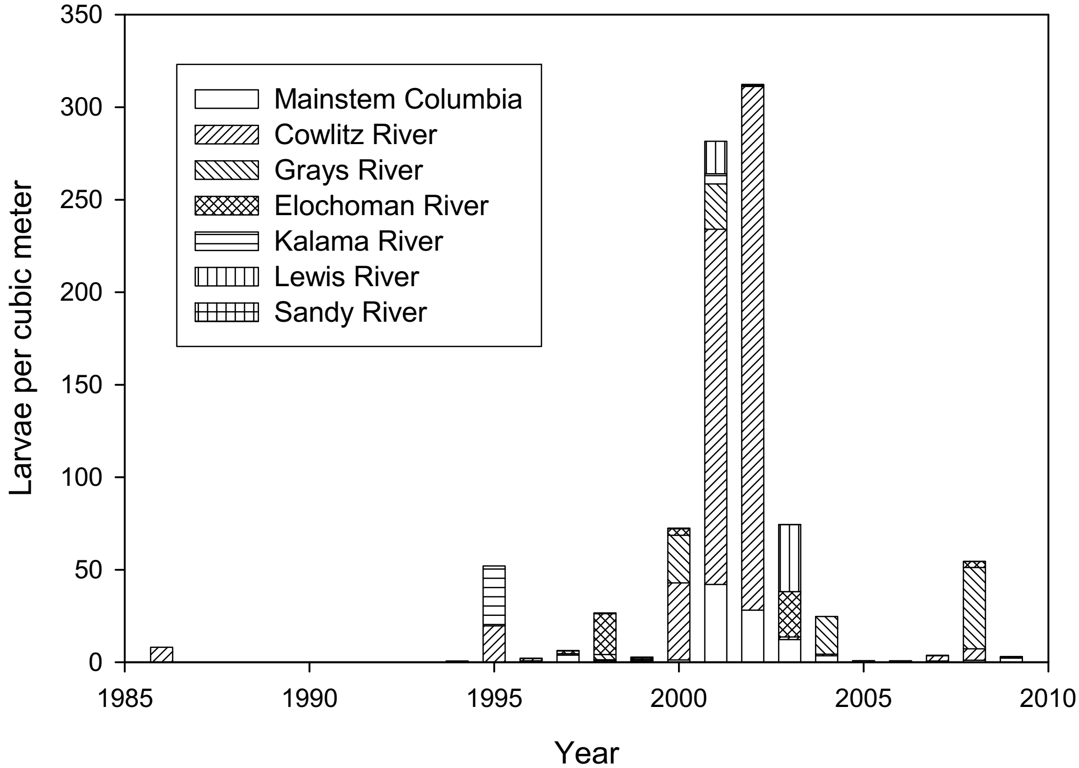

Figure 26. Columbia River larval eulachon sampling. Interannual comparisons are problematic due to inconsistent effort and methods from year to year. Larvae were encountered in the Sandy River in 1998–2000 and 2003; however, values are too small (0.1 per cubic meter) to be evident on the graph. Data from JCRMS (2008, 2009, its Table 18).

In the past, Fraser River eulachon runs supported First Nations subsistence fisheries and large commercial and recreational fisheries. Between 1941 and 1996, commercial landings averaged about 83 mt (Table 9, Table 10, and Figure 27). For much of this period, the commercial fishery landings are not a good indicator of relative abundance, since landings were largely driven by market demand (Moody 2008). In 1997 the commercial eulachon fishery was closed and commercial landings have occurred in only 2 of the last 10 years; 2002 and 2004, when 5.76 and 0.44 mt were landed, respectively (Table 9, Figure 27) (DFO 2006a). Hay et al. (2003) estimated that First Nations and recreational fisheries historically landed about 10 mt annually. Estimates of recreational fishery landings were presented in graphical form in Moody (2008, her Figure 2.22) for a portion of the Fraser River (1956, 1963–1967, 1970–1980, closed since 2005).

Moody (2008) stated that the First Nation catch amounted to 2.57 mt in 2003. However, by 2005 all First Nation, commercial, and recreational fisheries were closed due to conservation concerns (DFO 2006a). A eulachon test fishery operated on the Fraser River near New Westminster from 1995 to 2005 (with the exception of 1999) (Figure 27); however, this fishery has not operated since 2005 (DFO 2008a). This test fishery was meant to be an in-season

Table 10. Estimated eulachon spawner biomass (mt) in the north arm and south arm of the Fraser River and total number of eulachon, assuming a range of 9.9 to 13.3 eulachon per pound, based on the mean reported weight of eulachon in the Fraser River of 34 to 46 g. Biomass data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.

Year	South arm	North arm	Total biomass (mt)	Total biomass (pounds)	Number of fish at 9.9 per pound	Number of fish at 13.3 per pound
1995	258	44	302	665,796	6,591,381	8,855,087
1996	1,582	329	1,911	4,213,034	41,709,035	56,033,350
1997	57	17	74	163,142	1,615,107	2,169,790
1998	107	29	136	299,829	2,968,304	3,987,721
1999	392	26	418	921,532	9,123,169	12,256,379
2000	76	54	130	286,601	2,837,349	3,811,793
2001	422	187	609	1,342,615	13,291,890	17,856,782
2002	354	140	494	1,089,084	10,781,927	14,484,812
2003	200	66	266	586,430	5,805,653	7,799,514
2004	24	9	33	72,753	720,250	967,609
2005	14	2	16	35,274	349,212	469,144
2006	24	5	29	63,934	632,947	850,323
2007	34	7	41	90,390	894,856	1,202,181
2008	8	2	10	22,046	218,258	293,215
2009	12	2	14	30,865	305,561	410,501

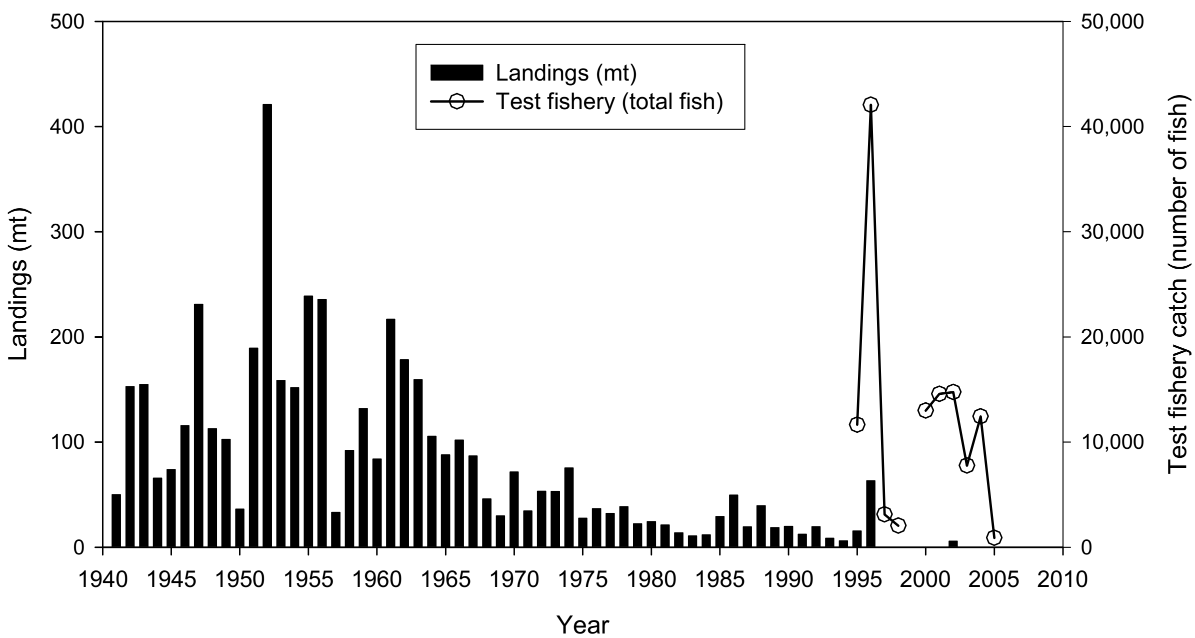

Figure 27. Eulachon landings in Fraser River commercial fishery (1940–2009) and total fish caught in Fraser River test fishery (1995–2005). Commercial fishery was closed in 1997–2001, 2003, and 2005–2009. Data from Hay (2002) and DFO (2008a).

measure of eulachon run strength and resulting data consisted of the total number of eulachon caught daily at the same site, with the same gear, over the same time period, and at similar tidal conditions (Therriault and McCarter 2005, DFO 2008a). When in operation, a catch of less than 5,000 in this test fishery was considered a conservation concern (DFO 2006a).

Table 10, Table 11, and Figure 28 present spawning stock biomass data (DFO 2008a, p. 11) that is derived from:

> an intensive sampling process [that] takes place in the Fraser River during the seven to eight weeks following spawning (April/May). This survey uses towed, small mesh nets to gather samples of eulachon eggs and larvae. The number of eggs and larvae gathered in each tow are hand counted at the Pacific Biological Station. The egg and larval count is then combined with data on the daily Fraser River discharge and historical data on eulachon fecundity (eggs produced per female) to generate an estimate of spawning stock biomass.

DFO (2008a, p. 11) stated that:

> A low spawning stock biomass for one year is cause for caution and a low spawning stock biomass for two consecutive years indicates a conservation concern. A low spawning stock biomass has been defined as less than 150 mt.

A recent population assessment of Fraser River eulachon by DFO (2007a, p. 3) stated that:

> Despite limited directed fisheries in recent years, the Fraser River eulachon stock remains at a precariously low level. This stock has failed to recover from its collapse. SSB [spawning stock biomass] estimated from the egg and larval survey conducted in 2006 was 29 tonnes. The framework documents suggest that a low SSB (<150 tonnes) for one year is cause for concern and a restriction on removals should be activated, while a low SSB for two (or more) consecutive years is more cause for alarm and should signal a halt to all removals (Hay et al. 2003, 2005). Since 2007 is the fourth consecutive year where Fraser River eulachon SSB has been below 150 tonnes, unprecedented in this short time series, no removals should be allowed in 2008.

Subsequent to this statement, spawner biomass for the 2008 and 2009 eulachon run in the Fraser River has been estimated at 10 and 14 mt, respectively (data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm). Figure 29 presents the Fraser River eulachon spawner abundance trend over the time period of the available data (1995–2009). A trend of 0.76 (95% CI, 0.67–0.88) for Fraser River eulachon was calculated from these data. Over the three-generation time of approximately 10 years, the overall biomass of the Fraser River eulachon population has undergone a 96.6% decline (1999, 418 mt; 2009, 14 mt). Under the International Union for the Conservation of Nature (IUCN) decline criteria (A1), a reduction in population size of this magnitude, "where the reduction or its causes may not have ceased or may not be understood or may not be reversible" (IUCN 2006), would place Fraser River eulachon in the IUCN critically endangered category (IUCN 2001, 2006).

The methodology on the Fraser River of utilizing mean egg and larval plankton density and river discharge rates (gathered throughout a seven-week outmigrant period at five locations) in combination with known relative fecundity (egg production per gram of female) and sex ratio

Table 11. Available estimated eulachon spawner biomass (mt) or estimated total number of spawners in British Columbia rivers in the DPS.

Year	Fraser River (mt)[a]	Klinaklini River (mt)[b]	Kingcome River (mt)[b]	Wannock/Kilbella rivers (no. of fish)[c]	Bella Coola River (mt)[c]	Kitimat River (no. of fish)[d]	Skeena River (mt)[e]
1993	—					514,000	
1994	—					527,000	
1995	302	40					
1996	1,911					440,000	
1997	74		14.4				3.0
1998	136						
1999	418						
2000	130						
2001	609				0.039		
2002	494				≈0.050		
2003	266				0.016		
2004	33				0.007		
2005	16			2,700			
2006	29			23,000		<1,000	
2007	41						
2008	10						
2009	14						

[a]Data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.
[b]Berry and Jacob 1998 (as cited in Moody 2008).
[c]Moody 2008.
[d]Pederson et al. 1995 and Ecometrix 2006 (as cited in Moody 2008).
[e]Lewis 1997.

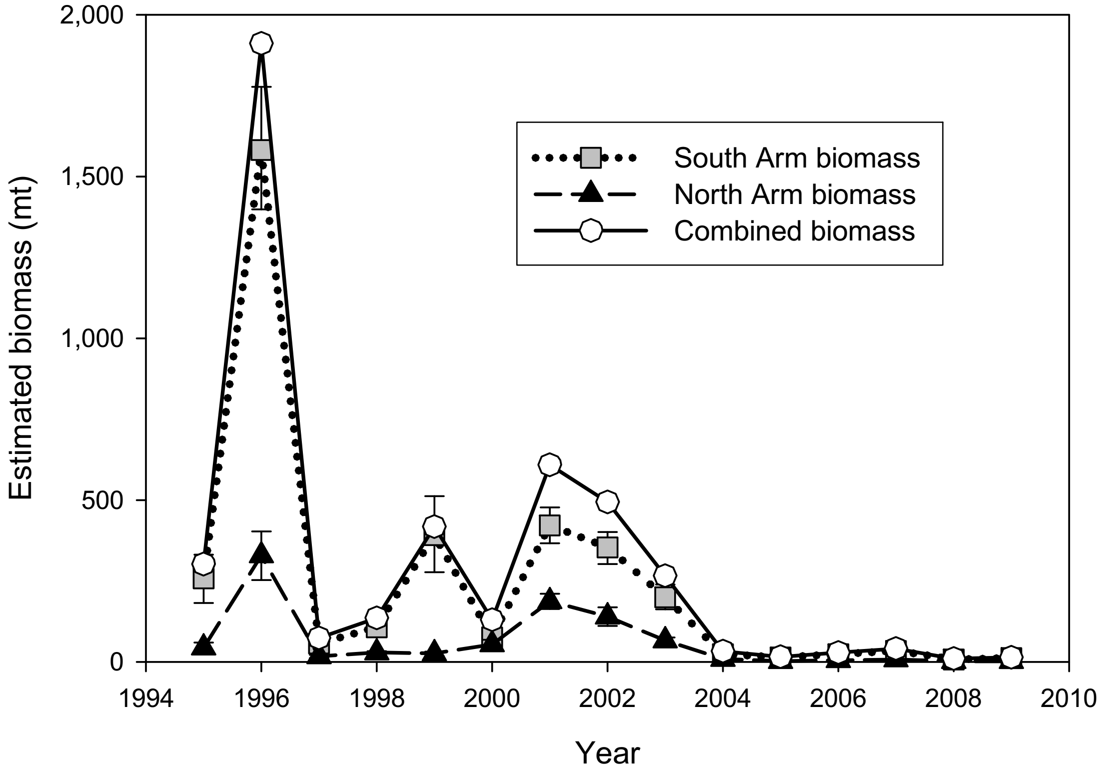

Figure 28. Fraser River eulachon spawning stock biomass from 1995 to 2009 (estimated from egg and larval surveys). Data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.

to estimate spawning stock biomass has passed rigorous scientific review in Canada (Hay et al. 2002, 2003, 2005, McCarter and Hay 2003, Therriault and McCarter 2005). This methodology is similar to methods used since the early 1970s by many fisheries agencies (WDFW, DFO, CDFG, and Alaska Department of Fish and Game) to calculate Pacific herring spawning stock abundance based on estimates of intertidal and subtidal egg deposition and relative fecundity. The BRT therefore was confident that observed trends in the Fraser River spawning stock abundance data represented a true picture of the status of Fraser River eulachon.

According to Therriault and McCarter (2005), the Fraser River test fishery data did not correspond well with the spawning stock estimates that were based on the egg and larval survey and this may have resulted from variation in the catchability of adults. Eulachon abundance can be inflated when they form dense schools, which can lead to an overestimate of abundance. On the other hand, eulachon may avoid the test fishery gear, leading to an underestimate of the run size. Due to these and other problems with the test fishery methodology (Therriault and McCarter 2005), the BRT did not put a lot of confidence in these data.

The BRT did not formally analyze commercial, recreational, or subsistence fishery landings between 1881 and the present in the Fraser River, as it is believed that for much of this period the commercial fishery landings were largely driven by market demand (Hay et al. 2002,

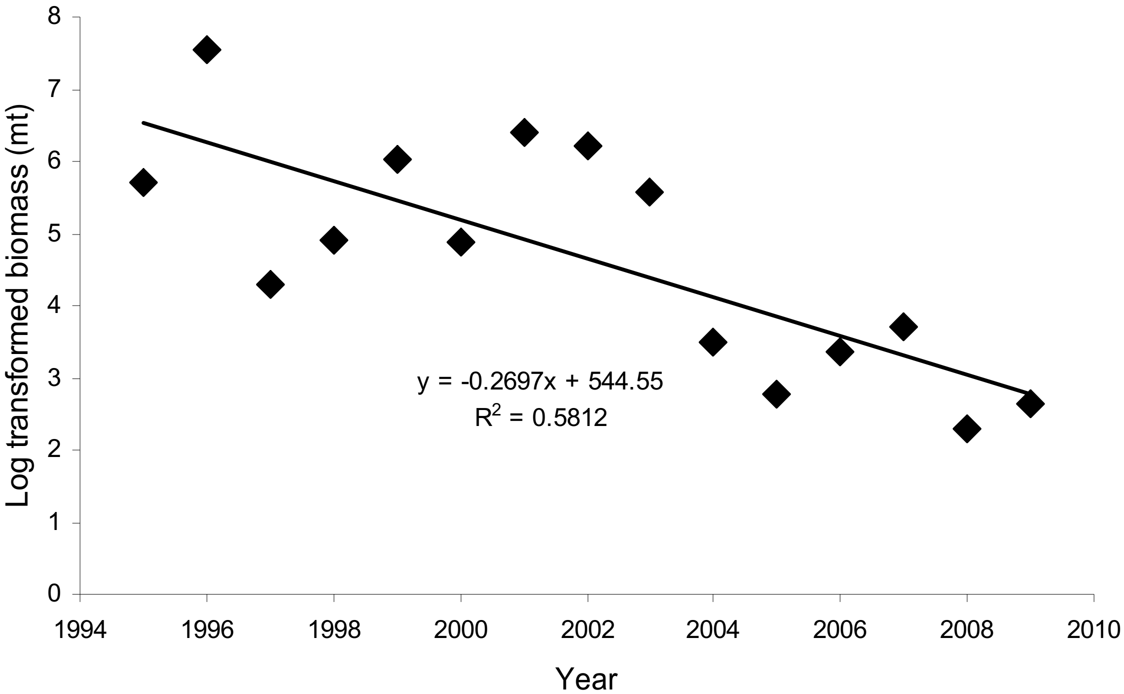

Figure 29. Trend of Fraser River eulachon spawner abundance (mt) from 1995 to 2009. Trend calculated from data in Figure 28.

Moody 2008). However, these data do indicate that eulachon were generally present at harvestable abundance levels in the Fraser River during this time period.

Knight Inlet

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Klinaklini River at the head of Knight Inlet on the British Columbia coast (Table A-1, Figure 3). Irregular eulachon runs in the Johnstone Strait Region include the Kakweiken River, Homathko River (Bute Inlet), and Stafford and Apple rivers (Loughborough Inlet). Peak spawn timing in the area occurs about the middle of April (Hay and McCarter 2000, Hay 2002, Moody 2008).

There is only a single year's estimate of spawning stock biomass for the Klinaklini River (1995) (Table 11). Records of a commercial fishery are available for 1943–1945 and 1947. First Nations fisheries landings on the Klinaklini River are available for 1947, 1949–1950, 1952, 1959–1973, and 1977 (Table 9); however, after 1977 there is very limited documentation of run sizes of eulachon on the Klinaklini River and these are all anecdotal in nature. These anecdotal qualitative run size comments are listed in Table 12 and indicate an improvement in recent run size estimates.

Prior to 1943 when fisheries-dependent catch records begin, our information for run size of the Klinaklini River is either anecdotal or comes from ethnographic studies. Numerous ethnographic studies describe a large First Nations eulachon fishery on the Klinaklini River that

Table 12. Qualitative assessments of eulachon run strength for rivers north of the Fraser River, 1991–2007.

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

[a]Moody 2008
[b]Hay and McCarter 2000
[c]Appendix C in Pickard and Marmorek 2007
[d]Alcan 2005
[e]Alcan 2006
[f]Alcan 2007
[g]Kitamaat Village Council 2007

attracted up to 2,000 Kwakiutl First Nation members in the late nineteenth century (Macnair 1971), some from as far as 250 miles away by canoe (Codere 1990).

There were commercial eulachon fisheries in Knight Inlet in the 1940s that primarily supplied food for the fur farm industry. Combined commercial and First Nations subsistence fisheries landed between 18 and 90 mt annually from 1943 and 1977 in Knight Inlet (Moody 2008), although landings reported by Hay and McCarter (2000) and reported in Table 9 were somewhat higher. At times, eulachon landings from Kingcome and Knight Inlet may have been reported as Knight Inlet landings, which may explain some of this discrepancy (Moody 2008). Berry and Jacob (1998, as cited in Moody 2008) "estimated spawning biomass at approximately 40 mt in the Klinaklini River in 1995" with a larval-based assessment (Hay and McCarter 2000). This value was "thought to be approximately 15% of the historic run size" (Berry and Jacob 1998, as cited in Moody 2008). Based on anecdotal information, Moody (2008) stated that eulachon returns to the Klinaklini River were said to be low "during the 2004 and 2005 seasons … but in 2007, the Klinaklini returns improved and, overall, it appeared to be a very good run" (Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Knight Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the available information. However, the BRT concluded that available catch records, the extensive ethnographic literature, and anecdotal information indicates that Klinaklini River eulachon were probably present in larger annual runs in the past and that current run sizes of eulachon appear inconsistent with the historic level of grease production extensively documented in the ethnographic literature (summaries in Macnair 1971, Codere 1990). However, anecdotal information indicates that recent returns of eulachon to the Klinaklini River have improved from a low point in 2004–2005, so the status of this population is not entirely clear.

Kingcome Inlet

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kingcome River at the head of Kingcome Inlet on the British Columbia central coast (Table A-1, Figure 3). Peak spawn timing in the area occurs about the middle of April (Moody 2008). Berry and Jacob (1998, p. 4) reported that "there were at least four waves of spawning with peaks on April 2, April 15, April 21, and May 2, 1997, with the largest occurring around April 15" in the Kingcome River. Berry and Jacob (1998) also reported that there was a spawn in the Kingcome River prior to March 16 and again in early June as indicated by the presence of eggs in the water column.

There is only a single year's estimate of spawning stock biomass for the Kingcome River (1997) (Table 11). First Nations fisheries landings on the Kingcome River are available for 1950, 1957, 1960, 1961, 1963, and 1966 (Moody 2008, her Figure 2.20); however, after 1977 there is very limited documentation of run sizes of eulachon on the Kingcome River and these are all anecdotal in nature. These qualitative run-size comments are listed in Table 12 and indicate a decline in recent run-size estimates.

When Kingcome Inlet First Nation fisheries landings have been reported separately from Knight Inlet, the estimates have averaged around an annual catch of 9 mt (Moody 2008). Moody (2008) reported that the eulachon run in the Kingcome River in 1971 was very small and light catches were reported in 1972. Berry and Jacob (1998) stated that a minimum estimated 14.35 mt of eulachon spawned in the Kingcome River from March 16 to June 3, 1997. Based on anecdotal information, Moody (2008) reported that "In 2001 the Kingcome run improved and was considered good in 2002, with approximately 330 gallons of grease produced." The eulachon run to the Kingcome River was considered to be poor in 2003 and 2004 and of average size in 2005 (Moody 2008). However, eulachon were reportedly absent from the Kingcome River in 2006 "and only small returns were seen in 2007" (Table 12) (Moody 2008).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Kingcome Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. However, the BRT believed that available catch records and anecdotal information indicates that Kingcome River eulachon were probably present in larger annual runs in the past.

Rivers Inlet

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Wannock, Chuckwalla, and Kilbella rivers in Rivers Inlet on the central coast of British Columbia (Table A-1, Figure 3). The spawning stock biomass of eulachon in Rivers Inlet was estimated using scientific survey methods in 2005 and 2006. First Nations fisheries landings on the Wannock River are available for 1967, 1968, and 1971; however, after 1971 there is very limited documentation of run sizes of eulachon in Rivers Inlet and (with the exception of the information available for 2005 and 2006) these are anecdotal in nature. These anecdotal qualitative run-size comments are listed in Table 12 and indicate a decline in recent run-size estimates.

First Nation fishery landings data for the Wannock River were limited to the years 1967, 1968, and 1971 when catches were 1.81, 2.27, and 4.54 mt, respectively (Moody 2008). Moody (2008) stated that eulachon in "the Wannock River had been gradually declining since the 1970s" and that no eulachon have been caught in First Nations fisheries in the Rivers Inlet area since 1997, when about 150 kg of eulachon were landed from the Kilbella and Chuckwalla rivers (Berry and Jacob 1998). Berry and Jacob (1998, p. 3–4) further reported that "Virtually no eulachon eggs or larvae were found in any of the 376 samples from the Wannock River in 1997" and "this observation is consistent with in-field observations of eulachon entering the river mouth only to exit and possibly go to the nearby Chukwalla or Kilbella rivers to spawn." In 2005 an estimated 2,700 adults returned to the Wannock River, based on the capture of only 11 adults during spawner abundance surveys (Moody 2008) (Table 11). An additional three adult eulachon were taken on the Kilbella River in 2005 (Moody 2008). Moody (2008) stated that this adult spawner survey was repeated in 2006 and although "no adults [were] captured … an estimate of 23,000 adult spawners was calculated" (Table 11 and Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Rivers Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. The BRT was also concerned that the incomplete record of eulachon catch and spawn biomass in Rivers Inlet does not establish whether eulachon returned on an annual basis to this system in the past. However, the BRT believed that available recent estimates of spawning stock abundance, catch records, ethnographic literature (Hilton 1990), and anecdotal information indicates that Rivers Inlet eulachon were present in larger annual runs in the past. The BRT also believed that the recent spawning stock estimates of 2,700 to 23,000 individual spawners is cause for concern, as these numbers indicate that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

Dean Channel

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Bella Coola, Dean, and Kimsquit rivers in Dean Channel (Table A-1, Figure 3). Kennedy and Bouchard (1990, p. 325) summarized ethnographic studies on the Nuxalk (Bella Coola) First Nation and stated that "because of their abundance and their value as a trade item, eulachons (particularly when rendered into highly valued grease) were second only to salmon in importance to the Bella Coola." Moody (2008) indicated that historically, peak run timing of eulachon in the Bella Coola River occurred in late March or early April (Table A-9). Moody (2007) also reported that recent run timing of eulachon to the Bella Coola River occurs earlier in the season than it did historically.

Spawning stock biomass data for the Bella Coola River were available for 2001–2004 (Table 11). Records of the Nuxalk First Nation eulachon fishery on the Bella Coola River are available for 1945 and 1946, 1948–1989, 1995, and 1998 (Moody 2008, her Figure 3.13). Moody (2008) also provided estimated First Nations eulachon catch based on a model of eulachon grease production from 1980 to 1998. Anecdotal qualitative run-size comments are listed in Table 12.

Moody (2007) reports relative abundance estimates, based on egg and larval surveys similar to those used on the Fraser River, for the Bella Coola River in 2001 (0.039 mt), 2002 (0.045–0.050 mt), 2003 (0.016 mt), and 2004 (0.0072 mt) (Table 11). Nuxalk First Nation subsistence fishery landings of eulachon from the Bella Coola River show an average catch of 18 mt between 1948 and 1984 (Table 9, Figure 30), with a low of 0.3 mt in 1960 and a high of nearly 70 mt in 1954, based on data available in Hay (2002). These data suggest that recent (2001–2004) spawner biomass in the Bella Coola River is approximately two orders of magnitude less than the average First Nations eulachon landings were between 1948 and 1984. According to Moody (2007), it has been 9 years since the last First Nations fishery occurred on the Bella Coola River.

Anecdotal information indicated that only a very few eulachon are currently found in other rivers in Dean Channel such as the Kimsquit River and the Taleomy, Assek, and Noeick rivers in South Bentnick Arm off Dean Channel (Moody 2008). Moody (2007, 2008) also stated that "it appears that 1996 was the last large run of eulachon to the Bella Coola River" and noticeable runs have not returned to the Dean Channel/Bella Coola area since 1999 (Table 12).

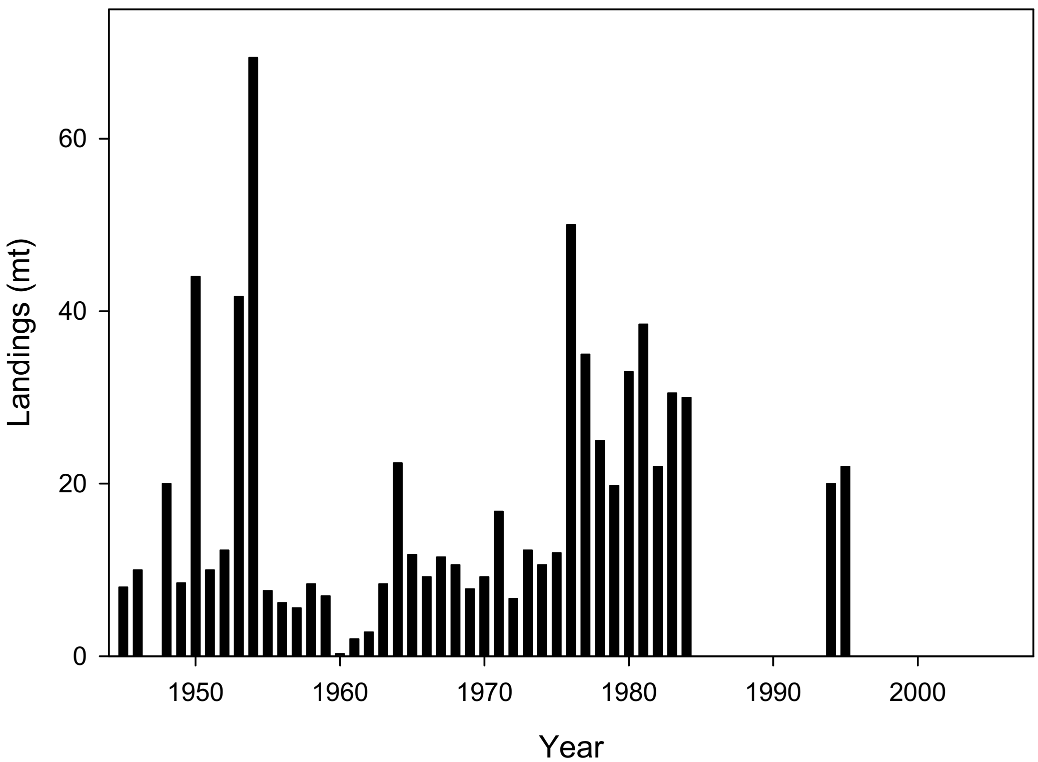

Figure 30. Estimated eulachon First Nations fishery landings on the Bella Coola River (data from Hay 2002). Landings of unknown size occurred from 1985 to 1993 and from 1996 to 1998 (Hay 2002). No fishery has occurred on the Bella Coola River since 1999.

The BRT believed that available spawning stock biomass data collected since 2001, catch records, extensive ethnographic literature, and anecdotal information indicate that Bella Coola River and Dean Channel eulachon in general were present in much larger annual runs in the past. The present run sizes of eulachon appear inconsistent with the historic level of grease production that is extensively documented in the ethnographic literature on the Nuxalk First Nations Peoples (Kennedy and Bouchard 1990, Moody 2008). The BRT was concerned that this information and available data indicate that eulachon in Dean Channel may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

Gardner Canal

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kemano, Kowesas, and Kitlope rivers in Gardner Canal (Table A-1, Figure 3). Eulachon spawn in late March and early April on the Kemano River, which is unusual in that it is a clear, nonturbid system in a region that is dominated by glacially turbid rivers (Moody 2008).

First Nations fisheries landings on the Kemano River are available for 1969–1973 and 1988–2007. CPUE data in this fishery from 1988–2007 (reported as metric tons caught per set) were presented in graphical form in Moody (2008, her Figure 2.16). A summary of ethnographic studies of the Haisla First Nation indicates that "eulachon were especially important with runs in the … Kemano and Kitlope rivers … in such numbers that they were an important export" (Hamori-Torok 1990, p. 306). Anecdotal qualitative run-size comments on Kemano River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

First Nation fisheries landings on the Kemano River ranged from 18.1 to 81.7 mt from 1969 to 1973 (average of 44.3 mt) (Moody 2008, her Figure 2.16). Rio Tinto Alcan Inc. operates a hydroelectric generation facility on the Kemano River and, as part of an environmental management plan, has funded monitoring of eulachon since 1988 (Lewis et al. 2002). From 1988 to 1998, landings ranged from 20.6 to 93.0 mt (average of 57 mt) (Lewis et al. 2002, Moody 2008) (Table 9). However, according to Moody (2008), no run occurred in 1999.

First Nations landings in the Kemano River were low from 2000 to 2002, but improved to between 60 and 80 mt in 2003 and 2004 (Alcan 2005, Moody 2008, her Figure 2.16); however, anecdotal information indicated that eulachon returns were not detected in the Kemano River in 2005 and 2006 (Table 12) (Alcan 2006, 2007, EcoMetrix 2006, as cited in Moody 2008). Based on anecdotal information, Moody (2008) reported that "eulachon were seen in the Kemano estuary in 2007. However, they did not ascend the river." CPUE data showed similar trends to First Nation fishery landings, with a sharp drop from about 2.5 mt per set in 1998 to less than 0.5 mt per set from 1999 to 2002, a rebound to between 0.5 and 1 mt per set in 2003–2004, and no fish caught in 2005–2007 (Lewis et al. 2002, Moody 2008, her Figure 2.16).

It was the BRT's best professional judgment that available CPUE data collected since 1988, First Nations catch records, extensive ethnographic literature, and anecdotal information indicate that Kemano River, and Gardner Canal eulachon in general, were present in larger annual runs in the past and that present run sizes of eulachon appear inconsistent with the historic level of grease production that is well documented for this region in the ethnographic literature (Hamori-Torok 1990).

In addition, the BRT believed that the inability to detect eulachon in the Kemano River since 2004 using the same monitoring methods that have been in place since 1988 (Lewis et al. 2002, Moody 2008, her Figure 2.16) and anecdotal information from Rio Tinto Alcan biological surveys that eulachon have failed to return to the Kemano River in 2005–2007 (Alcan 2005, 2006, 2007) is cause for concern, as this information indicates that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

Douglas Channel

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kitimat and Kildala rivers in Douglas Channel (Table A-1, Figure 3). Spawning in the Kitimat River reportedly peaks in mid to late March (Moody 2008).

The spawning stock biomass of eulachon in the Kitimat River was estimated using scientific survey methods in 1993 (Table 11). First Nations fisheries landings on the Kitimat

River are available for 1969 to 1972. CPUE in this fishery, reported as number of fish caught in a 24-hour period, and estimated spawner abundance are available for 1994–1996 and 1998–2007. A summary of ethnographic studies of the Haisla First Nation indicates that "eulachon were especially important with runs in the Kitimat [and] Kildala … rivers in such numbers that they were an important export" (Hamori-Torok 1990, p. 308). Anecdotal qualitative run-size comments on Kitimat River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

Between 1969 and 1972, Kitimat River First Nations fisheries landings of eulachon ranged from 27.2 to 81.6 mt (Moody 2008, her Figure 2.14). The Kitimat River First Nations eulachon fishery reportedly came to an end in 1972 as pollution by industrial (pulp mill) and municipal effluent discharges made the eulachon unpalatable (Pederson et al. 1995, Moody 2008). Pederson et al. (1995) estimated a total spawning biomass in the Kitimat River of 22.6 mt or about 514,000 individual eulachon in 1993. According to Moody (2008, p. 34), CPUE of eulachon on the Kitimat River, as presented in EcoMetrix (2006), declined from 50–60 fish per 24-hour gill net set in 1994–1996 to less than 2 eulachon per gill net set since 1998. According to EcoMetrix (2006, as cited in Moody 2008), abundance of eulachon from 1994 to 1996 ranged between 527,000 and 440,000 individual spawners and from 1998 to 2005 ranged between 13,600 and less than 1,000 (Table 11). Based on anecdotal information, Moody (2008, p. 34) stated that "the last strong run returned to the Kitimat River in 1991 and runs from 1992 to 1996 were estimated at half the size of 1991" (Table 12).

The BRT believed that the available spawning stock biomass data available for 1993, CPUE data since 1994, First Nations landing records, extensive ethnographic literature, and anecdotal information indicate that Kitimat River and Douglas Channel eulachon in general were present in larger annual runs in the past and that present run-size estimates of eulachon appear inconsistent with the historic level of grease production extensively documented in the ethnographic literature (Hamori-Torok 1990). The BRT believed that the decline in estimated spawning stock on the Kitimat River from an annual run size of more than 500,000 eulachon in the mid-1990s to levels of less than 1,000 individual eulachon in 2005 (EcoMetrix 2006, Moody 2008) is cause for concern, as these numbers indicate that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

Skeena River

Hay and McCarter (2000) and Moody (2008) reported that an annual run of eulachon return on a regular basis to the Skeena River and its tributaries (particularly the Ecstall and Khyex rivers) (Table A-1, Figure 3). The Skeena River run was reportedly small, of short duration, and difficult to harvest because of the large size of the mainstem Skeena River (Stoffels 2001, Moody 2008). Based on anecdotal information, eulachon historically returned to the Skeena River around the first week of March, but in the past decade returns have occasionally returned as early as mid-February (Moody 2008).

The spawning stock biomass of eulachon in the Skeena River was estimated using scientific survey methods in 1997 (Table 11). Combined commercial and First Nations fisheries landings on the Skeena River are available for 1900–1916, 1919, 1924, 1926, 1927, 1929–1932, 1935, and 1941 (Table 9). Qualitative run-size comments on Kitimat River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

Lewis (1997) estimated the total spawning stock abundance of the Skeena River eulachon at only 3.0 mt in 1997. A small commercial eulachon fishery operated between 1924 and 1946 (landings ranged from 15.4 mt in 1924 to 0.9 mt in 1935) (Moody 2008). However, total landings records were as high as 100 mt at one time and averaged 27.5 mt from 1900 to 1941 (Table 9). It is likely that local market demands have driven subsistence and past commercial fisheries statistics on the Skeena River and the BRT did not believe that these data were a good index of abundance. Moody (2008) reported anecdotal information indicating that very few Skeena River eulachon were observed between 1997 and 1999, a good run occurred in 2005, and virtually no eulachon were observed in 2006 (Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in the Skeena River, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. However, the BRT believed that available catch records and anecdotal information indicate that Skeena River eulachon were present in larger annual runs in the past that at one time supported a large fishery. Although the current status of this subpopulation is unknown, the BRT believed that anecdotal information indicates declines in abundance have occurred.

Assessment of Demographic Risk and the Risk Matrix Approach

In previous NMFS status reviews, BRTs have used a risk matrix as a method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainright and Kope (1999) and has been used for more than 10 years in Pacific salmonid status reviews (e.g., Good et al. 2005, Hard et al. 2007), as well as in reviews of Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), Puget Sound rockfishes (Stout et al. 2001b), Pacific herring (Stout et al. 2001a, Gustafson et al. 2006), and black abalone (*Haliotis cracherodi*) (VanBlaricom et al. 2009). In this risk matrix approach, the collective condition of individual populations is summarized at the DPS level according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity (Table 13). These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well founded in conservation biology and generally applicable to a wide variety of species. These criteria describe demographic risks that individually and collectively provide strong indicators of extinction risk. The summary of demographic risks and other pertinent information obtained by this approach is then considered by the BRT in determining the species' overall level of extinction risk.

After reviewing all relevant biological information for the species, each BRT member assigns a risk score (see below) to each of the four demographic criteria. The scores are tallied (means, modes, and range of scores), reviewed, and the range of perspectives discussed by the BRT before making its overall risk determination (see Table 13 for a summary of demographic risk scores). Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. For example, a DPS with a single extant subpopulation

Table 13. Template for the risk matrix used in BRT deliberations. The matrix is divided into five sections that correspond to the four viable salmonid population parameters (McElhany et al. 2000) plus a recent events category.

Risk category	Mean (± SD) and modal score
Abundance[a] Comments:	4.3 (±0.48) 4
Growth rate/productivity[a] Comments:	3.0 (±1.05) 2
Spatial structure and connectivity[a] Comments:	3.7 (±0.67) 4
Diversity[a] Comments:	2.6 (±0.52) 3
Recent events[b]	

[a]Rate overall risk to the DPS on 5-point scale (1–very low risk, 2–low risk, 3–moderate risk, 4–high risk, 5–very high risk).
[b]Rate recent events from double plus (++) strong benefit to double minus (– –) strong detriment.

might be at a high level of extinction risk because of high risk to spatial structure/connectivity, even if it exhibited low risk for the other demographic criteria. Another species might be at risk of extinction because of moderate risks to several demographic criteria.

For scoring population viability criteria, risks for each demographic criterion are ranked on a scale of 1 (very low risk) to 5 (very high risk):

1. *Very low risk*. Unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors.

2. *Low risk*. Unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.

3. *Moderate risk*. This factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.

4. *High risk*. This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the foreseeable future.

5. *Very high risk*. This factor by itself indicates danger of extinction in the near future.

Recent events: The recent events category considers events that have predictable consequences for DPS status in the foreseeable future but have occurred too recently to be reflected in the demographic data. Examples include a climatic regime shift or El Niño that may be anticipated to result in increased or decreased predation in subsequent years. This category is scored as follows:

++	expect a strong improvement in status of the DPS,
+	expect some improvement in status,
0	neutral effect on status,
–	expect some decline in status, and
– –	expect strong decline in status.

Threats Analysis

According to Section 4 of the ESA, the Secretary of Commerce or the Interior shall determine whether a species is threatened or endangered as a result of any (or a combination) of the following factors: 1) destruction or modification of habitat; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or human factors. Collectively, these are often referred to as factors for decline. Herein we examine four of these five factors for their historical, current, or potential impact on eulachon. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species. Current and potential threats, along with current species distribution and abundance, help determine the species' present vulnerability to extinction. We include information regarding historic threats to assist in interpretation of population trends. The relationship between historic threats and population trends also provides insights that may help project future population changes in response to current and potential threats.

Destruction or Modification of Habitat

Dams and water diversions

Dams and water diversions can change downstream flow intensity and flow timing, reduce transport of fine sediments, and cut off the source of larger sediments like sand and gravel for downstream habitats. Reduced peak flows as a result of upstream dams can also lead to less scouring of the streambed, less erosion, and less deposition of sediments. The streambed downstream of dams may become progressively coarser and become dominated by cobbles and large gravels as smaller gravels and sand are transported downstream without being replaced by transport from upstream sources.

Klamath River—There are six hydroelectric dams on the Klamath River (Link River, Keno, J.C. Boyle, Copco 1, Copco 2, and Iron Gate) (NRC 2008). The impact of these dams, and others on the tributary Trinity River (Lewiston and Trinity dams), as well as associated irrigation withdrawals in the upper Klamath River basin, have shifted the spring peak flow of the lower Klamath River from its historical peak in April to its current peak in March, one full month earlier (NRC 2004).

Columbia River—Operation of 28 mainstem and about 300 tributary dams and water withdrawals for irrigation have significantly altered the natural hydrologic pattern of the Columbia River (Sherwood et al. 1990, Bottom et al. 2005). According to Bottom et al. (2005, p. xxix):

> the magnitude of maximum spring freshet flow [in the Columbia River] has decreased more than 40% from the predevelopment period (1859–1899) to the present. Flow regulation is responsible for approximately 75% of this loss, irrigation withdrawal for approximately 20%, and climate change for approximately 5% … The timing of maximum spring freshet flow also has changed, primarily because of hydropower and irrigation development upriver, resulting in an approximate two-week shift earlier in the year (mean predevelopment date of 12 June compared to modern mean date of 29 May).

Bottom et al. (2005, p. xx) also stated that:

> Riverine sediment transport to the estuary, an important process affecting the quantity and quality of estuarine habitat for salmon [and other fishes], is correlated with peak river flows … [It] is estimated that the … change in annual average sediment transport (at Vancouver, Washington) for 1945–1999 flows has been about 50–60% of the nineteenth century (1858–1899) virgin sediment transport. The reduction in sands and gravels is higher (>70% of predevelopment) than for silts and clays.

Bonneville Dam on the mainstem Columbia at RKM 235 also impedes migration of eulachon to historical spawning habitat above the dam in the Hood River and possibly the Klickitat River (Smith and Saalfeld 1955, WDFW and ODFW 2008). Eulachon reportedly are unable to ascend fish ladders designed for Pacific salmon (LCFRB 2004a).

Columbia River tributaries—In the mid 2000s, Sandy River Basin Partners (2005, p. 2-30) stated that:

> Natural discharge patterns in the Sandy River Basin are primarily altered by 1) storage and diversion of water on the Sandy River (Marmot Dam at RM 30 [RKM 48.3]) and Little Sandy River (Little Sandy Diversion Dam at RM 1.7 [RKM 2.7]), 2) storage and diversion of water from the Bull Run River since 1891 to supply the City of Portland's municipal water needs (the Headworks Dam at RM

> 6 [RKM 9.6]), and 3) diversion of water from the Sandy Hatchery weir on Cedar Creek at RM 0.05 (RKM 0.8), as well as withdrawal of water from Alder Creek to partially supply the City of Sandy's municipal requirements.

Subsequently, Marmot Dam was removed in 2007 and the Little Sandy Dam was taken down in 2008, which should restore much of the river's natural hydrology and result in significant sediment transport into the lower Sandy River where eulachon have spawned in the past.

There are two major dams on the mainstem Cowlitz River: Mayfield Dam at RKM 83.7 forms Mayfield Lake and Mossyrock Dam at RKM 104.6 forms Riffe Lake (Wade 2000b). These dams and other run-of-river dams in the hydropower system largely control flow in the mainstem Cowlitz River. Following the eruption of Mount St. Helens in 1980, the USACE constructed an SRS on the North Fork Toutle "to prevent the continuation of severe downstream sedimentation of stream channels, which created flood conveyance, transportation, and habitat degradation concerns" (LCFRB 2004a, p. E-374). The SRS was constructed in 1989 about 49 km above the confluence of the Toutle and Cowlitz rivers, is approximately 50 m in height, and extends 600 m across the valley of the North Fork Toutle River. The SRS continues to be a source of fine sediment to the lower Cowlitz River (LCFRB 2004a). Anderson (2009, p. 5) stated that:

> The SRS [on the Toutle River], constructed by the USACE, has become ineffective at trapping sediments. Lower Cowlitz River eulachon spawning habitat is considered degraded while the Toutle River is assumed absent of spawning habitat due to this fine sediment inundation. … WDFW considers past and continued fine sediment deposition in the Toutle and Cowlitz rivers as a moderate to high risk for eulachon.

There are three major dams on the mainstem Lewis River, also known as the North Fork Lewis River: Merwin Dam (aka Ariel Dam) at RKM 31.4, built in 1931, forms Lake Merwin; Yale Dam at RKM 55, built in 1953, forms Yale Lake; and Swift Dam at RKM 77.1, built in 1958, forms Swift Creek Reservoir (Wade 2000a). The Lower Columbia Fish Recovery Board (LCFRB 2004a, p. G-35) stated that:

> Hydropower regulation has altered the hydrograph of the lower mainstem [of the Lewis River].… Predam data reveals peaks due to fall/winter rains, winter rain-on-snow, and spring snowmelt. Postdam data shows less overall flow variation, with a general increase in winter flows due to power needs. Postdam data shows a decrease in spring snowmelt flows due to reservoir filling in preparation for dry summer conditions.… The risk of extreme winter peaks has also been reduced, with the trade-off being the reduction of potentially beneficial large magnitude channel-forming flows. … The long-term effects on channel morphology and sediment supply have not been thoroughly investigated.

British Columbia—In the mid-1980s there were an estimated 802 licensed dams in the Fraser River basin, mostly for irrigation purposes in the dryer areas above Hope (Birtwell et al. 1988). The impact on eulachon of water withdrawals associated with reservoirs in the Fraser

River has not been studied. The other eulachon river in British Columbia where hydrology has been significantly altered by water diversions is the Kemano River. A hydroelectric plant began operating on the Kemano River in 1954 (Lewis et al. 2002, p. 1), that is powered by:

> water from the Nechako Reservoir [in the Fraser River basin] [that] passes through a 16-km-long diversion tunnel, past the turbines at the Kemano Powerhouse, and into the Kemano River, dropping a total of 850 m. ... The powerhouse outflow combines with the natural flow of the Kemano River and tributaries and flows 16 km to saltwater at Kemano Bay on Gardner Canal.

Lewis et al. (2002, p. 22) further stated that:

> Flow at the Kemano/Wahoo confluence is composed of Kemano Powerhouse discharge and the natural flow from the Kemano River and tributaries. On average, the Kemano powerhouse contributes 57% of the flow at the Kemano/Wahoo confluence. Within the period of eulachon spawning, when natural flows are near the seasonal minimum, discharge from the powerhouse accounts for 80% of the flow at the Kemano/Wahoo confluence. The relative contribution of powerhouse discharge declines to 64% during eulachon incubation and later, during larval migration, to 38% as natural discharges increase.

According to DFO and Transport Canada (2008):

> Kleana Power Corporation proposes to develop a run-of-river hydroelectric power project on the Klinaklini River. … The project consists of: head pond, diversion weir and intake, 18 km penstock/tunnel, powerhouse, tailrace, waste rock disposal, upgrading of the existing logging roads and new road extension where necessary, upgrade to the existing barge landing facility, construction camp, concrete batch plant, and a 180 km twinned aerial transmission line from the powerhouse to Campbell River.

Sediment dredging

Potential dredging impacts on eulachon consist of direct effects of entrainment of adults and eggs and potential for smothering of eggs with sediment (Howell and Uusitalo 2000, Howell et al. 2001). Indirect effects may consist of altering the freshwater spawning habitat and estuarine nursery habitat. Larson and Moehl (1990) documented direct entrainment of small amounts of eulachon by hopper dredge at the mouth of the Columbia River during May-October 1985–1988. Johnston (1981, p. 427) reviewed dredging activities in estuarine environments and listed “increased turbidity; altered tidal exchange, mixing, and circulation; reduced nutrient outflow from marshes and swamps; increased saltwater intrusion; and creation of an environment highly susceptible to recurrent low dissolved oxygen levels” as negative impacts. In addition, dredging can resuspend harmful contaminants contained in sediments where they may be more available to estuarine biota in the water column. Lasalle (1990, p. 1) also reviewed the potential physical effects of dredging and listed mobilization of sediment-associated chemical compounds and increased turbidity, as well as the potential “reduction in dissolved oxygen (resulting from the oxidation of anoxic sediment compounds)” as generally expected alterations.

Hay and McCarter (2000) indicated that dredging during the eulachon spawning season in the Fraser River continued until the late 1990s. Tutty and Morrison (1976) estimated about 0.9 mt of adult eulachon were directly entrained during hopper dredging activities between March 15 and June 4, 1976, on the lower Fraser River. Hay and McCarter (2000, p. 38) stated that "the direct loss of about 1 tonne of eulachons may have been small relative to potential deleterious impacts on survival of eulachons eggs—either from the direct effect of entrainment of spawned eggs, or the silt-induced smothering of eggs deposition [sic] in waters downstream of the dredging operations." Hay and McCarter (2000) suggested dredging should be confined to periods outside of the spawning season to minimize impacts on eulachon and that the effects of sediment removal on eulachon spawning habitats should be a topic of research.

FREMP (2007) estimated that from 0.76 to 3.22 million cubic meters of sediment were dredged annually from the lower Fraser River during the years 1997–2007 to prevent grounding of commercial shipping. Increases in vessel size have required deepening of the shipping channel in recent years (FREMP 2007). As mentioned in Pickard and Marmorek (2007), suction dredging is currently restricted to months when eulachon are not spawning in the Fraser and Kitimat rivers. According to FREMP (2006, p. 40), "hydraulic suction dredging and large-scale clamshell dredging undertaken in the Fraser River estuary is restricted so that there is no dredging conducted from March 1 to June 15 of any given year."

It has been suggested that eulachon spawning distribution in the Fraser River has changed in response to dredging and channelization and that dredging, even outside of the spawning period, affects eulachon by destabilization of substrates (Pickard and Marmorek 2007). Pickard and Marmorek (2007, p. 8) reported in their summary of findings of a DFO workshop to determine research priorities for eulachon that "there is consensus that dredging is not the cause of the coastwide decline in eulachon, but there is disagreement about the importance of dredging impacts on eulachon resilience in rivers where it occurs."

The Cowlitz Indian Tribe (2007, p. 15–16) observed that:

> the Cowlitz River and in particular the Toutle River has been greatly impacted by the eruption of Mount St. Helens in 1980 and the resulting SRS built by the U.S. Army Corps of Engineers. Releases of fine sediment from behind the SRS during the spring, when normally the river is clear, have been negatively correlated with Cowlitz River eulachon returns 3 to 4 years later (Lou Reebs, personal communication).

USACE (2007) stated that:

> as much as 414 million cubic yards (mcy) of material will erode from the Mount St. Helens sediment avalanche through year 2035. In addition, it was estimated that over the period from 2000 to 2035 as much as 27 mcy of this material would be deposited in the lower Cowlitz River and will need to be removed in order to maintain flood protection levels in Kelso, Longview, Castle Rock, and Lexington. … This trend is a result of increased sedimentation from the Toutle River watershed from sediments being passed through the SRS in greater amounts. The ability of the SRS to trap sand has decreased since 1998 when the sediment reservoir behind the dam filled in. All flow now passes through the spillway as

designed, carrying sediment downstream. … Significant sand deposition … continues to occur at the mouth of the Cowlitz River, which has severely reduced the capacity of the river channel to transport sand. … Channel capacity and the authorized levels of flood protection for Kelso, Longview, Lexington, and Castle Rock have been reduced below authorized levels due to sediment deposition in the lower Cowlitz River. … In addition to the initial dredging effort, annual follow-on dredging from the transition area to Cowlitz RM 2.5 [RKM 4.0] to maintain the dredged channel depths and bottom widths will be needed to maintain flood protection levels for the next 5 years. The Corps is also investigating long-term dredging and nondredging alternatives that would maintain the authorized levels of flood protection for the communities on the lower Cowlitz River through the year 2035.

Furthermore, USACE's environmental assessment of interim dredging activities on the Cowlitz River (USACE 2007, p. 33) indicated that:

> The proposed … dredging action may affect spawning adults, outmigrating juveniles, and larvae [of eulachon] in the water column by entrainment. Eggs may be affected by removing substrate needed to allow egg adhesion for incubation and by covering of incubating eggs by increasing suspended sediment.

Sherwood et al. (1990) provided a detailed analysis of historical dredging activities in the Columbia River estuary through the 1980s. They estimated that about 300 million cubic meters of largely sand-sized material were removed from the estuary and river channels between 1909, when substantial dredging started, and 1982. Currently, USACE routinely dredges the mainstem Columbia River shipping channel. The Washington and Oregon Eulachon Management Plan (WDFW and ODFW 2001, p. 25) stated that this "Dredging should not be conducted in winter and early spring to avoid entrainment of eulachon adults or larvae." Romano et al. (2002) suggested that the dynamic nature of sand sediments in areas proposed for channel deepening in the Columbia River were unlikely to support eulachon egg incubation and that direct effects of dredging in these areas on eulachon would be minimal. However, "[eulachon] eggs incubating in near-shore areas in the proximity of dredging activities might be affected if these activities alter flow patterns or increase sedimentation" (Romano et al. 2002, p. 8).

In response to an earlier draft of the present status review document, Anderson (2009, p. 4–5) stated that:

> Risks dependent on timing, location, and life history stage in relation to dredging and in-water dredge material disposal pose a low to moderate threat for adult eulachon and a high risk for incubating eggs. … WDFW considers dredging effects on adult eulachon as a low risk in the mainstem Columbia River and a low to moderate risk in the tributaries. … The risk to larval eulachon from mainstem Columbia River dredging activities is low and in the tributaries is moderate. … Dredging activities can affect egg survival through direct entrainment and from suffocation through burial. The risk to eulachon eggs from dredging and in-water dredge material disposal in eulachon spawning habitat is high.

Shoreline construction

Columbia River—Estuarine habitat in the Columbia River has been modified through "shoreline armoring and construction of structures over water, channel dredging and removal of large woody debris, channelization by pile dikes, and other structures" (Bottom et al. 2005, p. 18). Thomas (1983) estimated that estuarine acreage at the time of his study was only about 76% of the acreage of the estuary in 1870. This reduction was largely the result of dike and levee construction. Approximately 43% of tidal marshes and 77% of tidal swamps in the Columbia River estuary were estimated to have been lost since 1870 (Thomas 1983). Sherwood et al. (1990, p. 299) also reviewed historical changes in the Columbia River estuary and found that "large changes in the morphology of the estuary have been caused by navigational improvements (jetties, dredged channels, and pile dikes) and by the diking and filling of much of the wetland area." Sherwood et al. (1990) suggested that the greatest cause of change in the morphology of the Columbia River estuary was due to construction of permeable pile dikes and jetties, particularly jetties at the mouth of the river. LCFRB (2004a, p. A-157) reported that:

> Artificial channel confinement has altered river discharge and hydrology, as well as disconnected the [Columbia] river from much of its floodplain. … Additionally, channel manipulations for transportation or development have also had substantial influence on river discharge and hydrologic processes in the river.

Bottom et al. (2005, p. xxii) provided a chronology of changes in the Columbia River estuary and stated that:

> The productive capacity of the estuary has likely declined over the past century through the combined effects of diking and filling of shallow-water habitats…. Loss of approximately 65% of the tidal marshes and swamps that existed in the estuary prior to 1870, combined with the loss of 12% of deepwater area, has contributed to a 12–20% reduction in the estuary's tidal prism.

Columbia River tributaries—The LCFRB (2004a, p. E-89) observed that "the mainstem Cowlitz below Mayfield Dam has been heavily altered due to adjacent land uses including agriculture, rural residential development, transportation corridors, urbanization, and industry." The LCFRB (2004a, p. E-30) also reported that "the lower 20 miles of the Cowlitz has experienced severe loss of floodplain connectivity due to dikes, riprap, or deposited dredge spoils originating from the Mount St. Helens eruption" (see also Wade 2000b). Major population centers in the lower Cowlitz River basin with their associated industrial and residential development include the towns of Castle Rock, Longview, and Kelso (LCFRB 2004a).

The only urban area in the Kalama River basin is the City of Kalama, located near the river's mouth where dikes have been constructed in the historical floodplain to protect nearby roads and industrial developments (Wade 2000a, LCFRB 2004a). Future development is likely to be concentrated along the lower mainstem Kalama River, where increasing residential development has also occurred in recent years (LCFRB 2004a).

Much of the lower mainstem Lewis River is also “disconnected from its floodplain by dikes and levees” (LCFRB 2004a, p. G-55) and “the largest urban population center, the City of Woodland, lies near the mouth of the river” (Wade 2000a, p. 23). According to (LCFRB 2004a, p. G-87), “the mainstem Lewis below Merwin Dam has been heavily altered due to adjacent land uses including agriculture, residential development, transportation corridors, and industry.”

British Columbia—Pickard and Marmorek (2007) reported that results of a DFO workshop to determine research priorities for eulachon indicated that shoreline construction in the form of roads, bridges, dikes, piers, wharfs, and so forth may have an impact on eulachon in the Skeena, Kitimat, Kemano, Fraser, and Columbia rivers. According to Pickard and Marmorek (2007, p. 14):

> There is evidence of change in the habitat in developed rivers such as the Fraser and Kitimat. These changes include the loss of side channels, loss of habitat complexity/diversity, and increase in velocity. These habitat changes are thought to affect eulachon, however the magnitude of the effect is not clear.

Pickard and Marmorek (2007) also suggested that an increase in river velocities likely would result in eggs and larvae being rapidly washed downstream, where they may encounter high salinities at an early age. The fate of eggs and larvae that may be prematurely washed out to sea is unknown.

The largest city in British Columbia, Vancouver, together with all of its associated industrial and urban development, abuts the Fraser River estuary (Birtwell et al. 1988). Moody (2008) indicated that an extensive system of dikes was constructed in the lower Fraser River following the 1948 flood. According to Plate (2009, p. 3 and p. iii), recent plans to construct “a new 10-lane Port Mann Bridge [over the Fraser River] represents a major addition to shoreline and in-river construction on the lower Fraser River” and is of concern because “eulachon spawn directly beneath the [current] Port Mann Bridge pillars and in the close upstream vicinity of the bridge, and as expected eulachon use all channels under the bridge for migration to upstream areas.”

Climate change impacts on freshwater habitat

Analyses of temperature trends for the U.S. Pacific Northwest (Mote et al. 1999); the maritime portions of Oregon, Washington, and British Columbia (Mote 2003a); and the Puget Sound–Georgia Basin region (Mote 2003b) have shown that air temperature increased 0.8°C, 0.9°C, and 1.5°C in these respective regions during the twentieth century. Warming in each of these areas was substantially greater than the global average of 0.76 ± 0.19°C (IPCC 2007). During the next century, warming in the Pacific Northwest is predicted to range from 0.1°C to 0.6°C per decade with a mean estimate of 0.3°C per decade, compared to an approximate 0.1°C per decade warming that occurred during the twentieth century (Mote et al. 2005b). Although fluctuations in climate related indices like the PDO and El Niño Southern Oscillation (ENSO) may explain about a third of this temperature rise, “the widespread and fairly monotonic increases in temperature exceed what can be explained by Pacific climate variability and are consistent with the global pattern of anthropogenic temperature increases” (Mote et al. 2005a, p. 47). Results from 10 different climate model simulations that assume two different greenhouse gas emission scenarios predict a 1ºC to 6ºC increase in air temperature for the Pacific Northwest by 2100 (ISAB 2007).

These higher temperatures have led to declines in snowpack, measured as springtime snow water equivalent, in much of the North American west, with the Oregon (Mote et al. 2005a) and Washington (Mote 2006) Cascade Mountains having the largest losses in snow water equivalent. Projected milder wintertime temperatures in much of the North American west suggest that "losses in snowpack observed to date will continue and even accelerate" (Mote et al. 2005a, p. 48). Additional hydrological changes that have occurred in the North American west over the past 50–70 years include more precipitation falling as rain rather than snow (Knowles et al. 2006) and an earlier onset of snowmelt (Groisman et al. 2004, Knowles et al. 2006), resulting in "increased fractions of annual flow occurring earlier in the water year by 1–4 weeks" relative to conditions during the 1950s to 1970s (Stewart et al. 2005, p. 1,136). Trends toward earlier flows "are strongest for midelevation gauges in the interior Northwest, western Canada, and coastal Alaska" (Stewart et al. 2005, p. 1,152).

It is expected that snowmelt dominated systems at low to moderate elevations (Regonda et al. 2005, Knowles et al. 2006) and near-coastal mountains in the Pacific Northwest and California (Hamlet et al. 2005, p. 4,560) will be particularly impacted by declines in the fraction of precipitation falling as snow and thus may experience the greatest changes in river hydrology. Some systems are expected to change from a pattern of steady snow accumulation to a pattern of repeated snow accumulation and loss during the winter season. The Independent Scientific Advisory Board (ISAB 2007, p. iii) summarized projected changes associated with climate change in the Columbia Basin and stated that "Warmer temperatures will result in more precipitation falling as rain rather than snow; snow pack will diminish, and stream flow timing will be altered; and peak river flows will likely increase."

Pickard and Marmorek (2007) summarized similar findings, reported by participants at a DFO workshop to determine research priorities for eulachon, relative to climate-driven changes in freshwater hydrology that are occurring in coastal British Columbia. This report presented evidence that "snowpack accumulations have been declining in many watersheds (e.g., Kitimat, Fraser)" (Pickard and Marmorek 2007, p. 20). Spring freshets throughout British Columbia are also reported to be occurring earlier in the year and more precipitation at lower elevations is reported to be coming as rain than in snow (Pickard and Marmorek 2007, p. 20). Glaciers in British Columbia are also reported to be melting at a faster rate, although "overall runoff from B.C. glaciers is declining due to their reduced size" (Pickard and Marmorek 2007, p. 20).

Foreman et al. (2001) and Morrison et al. (2002) examined historical temperatures and flows in the Fraser River over the past 100 years. Foreman et al. (2001) found that the date at which one-half of the Fraser River yearly discharge is reached occurred at a rate of 0.09 days earlier each year between 1913 and 2000, and that average summer temperatures at Hell's Gate on the Fraser River increased at a rate of 0.022°C per year (0.2°C per decade) from 1953 to 1998. Morrison et al. (2002) developed a flow model based on these trends and predicted that by 2070–2090 spring freshets in the Fraser River would occur on average 24 days earlier in the year and mean summer water temperatures would likely increase by 1.9°C. DFO (2008d) also predicted that peak flows will come earlier in the year and peak flows will be lower over the coming century in the Fraser River.

Meier et al. (2003) and Barry (2006) summarized data on the worldwide status of glaciers, which shows that pervasive glacial retreat has occurred over the past 100 years and suggests that glacial wastage has accelerated in the last several decades. Meier et al. (2003, p. 133) stated that "the retreats of the last century exceed any seen in the last several millennia and are out of the range of normal climate variability for this time period." ISAB (2007, p. 12), in reference to the Pacific Northwest stated that:

> Most glaciers in the region reached their recent maximum extent in the mid-1800s and since that time have been in rapid retreat. Recent studies indicate that the retreat of the past approximately 150 years has now brought many Northwest glaciers back to levels last seen approximately 6,000 years ago.

Since the majority of eulachon rivers are fed by extensive snowmelt or glacial runoff, elevated temperatures, changes in snow pack, and changes in the timing and intensity of stream flows will likely have impacts on eulachon. In most rivers, eulachon typically spawn well before the spring freshet, near the seasonal flow minimum, and this strategy typically results in egg hatch coinciding with peak spring river discharge. The expected alteration in stream flow timing may cause eulachon to spawn earlier or be flushed out of spawning rivers at an earlier date. Early emigration, together with the anticipated delay in the onset of coastal upwelling (see Climate Change Impacts on Ocean Conditions subsection below), may result in a mismatch between entry of larval eulachon into the ocean and coastal upwelling, which could have a negative impact on marine survival of eulachon during this critical transition period.

There are already indications, perhaps in response to warming conditions or altered stream flow timing, that adult eulachon are returning earlier in the season to several rivers within the southern DPS (Moody 2008). Based on accounts in Portland, Oregon, newspapers between 1867 and 1923, the mean date of initial appearance of eulachon in the Columbia River during that time was February 12 (Figure 6, Appendix B). Documented initial landings in the Columbia River commercial eulachon fishery for the years 1949 to 2008 were more than a month earlier, averaging around January 8, based on data supplied by WDFW.[13] Similarly, Lewis et al. (2002, p. 68) noticed a trend for the eulachon run in the Kemano River, British Columbia, to begin and end earlier over the 11-year period from 1988 to 1998. Pickard and Marmorek (2007, p. 20) also reported that "run timing has been getting earlier since 1988–2003 in [the] Kemano [River]."

Climate change impacts on ocean conditions

Evidence has accumulated over the last decade to demonstrate that there are natural decadal-scale oscillations in North Pacific climatic and oceanic conditions (Mantua et al. 1997, Zhang et al. 1997). One indicator of the ocean-atmosphere variation for the North Pacific is the PDO index whose opposite regimes, characterized by a positive and negative PDO, typically last for 20–30 years (Mantua and Hare 2002) (Figure 15). Negative PDO values are associated with relatively cool ocean temperatures off the Pacific Northwest, and positive values are associated

[13] B. James, Statewide Eulachon Landings database, WDFW, Vancouver, WA. Pers. commun., 20 June 2008.

with warmer, less productive conditions. Warmer, less productive conditions off the Pacific Northwest are also associated with the ENSO, which is unrelated to the PDO and occurs on average every 2 to 7 years and may last from 6 to 18 months.

Changes in regional patterns of the PDO and ENSO have been associated with variation in the abundance of Pacific salmon, forage fish, and species such as Pacific hake in the ocean off the Pacific Northwest (McFarlane et al. 2000, ISAB 2007). ISAB (2007, p. 57–58) suggested that conditions that occur during a positive PDO or an El Niño period may represent possible analogs for future impacts of global warming in the North Pacific and Pacific Northwest. However, as the Intergovernmental Panel on Climate Change (IPCC) stated in its fourth assessment report (IPCC 2007, p. 399), "Long-term trends [in temperature] are rather difficult to discern in the upper Pacific Ocean because of the strong interannual and decadal variability (ENSO and the PDO) and the relatively short length of the observational records."

According to ISAB (2007, p. v):

> Scientific evidence strongly suggests that global climate change is already altering marine ecosystems from the tropics to polar seas. Physical changes associated with warming include increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These changes will alter primary and secondary productivity … [and] the structure of marine communities.

Warmer ocean temperatures—Levitus et al. (2000, 2005) documented warming of the world's oceans that corresponds to a mean temperature increase of 0.037°C from 1955 to 1998 (Levitus et al. 2005, p. 1). Most of this warming has occurred in the upper 700 m of the ocean over the past 50 years (Levitus et al. 2005). Relatively smaller temperature increases in the world ocean over the past 50 years, compared to the mean worldwide terrestrial air temperature increase of 0.76 ± 0.19°C (IPCC 2007) over the past 100 years, illustrates the ocean's enormous heat capacity compared to the atmosphere (Levitus et al. 2005). According to the IPCC (2007, p. 387):

> The oceans are warming. Over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m. … Relative to 1961 to 2003, the period 1993 to 2003 has high rates of warming but since 2003 there has been some cooling.

The ISAB (2007, p. 65) reported that "In the subarctic Northeast Pacific, sea surface temperatures show a warming trend and salinities a decreasing trend, over the last half century." Sea surface temperatures compiled from lighthouse records in the Canadian portion of the Strait of Georgia show an increase from 1915 to 2004 of 1.0°C (Beamish et al. 2008). However, long-term temperature increase in the ocean off the Pacific Northwest is not occurring in a linear fashion. Crawford et al. (2007, p. 176) reported that the long-term temperature records along Line P, which extends out more than 1,400 km from the North American west coast into the mid Gulf of Alaska, show an increase in temperature by 0.9°C from 1958 to 2005 between depths of 10 and 50 m. But Line P temperature records showed no significant increase prior to 1972 or after 1981 and most of the long-term temperature trend was likely driven by the PDO increase associated with the 1977 regime shift (Crawford et al. 2007, IPCC 2007). Water temperatures off British Columbia were reportedly warmer in 2004 and 2005 than the previous 50 years (DFO 2006b); however, in 2008 water temperatures "off the Pacific coast of Canada were the coldest in 50 years of observations, and the cooling extended far into the Pacific Ocean and south along the American coast" (DFO 2009e, p. 4).

Changes in intensity and timing of upwelling—Primary productivity in the northern California Current ecosystem is fueled by wind-driven upwelling of cold, nutrient-rich, deep waters to the surface. Along the coasts of British Columbia, Washington, and Oregon, ocean upwelling is dependent on strong coastal northerly or equator-ward winds which drive warm surface waters offshore and induce upwelling of the deep waters (Bakun 1990, Ware and Thomson 1991, ISAB 2007). Upwelling-favorable winds are more frequent in the spring and summer, but do not occur uniformly even at those times. Ocean upwelling off California is much more consistent, less seasonal, and stronger on average than in areas farther north.

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, p. 198). 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 California Current Province. These land-sea pressure gradients may be further enhanced, leading to even more intense upwelling, if warming leads to less terrestrial vegetation and thus even higher land-sea thermal differences (Diffenbaugh et al. 2004). More intense upwelling should lead to increased primary productivity in the California Current, but the peak upwelling season might occur up to one month later, and primarily from June to September in the northern portion of the California Current (Snyder et al. 2003, Barth et al. 2007, ISAB 2007). Barth et al. (2007, p. 3719) stated that "Delayed early season upwelling and stronger late season upwelling are consistent with predictions of the influence of global warming on coastal upwelling regions." In addition, warming conditions are likely to increase the density of surface waters, resulting in strong water column stratification, which may impede wind-driven upwelling and reduce the availability of nutrients at the ocean surface (ISAB 2007).

Ocean acidification—Global increases in atmospheric CO_2 have caused an increase in the amount of CO_2 absorbed by the oceans. According to the IPCC (2007, p. 387):

> Ocean biogeochemistry is changing. The total inorganic carbon content of the oceans has increased by 118 ± 19 GtC [gigatons carbon] between the end of the preindustrial period (about 1750) and 1994 and continues to increase. … The increase in total inorganic carbon caused a decrease in the depth at which calcium carbonate dissolves, and also caused a decrease in surface ocean pH by an average of 0.1 units since 1750. Direct observations of pH at available time series stations for the last 20 years also show trends of decreasing pH at a rate of 0.02 pH units per decade.

Decreased pH of ocean waters "decreases the availability of carbonate ions and lowers the saturation state of major shell-forming carbonates in marine animals" and is expected to severely impact the abundance and distribution of calcareous organisms such as corals, shelled mollusks, foraminifera, coccolithophores, and pelagic pteropods (ISAB 2007, p. 71). These changes will have unknown consequences for pelagic communities.

Expected impact on eulachon—The ISAB functions to provide independent scientific advice to NMFS, the Columbia River Indian Tribes, and the Northwest Power and Conservation Council. In its document Climate Change Impacts on Columbia River Basin Fish and Wildlife, the ISAB (2007, p. 72) stated that:

> Global climate change in the Pacific Northwest is predicted to result in changes in coastal ecosystems … that may be similar or potentially even more severe than those experienced during past periods of strong El Niño events and warm phases of the PDO, with warmer upper ocean temperatures, increased stratification and decreased productivity along the coast. However, a lack of certainty in future wind and weather patterns yields large uncertainties for future changes. …if upwelling winds remain unchanged from those of the past century, coastal upwelling may become less effective at pumping cold, nutrient-rich [water] to the upper ocean because of increased stability in the upper ocean caused by surface warming. Or, as some modeling studies and hypotheses suggest, upwelling winds may become more intense, and perhaps the timing for the upwelling season will change because of timing shifts in upwelling wind patterns. With warmer ocean temperatures we can expect shifts in the size and species composition of zooplankton to smaller lipid-replete zooplankton instead of large, lipid-rich, cool-water species. Because of food chain effects and warm ocean waters, forage fishes will decline and warm-water predators will increase.

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

Initial eulachon survival during the critical transition period between larval and juvenile stages is likely linked to the intensity and timing of upwelling in the northern California Current Province. However, the potential shift of peak upwelling to one month later than normal may result in a temporal trophic match-mismatch between eulachon larval entry into the ocean and presence of preferred prey organisms whose productivity is dependent on the early initiation of upwelling conditions. These conditions would likely have significant negative impacts on marine survival rates of eulachon and recent recruitment failure of eulachon may be traced to mortality during this critical period. Larval and juvenile eulachon are planktivorous and are adapted to feed on a northern or boreal suite of copepods during the critical larval/juvenile transition.

There are two main suites or assemblages of copepod species over the continental shelf off the west coast of North America: a 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 is most abundant along the California coast (Mackas et al. 2001, 2007). 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). When warm conditions prevail, as during an El Niño year or when the PDO is positive, the distribution of zooplankton communities can shift to the north and the southern assemblage of copepods can become dominant off southern Vancouver Island (Mackas et al. 2007). For example, abundance of boreal shelf copepods was much lower than normal and southern species dominated off southern Vancouver Island during the warm years between 1992 and 1998 (Mackas et al. 2007). Thus warmer ocean conditions may be expected to contribute to a mismatch between eulachon life history and preferred prey species.

Ocean conditions off the Pacific Northwest in 2005 were similar to what may be expected if climate change predictions for the next 100 years are accurate. According to Barth et al. (2007, p. 3,719), there was a "1-month delay in the 2005 spring transition to upwelling-favorable wind stress in the northern California Current," and during May to July, upwelling-favorable winds were at their lowest levels in 20 years and "nearshore surface waters averaged 2°C warmer than normal." Eulachon returns to spawning rivers in the southern DPS were poor during this period of unfavorable ocean conditions from 2004 to 2008 (JCRMS 2008) and may portend how eulachon will respond to warming ocean conditions.

Water quality

General contaminants—The high lipid content of eulachon suggests they are susceptible to absorption of lipophilic organic contaminants (Higgins et al. 1987, Pickard and Marmorek 2007). Contaminants considered of most concern include: 1) synthetic chlorinated organic chemicals, such as hexachlorobenzene, DDTs, and the polychlorinated biphenyls (PCBs); 2) polycyclic aromatic hydrocarbons (PAHs) from petroleum and creosoted pilings; 3) dioxins and a host of other organic compounds; 4) metals such as mercury, arsenic, and lead; and 5) endocrine-disrupting compounds and new toxics like PBDE (polybrominated diphenyl ether, flame retardants).

No rigorous toxicological studies of the effects of environmental contaminants on eulachon were found. In the Washington Department of Fisheries Annual Report for 1953, Schoettler (1953, p. 54) stated that:

> The effects of the industrial waste products discharged directly into the Columbia River near the mouth of the Cowlitz are under study by the Fisheries Department in cooperation with the State Pollution Commission. In 1951 shipments of artificially fertilized smelt eggs were taken to the Deception Pass Marine laboratory. After hatching, the fry were subjected to various intensities of waste sulfite liquor. Results indicate that the liquors were harmful to young smelt. … Of equal importance were preliminary pollution studies on adult smelt. Effluents

from three industrial plants at Longview were used. The smelt were placed in a partitioned trough which held pure river water on one side and river water mixed with certain dilutions of effluent on the other. The number of fish emerging from either side of the trough were carefully enumerated. Under these circumstances smelt showed an aversion to the effluents in dilutions approximating 1 part to 800.

The Environmental Protection Agency (EPA 2002) examined contaminants in fish, including whole eulachon, from the Columbia River in 1996–1998. In general EPA (2002, p. 9-204) stated that whole body analysis revealed that:

> While eulachon … had a high lipid content, they had some of the lowest levels of organic chemicals of all the species tested. Aroclors [a mixture of PCBs] and chlordane were not detected in the eulachon. Eulachon had the highest average concentration of arsenic and lead.

Contamination levels in three combined whole body samples of eulachon in the Columbia River collected at RKM 63–66 ranged 860–930 μg/kg arsenic, 9–10 μg/kg cadmium, 920–990 μg/kg copper, 370–680 μg/kg lead, less than 35 μg/kg mercury, 270–300 μg/kg selenium, 10–11 μg/kg p,p'-DDE, less than 4 μg/kg p,p'-DDT, less than 37 μg/kg Aroclor 1254, less than 37 μg/kg Aroclor 1260, less than 0.00005–0.0001 μg/kg 2,3,7,8-TCDD [a chlorinated dioxin], and 0.00058–0.00078 μg/kg 2,3,7,8-TCDF [a chlorinated furan] (EPA 2002). In addition, EPA (2002, p. E-4) stated that:

> DDE [a metabolite of DDT], the most commonly found pesticide in fish tissue from our study … [was found at] 11 ppb [parts per billion] in whole body eulachon. … Aroclors [a PCB mixture] [were] … nondetectable in eulachon … [and] concentrations of arsenic … [were] 890 ppb in whole body eulachon. Mercury … [was at] nondetectable levels in … whole body eulachon.

Rogers et al. (1990, p. 713) examined tissues and whole eulachon from the Fraser River for organochlorine contaminants and found that:

> [eulachon] tissue samples contained chlorophenols from wood preservation operations and chloroguaiacols from pulp bleaching. Whole fish also contained DDE and DDD [metabolites of DDT], while PCBs were present in some fish gonads in 1986, but not in 1988. With the exception of whole body concentrations of 2,3,4,6-tetrachlorophenol (TeCP), concentrations of pentachlorophenol (PCP), 3,4,5- trichloroguaiacol (3,4,5-TCG), tetrachloroguaiacol (TtiCG), DDE, and DDD in whole bodies, livers and gonads revealed an increasing trend with distance of the eulachon capture site upstream from the Fraser River mouth.

Chan et al. (1996, p. 32) examined eulachon collected from the Nass, Kitimat, and Bella Coola rivers and from Kingcome and Knight inlets for levels of persistent organic pollutants including dichlorodiphenyltrichloroethane, hexachlorobenzene, hexachlorohexanes, dieldrin, chlordane, mirex, and PCBs and found that "levels of chlorinated pesticides and PCB increased from the north to the south, with the lowest from Nass River and highest from Knight Inlet." However, contaminant levels in eulachon "were at least an order of magnitude lower than the maximum residual limit established by Health Canada or the action level established by the U.S. Food and Drug Administration" (Chan et al. 1996, p. 40). Since eulachon do not feed during their freshwater spawning run, "the uptake of toxic chemicals must occur directly from the environment" (Rogers et al. 1990, p. 725).

There are innumerable publications analyzing chemical contaminants and their sources in the lower Columbia River basin and only a select number of large-scale reviews are mentioned herein. Rosetta and Borys (1996) estimated that approximately 48% of the volume of contaminant discharges to the lower Columbia River came from industrial sources (5% from chemical and allied products, 3% from primary metal, and 39% from paper and other product manufacturers) and 52% from sewage treatment plants. Fifty-seven facilities in the lower Columbia River were identified as having the potential to release chlorinated dioxins and furans and "55 environmental cleanup sites in the State of Oregon, and 13 sites in the State of Washington [were found to] contain PCB contamination in either groundwater, sediment, or soil which may have the potential to impact the lower Columbia River" (Rosetta and Borys 1996, p. E-7).

Further breakdown of contaminant sources for the lower Columbia River are presented in Tetra Tech (1996). Hinck et al. (2004, 2006) examined contaminant levels throughout the Columbia River Basin, primarily in three resident nonanadromous target species: common carp (*Cyprinus carpio*), bass (*Micropterus* sp.), and largescale sucker (*Catostomus macrocheilus*). Fish were exposed to a variety of chemical and elemental contaminants throughout the Columbia River (Hinck et al. 2004). Temporal trend analyses indicated that PCBs were decreasing in concentration in sites with historical data; however, concentrations of the organochlorine contaminants PCBs and total p,p′-DDE were higher in the lower and middle Columbia River than in the upper Columbia River (Hinck et al. 2004, 2006).

Hall (1976, p. 45) reviewed water quality and sources of pollution in the lower Fraser River and stated that:

> There appear to be two main water quality problems in the lower Fraser, both apparently attributable to the urban-industrial complex of metropolitan Vancouver, namely pathogens and trace metals. … Potential problems are apparent regarding toxic substances such as trace metals. Concentrations are not high enough to be acutely toxic to fish but the sporadic occurrence of higher concentrations of trace metals such as lead, mercury, and zinc in the lower reaches of the river and accumulations in sediments give some cause for concern, especially since these substances are not biodegradable and bioamplification through food chain concentration or direct absorption by the organism cannot be ignored in the sensitive estuarine areas of the lower Fraser.

Types and sources of contaminants in the lower Fraser River consist of insecticides and herbicides used in agricultural production; wood preservatives associated with the lumber industry (e.g., chromium, copper, arsenic, chlorinated phenols, dioxins, polynuclear aromatic hydrocarbons, phenolics, and creosote); leachates from landfills; a wide range of contaminants in stormwater discharge; industrial effluents associated with metal, cement, forest products, and food industries; and municipal effluents (Birtwell et al. 1988).

Although the central and north coast regions of British Columbia possess relatively pristine environments compared to areas to the south, even this area has marine environmental quality concerns. Haggerty et al. (2003) identified a number of contaminant sources in British Columbia's central coast, which extends from northern Vancouver Island to just south of the Queen Charlotte Islands, including: salmon aquaculture, oil pollution, wastewater, pollution from cruise ships, shipping and boating, forestry and forest products, mining, and atmospheric and oceanic transport of chemical contaminants.

Similarly, Johannessen et al. (2007a) identified the 10 main contaminant sources in the north coast regions of British Columbia, which includes eulachon spawning rivers from the Klinaklini to the Nass rivers, to be: vessel traffic, ports, forestry, pulp and paper mills, mining and smelting, aquaculture, Coast Guard and military sites, global pollutants, offshore oil and gas, and ocean dumping. In a larger context, incorporating both the central and north coasts of British Columbia (aka Pacific North Coast Integrated Management Area [PNCIMA]), Johannessen et al. (2007b) listed the main sources of chemical contaminants as: aquaculture, vessel traffic, ports/harbors/marinas, forestry, pulp and paper, mining and smelting, ocean dumping, Coast Guard and military sites, oil and gas, and global pollutants. Detailed analyses of these contaminant sources are found in the relevant publications (Haggerty et al. 2003, Johannessen et al. 2007a, 2007b) and only a selected few major contaminant sources are mentioned below.

Johannessen et al. (2007b) indicates that 78 finfish and 24 shellfish farms operate in the PNCIMA. Many of these are located in the Queen Charlotte Strait near Knight and Kingcome inlets and pose a source of organic waste materials and of "pesticides and other persistent pollutants in fish used in the production of feed" (Johannessen et al. 2007b, p. ix). An average of more than 400,000 vessels of all types transit the PNCIMA annually. About 56% of these vessels are passenger ferries and cruise ships that transport about 1.5 million passengers yearly through the PNCIMA (Johannessen et al. 2007b). According to Johannessen et al. (2007b, p. 12), "Contaminant issues associated with marine traffic include the discharge of sewage, grey water, oily bilge water, shipboard solid wastes, and release of antifouling compounds from ablative coatings."

Prince Rupert and Kitimat, the two main industrial ports in the PNCIMA, are expanding and increasing their capacity for large industrial shipping. The industrial port of Kitimat currently serves the Alcan aluminum smelter, the Eurocan paper mill, and the Methanex methanol plant (Johannessen et al. 2007b). A new Kitimat liquefied natural gas terminal is to begin construction in 2010, and there are plans for a new Kitimat Marine Terminal and pipeline to transport petroleum from near Edmonton, Alberta, to Kitimat and condensate from Kitimat to near Edmonton, together with numerous other industrial terminal projects (Port of Kitimat 2009). Johannessen et al. (2007b, p. ix) stated that:

> Four [pulp] mills exist in the area [PNCIMA], though two of them have operated intermittently. All Canadian pulp mills underwent significant effluent treatment upgrades in the 1990s such that discharge of solids, discharge of oxygen demand, and chlorinated compounds such as dioxins and furans are now significantly reduced.

Johannessen et al. (2007b, p. 25–26) indicated that within the PNCIMA, "12 [mine] sites are a risk to produce acid rock drainage and heavy metal leachate" and that the only active smelter in the PNCIMA is the aluminum smelter at Kitimat, where "several studies have detected elevated PAH concentrations in both marine biota and sediments in the Kitimat Arm area." Johnson et al. (2009) detected elevated concentrations of PAHs in sediments of Kitimat Arm, that are similar to PAHs originating from the Alcan smelter, and in salmon and flatfish collected in Kitimat arm. However, Johnson et al. (2009, p. xv) concluded that:

> The process changes introduced by Alcan appear to be effective at reducing inputs of PAHs into the environment and biota of Kitimat Arm, as PAH concentrations in sediments and fish and fish disease prevalences have remained stable or declined over the past 5 years of sampling.

Kime (1995, p. 67–68) reviewed the literature on the effects of contaminants on fish reproduction prior to fertilization, showed that these effects can occur throughout the reproductive system, and stated that:

> They may cause lesions, haemorrhage, or malformations in the gonads, pituitary, liver, and the brain. Production and secretion of hormones of the hypothalamus, pituitary, and gonads is usually inhibited and their metabolism by the liver can be altered. … Gametes have been shown to be particularly sensitive to pollutants, both in their development, particularly the production and growth of oocytes involving vitellogenin synthesis, and in their fertility. Sperm motility, in particular, has special potential as a rapid and sensitive indicator of pollutant activity.

Analyses of these reproductive biomarkers (quantifiable parameters of an organism's biological state) go beyond the traditional toxicological test of establishing the dose of a contaminant causing death in 50% of the test organisms (LD_{50}) and are an example of the problems researchers have in assessing the effects of chronic low-level exposure of contaminants or mixtures of contaminants on fish and fish populations (Eggen et al. 2004, Carvan et al. 2008). As pointed out by Carvan et al. (2008, p. 1,023), most of the problems facing modern ecotoxicology are much more subtle and require development of a suite of biomarkers and the use of controlled laboratory experiments on sentinel fish species, such as zebrafish (*Danio rerio*) (much as laboratory rats are used to assess risk of toxicant exposure to higher mammals), to assess risk to closely related fish species.

Temperature—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 are above about 4.4°C (WDFW and ODFW 2001). When river temperatures vary above or below normal, eulachon may fail to spawn in normal areas, delay spawning, or migrate into other tributaries (Smith and Saalfeld 1955, WDFW and ODFW 2001).

Snyder (1970) reported on studies in 1968 and 1969 that examined the temperature tolerance of adult eulachon and eggs taken from the Columbia and Cowlitz rivers and found that eggs were more tolerant to temperature increases than were adults. Increases of 2.8°C and 5.6°C killed 50% and 100% of adult smelt, respectively, within 8 days. Even when exposed to temperatures elevated by 9°C for a single hour, 50% of adult eulachon were dead after 32 hours. When placed in water 3.9°C above river temperatures, females failed to deposit eggs (Snyder 1970). Slightly different results were reported by Blahm and McConnell (1971) on effects of increased temperature on eulachon collected from the Cowlitz River in 1968 and 1969. They reported that the incipient lethal temperature for eulachon acclimated to 5°C was 11°C. All eulachon exposed to 11°C were dead after 8 days exposure. When eulachon had been acclimated to 10°C, a sudden exposure to 18°C for one hour followed by return to 10°C resulted in at least 50% mortality within 50 hours (Blahm and McConnell 1971). All female fish exposed to elevated temperatures failed to deposit eggs within 50 hours, in contrast to female eulachon in control conditions that successfully deposited eggs (Snyder and Blahm 1971).

When evaluating temperature criteria for Washington's water quality standards, Hicks (2000, p. 99) stated that:

> The studies on smelt indicate they have a lower lethal temperature limit than do the salmonids and a lower optimum temperature preferendum. … Given that adult spawners and outgoing juveniles may be in fresh waters as late as March to mid-April, and their temperature requirements may be more strict than most salmonids, the protection of smelt is an important consideration in setting water quality standards. In waters supporting smelt, it is recommended that the 7-day average of the daily maximum temperatures not exceed 12–14°C prior to May 1, with no single daily maximum temperature greater than 16°C.

Catastrophic events

Larson and Belchik (1998, p. 7) reported that "The eruption of Mount St. Helens severely impacted Cowlitz River spawning success in 1980 and the consequent return of adults in 1984."

Emmett et al. (1990) documented the effects of the dramatic increase in turbidity in the Columbia River on fishes in the estuary following the 18 May 1980 eruption of Mount St. Helens, which resulted in introduction of large quantities of volcanic ash and sediment into the Columbia River estuary. Although hampered by the absence of long-term pre-eruption data, Emmett et al. (1990) showed that densities of benthic invertebrates, particularly amphipods, were significantly reduced and feeding habits and distribution of estuarine fishes were altered following the eruption.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Commercial harvest

Landing records of eulachon in commercial fisheries in the Fraser and Columbia rivers were discussed in the above Summary of Regional Demographic Data subsection. Eulachon have been commercially harvested in the Columbia River since the late 1860s and commercial landing records begin in 1888 (Table 7, Figure 22). Smith and Saalfeld (1955), the Washington and Oregon Eulachon Management Plan (WDFW and ODFW 2001), and Bargmann et al. (2005) describe gear types and fishery regulations pertaining to the modern era of the Columbia River commercial eulachon fishery. As described in the Summary of Regional Demographic Data subsection, the Columbia River eulachon commercial fishery has been managed according to the Joint State Eulachon Management Plan since 2001, which provides for three levels of fishing intensity based on an in-season estimate of parental run strength and preseason estimates of juvenile production and ocean productivity (WDFW and ODFW 2001, Bargmann et al. 2005).

More recently, JCRMS (2009, p. 26–27) stated that:

> For January 1–March 31, 2009, the mainstem Columbia River commercial fishery was open from 7 a.m. to 2 p.m. on Mondays and Thursdays. … The Cowlitz River was open from 6 a.m. to 10 p.m. on Saturdays. The Sandy River was open year-round, 7 days a week, 24 hours a day, per permanent regulations. ... Pounds landed in the mainstem Columbia River commercial fisheries [amounted to] 5,600 pounds. No commercial landings were made in Oregon tributaries (i.e., Sandy River) during 2009. Pounds landed in the Cowlitz River commercial fishery [amounted to] 12,100 pounds. … All other Washington tributaries were closed to commercial fishing during 2009.

DFO (2008c) provides a brief history of the Fraser River commercial eulachon fishery, which began in the 1870s and, besides the Nass River fishery which ended in the 1940s, has been the only commercial eulachon fishery operating in British Columbia. DFO (2008c) reported that:

> From 1903 to 1912, the Fraser River eulachon fishery was the fifth largest commercial fishery in BC. … Historically, anyone with a Category C licence or a limited entry vessel-based category of licence was eligible to fish eulachon. … Up to 1995, the fishery was passively managed with an open time from March 15 to May 31 for commercial drift gill nets with a one day per week closure. In 1995 … the fishery was restricted to three days per week in an attempt to provide a "spawning window" which would allow some fish to swim unimpeded by nets to their spawning areas. … The commercial eulachon fishery was closed in 1997 due to the inability to control effort and participation and to ensure conservation objectives were met. … The commercial eulachon fishery sells to the fresh fish market for food. Some of the catch is sold as bait for recreational sturgeon fishing. Based on fish slip records for the period 1980 to 1995, the number of active vessels ranged between 8 and 45.

The Fraser River commercial fishery for eulachon has essentially been closed since 1997, only opening briefly in 2002 and 2004, when 5.76 and 0.44 mt were landed, respectively (Table 9, Figure 27) (DFO 2006a).

Recreational harvest

Fry (1979, p. 90) reported that in California, in the past, there were "relatively minor [eulachon] sport fisheries near river mouths, the Klamath fishery being the largest. Dip nets are used." Numerous anecdotal digital newspaper sources were found that indicate substantial recreational fisheries existed in the Klamath River and in other northern California rivers, as well as in the Umpqua River during the 1960s to the 1980s (see Appendix B).

A large recreational dipnet fishery that occurs almost exclusively in Columbia River tributaries, and for which catch records are unavailable, has existed in concert with commercial fisheries (Bargmann et al. 2005). JCRMS (2008) stated that:

> Prior to 1997, the recreational fishery in Washington tributaries was open 7 days per week the entire year. ... Smelt dippers in Washington were allowed 20 pounds [9.1 kg] per person each day, but beginning in late 1998 the limit has sometimes been 10 pounds [4.5 kg] per person. In Oregon the daily limit remains 25 pounds [11.4 kg] per person with the season open throughout the year. The recreational dip net fishery is very popular, drawing thousands of participants. Smelt are used for human consumption and are also in great demand for sturgeon bait. Annual recreational catch estimates are not available; however, limited past creel census information suggests that the recreational catch may equal the commercial landings in some years when smelt are abundant for a long period of time.

USACE (1952, p. 2,873) reported that:

> During the smelt run literally thousands of people line the banks of the streams, utilizing all sorts of gear to make a catch of this delectable fish. Data are lacking to show the magnitude of this catch, but during the 1948 smelt run to the Sandy River, 32,422 noncommercial licenses were issued to persons engaged in dipping this fish.

In reference to the 2009 recreational fishery season, JCRMS (2009, p. 27) stated that:

> The mainstem Columbia River was open to both Washington and Oregon recreational fishers 7 days per week on a 24-hour basis, with a bag limit of 25 pounds per person under Level One restrictions. The Washington tributary season was restricted to the Cowlitz River from 6 a.m. to 10 p.m. on Saturdays with a bag limit of 10 pounds per person. All Oregon tributaries were open to recreational dipping 7 days per week the entire year as per permanent regulations. Recreational fishing was poor due to low abundance.

Currently, recreational fishing for eulachon with dip nets, gill nets, minnow nets, or cast nets is prohibited in all freshwater systems of British Columbia (DFO Web site at http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/opportunities-possibilites/fin-nageoire-eng.htm. In saltwater, recreational fishing for eulachon is prohibited due to conservation concerns in Areas 6 to 10 (central coast of British Columbia) and 28 and 29 (near the mouth of the Fraser River). In Areas 1 to 5 (north coast of British Columbia) and 11 to 27 (Queen Charlotte Strait, Strait of Georgia, and west coast Vancouver Island), a year round daily limit of 20 kg of eulachon can be recreationally harvested with dip net or gill net, although this harvest is likely minor since eulachon are only accessible to the recreational fishery when they return to spawn in the spring and are close enough to the surface and shore to be caught (DFO 2009f).

Tribal and First Nations fisheries

The importance of the eulachon run to local Indian tribes in the lower Columbia River was documented as early as the Lewis and Clark Expedition (Burroughs 1961, WDFW and ODFW 2001). JCRMS (2009, p. 26) stated that currently:

> Tribal harvest is essentially nonexistent. … However, the Yakama Nation has taken a few pounds of smelt from the Cowlitz River annually, for ceremonial and subsistence purposes.

Available landing records of eulachon in First Nations subsistence fisheries in British Columbia south of the Nass River were discussed in the above Summary of Regional Demographic Data subsection. Rivers where some data were available included the Fraser, Klinaklini, Kingcome, Wannock, Bella Coola, Kemano, and Kitimat. DFO (2008c) stated that:

> Aboriginal communal licences specify the locations and method permitted for use by First Nations for food, social, and ceremonial harvests. Eulachons are harvested when they return to freshwater to spawn. … Fishing methods will vary by First Nations and river system, but may include beach seine, gill net, conical nets, and dip nets. … Limited information is available on the extent of First Nations' harvest of eulachons for food, social, and ceremonial purposes.

Pickard and Marmorek (2007, p. 40) reported in their summary of findings of a DFO workshop to determine research priorities for eulachon that "it seems unlikely that overfishing is the cause of the recent sharp declines in eulachon abundance; however, it is important to understand how harvesting severely depressed populations may affect the recovery of populations."

Predation and Disease

Predation

WDFW and ODFW (2001, p. 5) stated that "impressive numbers of predators and scavengers accompany large runs of smelt from the time they first enter the Columbia through completion of spawning." Beach et al. (1981, 1985) and Jeffries (1984) observed that harbor seals, California sea lions, and Steller sea lions (*Eumetopias jubatus*) move into the Columbia River to feed on eulachon runs in the winter. Jeffries (1984, p. 20) observed that "harbor seals were frequently reported in the area where the Cowlitz River enters the Columbia" and "these population increases … were apparently due to the migration of eulachon into spawning tributaries." Many harbor seals migrate from Grays Harbor and Willapa Bay to the Columbia River in the winter (Beach et al. 1985). Between 1,000 and 1,500 harbor seals have been observed using haul out sites as far as 45 miles upriver on the Columbia River at this time of year and "are frequently seen as far upriver as Longview, Washington (RM 55 [RKM 88.5]), apparently following eulachon runs into this area" (Beach et al. 1981, p. 73). NMFS (1997, p. 29) stated that the highest counts of seals in the river coincide with the winter spawning of eulachon.

Based on the presence of otoliths in harbor seal scat collected from the Columbia River during 1981–1982, Jeffries (1984) reported that eulachon were eaten by 50%, 87%, 44%, and 12% of the harbor seals present in January, February, March, and April, respectively. Brown et al. (1989) determined that 98% of the prey eaten by harbor seals in the Columbia River during the winters of 1986 to 1988 were eulachon, and that 100% of harbor seal stomachs examined contained eulachon (Brown et al. 1989, NMFS 1997). Brown et al. (1989) also estimated that the more than 2,000 harbor seals present during mid winter 1987 in the Columbia River consumed from 2.5 to 10.2 million eulachon or from 105 to 428 mt (assuming an average weight of 42 g per eulachon), which is equal to 12% to 50% of the Columbia River commercial fishery landings of eulachon for that year.

Although accounting for only 0.4% of the diet, Olesiuk (1993) estimated that the 12,000–15,000 harbor seals present in the Strait of Georgia during 1988 consumed an average of approximately 40 mt of eulachon. Harbor seals were known to concentrate and feed on eulachon in the Klinaklini River estuary at the head of Knight Inlet during the eulachon spawning migration in March (Spalding 1964). Eulachon also congregate in the Skeena River off Point Lambert during the eulachon spawning migration in that river (Fisher 1947) and likely follow the eulachon up the tributary Ecstall River (Fisher 1952). Both Imler and Sarber (1947) and Pitcher (1980) indicate that eulachon were the dominant prey of harbor seals from late May to mid-July during eulachon spawning migrations on the Copper River Delta in Alaska. Based on stomach content analyses, harbor seals also prey on eulachon in Prince William Sound (Pitcher 1980, Lowry et al. 2001), lower Cook Inlet, and off Kodiak Island (Pitcher 1980). Nearly 5% of 269 harbor seal stomachs examined in all areas of the Gulf of Alaska by Pitcher (1980) contained eulachon remains.

Eulachon are also a primary prey species of California sea lions in the Columbia River in January to June (Beach et al. 1985, Brown et al. 1995, NMFS 1997), and California sea lions have been observed near Longview at the time of the eulachon run (Beach et al. 1981). Jeffries (1984, p. 17) observed that peak numbers of California sea lions (200–250) in the Columbia River occurred during the months of February and March and they were believed to "move upriver following and feeding on the annual eulachon smelt runs." Maximum numbers of Steller sea lions (80–100) in the Columbia River also occurred during this time of year when they "have been observed feeding upriver on eulachon" (Jeffries 1984, p. 19). Seals and sea lions have also been observed above New Westminster in the Fraser River during the eulachon spawning migration (Hay and McCarter 2000).

Bigg (1988) noted that about 60 individual Steller sea lions congregated each year between 1978 and 1982 near the mouth of the Fraser River at Sand Heads in mid-March to early May to feed on eulachon that spawn in the Fraser at that time. Steller sea lions were similarly reported by fishery officers to enter numerous inlets on the mainland coast of British Columbia to feed on returning eulachon during February to April (Bigg 1988). Although Pitcher (1981) reported that eulachon were not a part of the diet of Steller sea lions in the Gulf of Alaska, numerous other studies (Womble 2003, Sigler et al. 2004, Womble and Sigler 2006, Womble et al. 2005, 2009) have emphasized the seasonal importance of eulachon to Steller sea lions in Southeast Alaska. Steller sea lions are attracted in large numbers to spawning eulachon runs in April and May in various locations in northern Southeast Alaska, especially the Yakutat forelands and Lynn Canal (Sigler et al. 2004, Womble et al. 2005, 2009). Eulachon provide a predictable energy-rich prey item for Steller sea lions during the spring gestation and pupping season (Womble 2003, Sigler et al. 2004). Sigler et al. (2004) estimated that about 10% of the population of Southeast Alaska Steller sea lions were in Berners Bay on Lynn Canal during the 2002 eulachon run and that many other Steller sea lions were likely aggregated in the vicinity of one of the 32 other documented eulachon spawning runs in Southeast Alaska. Large aggregations of Steller sea lions have also been found in the vicinity of the mouth of the Alsek River and Taku, Lutak, and Taiya inlets during eulachon runs (Womble 2003).

Northern fur seals consume eulachon in the California Current (Antonelis and Fiscus 1980) and particularly offshore of Oregon and Washington (Antonelis and Perez 1984). Peak numbers of northern fur seals appear off Oregon and Washington in April (Antonelis and Perez 1984). Based on fur seal diet analyses, Antonelis and Perez (1984) calculated that fur seals consumed a yearly average of 600 mt of eulachon in this offshore region between 1958 and 1974. By comparison, the Columbia River commercial fishery landed an average yearly catch of 650 mt of eulachon over this same time period (Table 9). Spalding (1964) reported that about 100 yearling fur seals congregated at the head of Knight Inlet in March 1961 and that four of these fur seals had been feeding exclusively on eulachon in the Klinaklini River estuary, while another 60 fur seals in the middle of the inlet were feeding on squid. Clemens et al. (1936, p. 6) reported on an analysis of stomach contents of 593 northern fur seals sampled from late March to late June off the west coast of Vancouver Island and stated that:

> Eulachon proved to be the third most important organism in the food of the fur seals [after herring and salmon]. It was found to occur in some 20% of the full stomachs but as a rule in rather small quantities. It comprised about 3% of the total food.

Moore et al. (2000) reported that feeding behavior of beluga whales appears to coincide with the timing and pattern of eulachon runs in Cook Inlet, Alaska. Belugas congregate near the Susitna River Delta at the time of early summer eulachon runs and eulachon have been identified in beluga stomachs (Moore et al. 2000).

Marston et al. (2002) documented 34 separate bird species feeding on eulachon returning to spawn in rivers draining into Berners Bay, Alaska, amounting to more than 46,000 avian predators in 1996 and more than 36,500 in 1997. Thousands of gulls and some of the hundreds of eagles were observed feeding heavily on eulachon during the upriver migration, while shorebirds, waterfowl, corvids, and many eagles fed on spawned-out, dying fish (Marston et al. 2002). WDFW and ODFW (2001, p. 5) stated that "gull counts in the mid-1980s along the lower Cowlitz River during the peak of eulachon abundance exceeded 10,000 birds of 8 species" and that during the 1980s "peak counts of bald eagles in conjunction with eulachon upstream migration and spawning were as high as 50 in areas of the lower mainstem Columbia, along the Cowlitz, and along the Lewis" (Table A-10).

According to Fry (1979, p. 15) "Green sturgeon take advantage of spawning eulachon in the Klamath River, but (like eagles and gulls) probably do more scavenging than actual preying." Analysis of stomach contents revealed that eulachon eggs were a seasonally important prey item for juvenile white sturgeon in May and June 1988 in the Columbia River below Bonneville Dam at RKM 153 (2–12 % of the diet) and RKM 211 (25–50% of the diet) (McCabe et al. 1993).

Eulachon occurred in 100% of 229 spiny dogfish stomachs containing food taken in the Fraser River in May 1953, and in 23% and 92% of stomachs analyzed outside the river's mouth in May 1950 and 1953, respectively (Chatwin and Forrester 1953). According to Chatwin and Forrester (1953, p. 38), "The dogfish which support the fishery in the Fraser River in mid-May are clearly dependent upon the appearance of the eulachon." Analyses of more than 14,000 spiny dogfish stomachs in British Columbia waters over a 30-year period ending in 1977 revealed that eulachon represented approximately 5.5% of the annual dogfish diet, and represented a greater percentage of food types consumed for young (13.4%) and immature (10.2%) dogfish than for adults (1.6%) (Jones and Geen 1977).

Eulachon occurred at low frequency (<1%) in 416 Pacific cod stomachs examined in British Columbia (Hart 1949). Eulachon are also eaten by large Pacific hake, which become increasingly piscivirous as they age, with euphausiids being the dominant prey of small Pacific hake (Rexstad and Pikitch 1986, Buckley and Livingston 1997). Livingston (1983, p. 630) determined that eulachon off Oregon in the spring of 1980 "comprised 22% by weight of the diet of 450–549 mm Pacific whiting [hake] and 79.6% by weight of the diet of 550+ mm fish." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents 61% of the offshore pelagic biomass in the California Current system (Ware and McFarlane 1995), and recent evidence (Benson et al. 2002, Cooke et al. 2006, Phillips et al. 2007) indicates that the feeding migration of Pacific hake may be extending further north within the northern California Current system. Although only about 5% of Pacific hake stomachs examined by Outram and Haegele (1972) off the west coast of Vancouver Island in 1970 contained eulachon, the large biomass of Pacific hake in this region in summer may have a significant impact on eulachon biomass in the area (Hay and McCarter 2000).

Yang and Nelson (2000, p. 159–160) stated that "eulachon [in the Gulf of Alaska in 1990, 1993, and 1996] were consumed by the main piscivorous species (arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and pollock) but … comprised no more than 5% of the stomach content weight of each of the predator species in every year." These predator species consumed eulachon whose mean standard length ranged from 100 to 150 mm (Yang and Nelson 2000). In 1990 and 2001, eulachon comprised about 5.5% and 2.5% by weight, respectively, of the total sablefish stomach contents examined in the Gulf of Alaska (Yang 1993, Yang et al. 2006). In the Gulf of Alaska, "sablefish less than 55 cm FL only consumed smaller eulachon (<100 mm SL), whereas larger sablefish (>55 cm FL) also consumed some larger eulachon (about 150 mm SL)" (Yang 1993, p. 97). Eulachon were prey items in about 4% of 753 arrowtooth flounder stomachs examined (70% of stomachs contained no food) off the west coast of Vancouver Island in 1968 and 1969 (Kabata and Forrester 1974). Similarly, eulachon were found in about 5% of 341 arrowtooth flounder stomachs examined (about 49% of stomachs were empty) in the summer of 1989 off the coast north of Cape Blanco, Oregon (Buckley et al. 1999).

Barraclough (1967) reported on the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 6–8 June 1966, when eulachon larvae

(4.5–16 mm FL) and postlarvae/juveniles (24–49 mm FL) were in the water column. Species and the range of fork lengths of fish consuming eulachon larvae included Pacific herring (33–182 mm FL), surf smelt (70–133 mm FL), Pacific sand lance (35–73 mm FL), and Chinook (67–148 mm FL), sockeye (88–140 mm FL), and chum (37.5 mm FL) salmon. Numbers of eulachon larvae consumed by individual fish ranged from 3–14 for Pacific herring, 1–4 for surf smelt, 1–8 for Pacific sand lance, 9–137 for Chinook, 4–12 for sockeye, and 100 for chum salmon (Barraclough 1967). Similarly, Robinson et al. (1968b) reported on the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 5–9 June 1967, when large numbers of eulachon larvae (5–12 mm FL) were in the water column. Species and the range of fork lengths of fish consuming eulachon larvae included Pacific herring (37–258 mm FL), surf smelt (75 mm FL), Pacific sand lance (44–106 mm FL), kelp greenling (63–67 mm FL), threespine stickleback (68 mm FL), steelhead (150 mm FL), and Chinook (100 mm FL), sockeye (98 mm FL), and chum (63–86 mm FL) salmon. Numbers of eulachon larvae consumed by individual fish ranged 1–300 for Pacific herring, 1 for surf smelt, 3–16 for Pacific sand lance, 1–19 for kelp greenling, 12 for threespine stickleback, 1 for steelhead, and 4 for Chinook, 3 for sockeye, and 2–60 for chum salmon (Robinson et al. 1968b).

Barraclough and Fulton (1967) reported on larval/postlarval eulachon (16–26 mm FL) in the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 4–8 July 1966. Species and the range of fork lengths of fish consuming eulachon larvae and postlarvae included coho (160 mm FL), sockeye (117 mm FL), chum (95–112 mm FL), and pink (88–135 mm FL) salmon. Numbers of eulachon larvae and postlarvae consumed by individual fish ranged 7 for coho, 13 for sockeye, 2–20 for chum, and 2–118 for pink salmon (Barraclough and Fulton 1967). Moffitt et al. (2002, p. 4) indicated that coho salmon parr and adult Dolly Varden feed on eulachon eggs and larvae in rivers in Southeast Alaska and "returning adult sockeye salmon in the Copper River delta have been found with adult eulachon in their stomachs." Similarly, adult spring-run Chinook salmon have been found with upwards of a dozen eulachon in their stomachs on the Cowlitz River during the spring spawning migration of the two species (Rich 1921). These instances of returning adult salmon feeding on eulachon are highly unusual as "it is well known that the habit of adult salmon, entering streams for the purpose of spawning, is to cease feeding at least as soon as the freshwater is entered" (Rich 1921, p. 7).

Ecosystem impacts of the recent and ongoing expansion of large numbers of jumbo (aka Humboldt) squid (*Dosidicus gigas*) into waters off Oregon, Washington, and British Columbia are uncertain (Zeidberg and Robison 2007, Holmes et al. 2008). An analysis of the contents of 503 jumbo squid stomachs collected in the northern California Current, including 40 collected off Oregon and Washington, failed to record the presence of eulachon or other osmerid smelts in the jumbo squid diet (Field et al. 2007). Jumbo squid, however, were shown to prey heavily on Pacific hake in the size range of 15–45 cm and adult Pacific hake are known predators on eulachon. The absence of eulachon in the diet of jumbo squid analyzed by Field et al. (2007) may be due to a combination of low eulachon abundance in the study area and a lack of significant overlap in the two species' depth range; eulachon are commonly found between 20 and 150 m deep (Hay and McCarter 2000) and are seldom encountered below 200 m and jumbo squid in the Field et al. (2007) study were mostly collected below this depth. Further diet studies of jumbo squid collected off Oregon in 2009 are ongoing; however, a further 400 squid stomachs examined since the publication of Field et al. (2007) has yet to yield eulachon or any osmerids in the diet of jumbo squid.[14] Rapid digestion of small pelagic fish may also limit the ability to detect eulachon in jumbo squid stomachs.

Disease

Very little information was found relative to impacts of diseases on eulachon. Hedrick et al. (2003) isolated viral hemorrhagic septicemia virus (VHSV) for the first time from adult eulachon collected in March 2001 in Oregon's Sandy River. Six of 15 pooled samples, each consisting of 5 fish, tested positive for VHSV. The overall impact of this virus on eulachon is difficult to assess. This virus has been isolated from a wide range of marine fish hosts and given the right conditions may "cause significant disease associated with morbidity and mortality in populations of marine fish" (Hedrick et al. 2003, p. 212).

Other Natural or Man-made Factors

Competition

Euphausiids (principally *Thysanoessa spiniferia* and *Euphausia pacifica*) are a primary prey item of eulachon in the open ocean and are also eaten by many other competing species. Tanasichuk et al. (1991) showed that euphausiids were the most important prey for both spiny dogfish and Pacific hake off the lower west coast of Vancouver Island. Livingston (1983) determined that euphausiids constituted 72% and 90% of the diet by weight of Pacific hake examined off Oregon and Washington, respectively, in 1967, and 97% of the diet by weight of Pacific hake 350–449 mm long off Oregon in 1980. Similarly, Outram and Haegele (1972) indicated that euphausiids were the most numerous prey item of Pacific hake off the British Columbia coast in 1970, occurring in 94% of Pacific hake stomachs analyzed. Rexstad and Pikitch (1986, p. 955) stated that "euphausiids constitute the primary source of food for Pacific hake in the North Pacific." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents the largest component of the offshore pelagic fish biomass in the California Current system (Ware and McFarlane 1995). Recent evidence (Benson et al. 2002, Cooke et al. 2006, Phillips et al. 2007) indicates that Pacific hake spawning may be shifting further north within the northern California Current system. This places more young of the year Pacific hake in that ecosystem (Phillips et al. 2007) in direct competition with eulachon for their preferred prey, euphausiids.

Several studies (Suchman and Brodeur 2005, Ruzicka et al. 2007, Brodeur et al. 2008, Suchman et al. 2008) have suggested that seasonal predation by large jellyfish can have a substantial impact on zooplankton populations in the California Current and these jellyfish may represent significant competitors with pelagic fishes for zooplankton resources. Brodeur et al. (2008, p. 649) examined spatial and dietary overlap of large jellyfish with a number of pelagic fishes in the California Current and stated that:

[14] J. Field, Southwest Fisheries Science Center, Santa Cruz, CA. Pers. commun., 15 October 2009.

isotope and diet analyses suggest that jellyfish occupy a trophic level similar to that of small pelagic fishes such as herring, sardines, and northern anchovy. Thus jellyfish have the potential, given their substantial biomass, of competing with these species.

Although eulachon were not specifically examined in this study, a large percentage of the diets of the two large jellyfish examined (*Chrysaora fuscescens* and *Aurelia labiata*) consisted of copepods and various euphausiid life history forms from eggs to adults (Brodeur et al. 2008) that are also significant components of the eulachon diet.

Euphausiid fisheries

A commercial fishery for euphausiids (also known as krill) occurs in the British Columbia portion of the Strait of Georgia (DFO 2007b). According to DFO (2007b, p. 6), euphausiid biomass in British Columbia waters "is dominated by five [species]: *Euphausia pacifica*, *Thysanoessa spinifera*, *T. inspinata*, *T. longipes* and *T. raschii,*" and *E. pacifica* accounts for 70–100% of the biomass in the Strait of Georgia. The Integrated Fisheries Management Plan for euphausiids limits annual total allowable catch (TAC) of euphausiids in the Strait of Georgia to 500 mt (DFO 2007b). DFO (2007b, p. 3 of its Appendix A) stated that this level of harvest is considered to "be conservative and sustainable**"** within the Strait of Georgia. Eulachon originating from rivers draining into the Strait of Georgia likely leave the strait for waters over the continental shelf prior to reaching a size where they would begin consuming euphausiids, and thus the impact of this euphausiid fishery on eulachon is expected to be minor.

Although no directed commercial fishery for euphausiids has occurred in U.S. waters off the West Coast, recognition of the importance of krill in the diet of many species influenced the Pacific Fisheries Management Council to propose a ban on commercial harvest of all species of krill (euphausiids) in the Exclusive Economic Zone off the U.S. West Coast, which includes California, Oregon, and Washington (PFMC and NMFS 2008). This krill harvest ban was formally implemented as Amendment 12 to the Coastal Pelagic Species Fishery Management Plan in July 2009 (NMFS 2009).

Eulachon bycatch

Eulachon occur as bycatch in shrimp trawl fisheries off the coasts of Washington, Oregon, California, and British Columbia (Hay et al. 1999a, 1999b, Olsen et al. 2000, NWFSC 2008, Hannah and Jones 2009). Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur from the west coast of Vancouver Island to the U.S. West Coast off Cape Mendocino, California (Hannah and Jones 2003) (Figure 31). *Pandalus jordani* is known as the 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). Similar trawl fisheries operate in British Columbia, which mainly target ocean shrimp (aka smooth pink shrimp in Canada), northern pink shrimp (*P. borealis eous*), and sidestripe shrimp (*Pandalopsis dispar*) (Hay et al. 1999a, 1999b, Olsen et al. 2000, Hannah and Jones 2007, NWFSC 2008, DFO 2009c). Information on ocean shrimp fisheries can be found for Washington online at

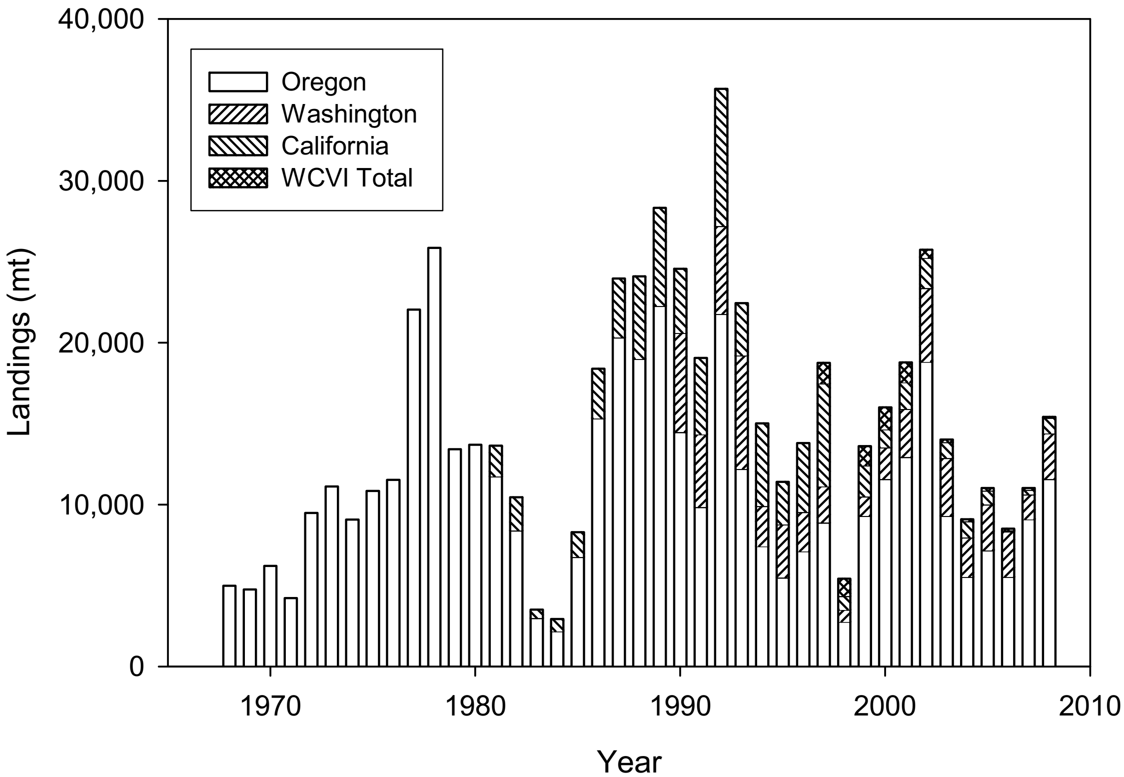

Figure 31. Commercial landings in ocean shrimp trawl fisheries off the U.S. West Coast and in British Columbia, Canada, off the west coast of Vancouver Island. Data for Washington from tables online at http://wdfw.wa.gov/fish/shelfish/shrimp/comm/index.html, for Oregon from Rien[15] and Hannah and Jones (2009), for California from tables online at http://swr.nmfs.noaa.gov/fmd/bill/landings.htm, and for the west coast of Vancouver Island from DFO (2009a).

http://wdfw.wa.gov/fish/shelfish/shrimp/comm/index.html, for Oregon online at http://www.dfw.state.or.us/MRP/shellfish/commercial/shrimp_landings.asp#about, for California in Frimodig et al. (2007), and for British Columbia online at http://www.pac.dfo-mpo.gc.ca/ops/fm/shellfish/shrimp/Default_e.htm.

Prior to the mandated use of bycatch reduction devices (BRDs) in the ocean shrimp fishery, 32–61% of the total catch in the ocean shrimp fishery consisted of nonshrimp biomass, made up mostly of Pacific hake, various species of smelt, yellowtail rockfish, sablefish, and lingcod (*Ophiodon elongatus*) (Hannah and Jones 2007). Reducing bycatch in this fishery has long been an active field of research (Hannah et al. 1996, 2003, Hannah and Jones 2007, 2009, Frimodig 2008) and great progress has been made in reducing bycatch, particularly of larger-bodied fishes. As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch and osmerid smelt bycatch was reduced to an estimated average of 0.73% of the total catch across all BRD types (Hannah and Jones 2007).

[15] T. Rein, ODFW, Clackamas, OR. Pers. commun., 24 June 2008.

Beginning in 2000 in British Columbia and 2003 in Washington, Oregon, and California, mandated use of of BRDs in offshore shrimp trawl fisheries has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig 2008). The nearly 97% use of rigid-grate BRDs and increasing use of grates with bar spacing of one inch or less in the Oregon shrimp trawl fishery (Hannah and Jones 2009), and the required use of rigid-grate BRDs with a grid space no greater than 44.5 mm (1.75 inches) and the recommendation to use a 25 mm (1 inch) space between the grid bars when targeting pink shrimp in the British Columbia shrimp trawl fisheries (DFO 2009c) are likely to reduce bycatch rates of small-bodied fishes even further.

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 "because of concerns for central coast eulachon stocks" (DFO 2009c, p. 11). Concerns over eulachon bycatch in offshore west coast Vancouver Island shrimp trawl fisheries also led DFO to set eulachon bycatch action levels for west coast Vancouver Island (DFO 2009c, 2009d). This action level is set at 1% of the west coast Vancouver Island eulachon abundance index, which is based on biomass estimates of eulachon derived from the annual shrimp abundance survey (DFO 2009c, p. 11). If estimated eulachon bycatch exceeds this 1% level, additional "management actions could include: closure of the shrimp trawl fishery, closure of certain areas to shrimp trawling, or restricting trawling to beam trawlers which have been found to have a lower impact on eulachon than otter trawlers" (DFO 2009d, p. 15). Similar action levels are not in place off the U.S. West Coast.

Although ocean shrimp fisheries operate in Washington, Oregon, and northern California, NMFS's West Coast Groundfish Observer Program (WCGOP) only observes vessels in Oregon and California, since Washington State has not yet issued a ruling allowing federal observer coverage of its state-managed fisheries (NWFSC 2008, p. 1). The BRT has recently received revised data collected by NMFS's WCGOP that update previous estimates of bycatch ratios of eulachon in the Oregon ocean shrimp fishery. Eulachon bycatch in the Oregon ocean shrimp trawl fishery in the years 2004, 2005, and 2007 was estimated at 0.0005, 0.0007, and 0.0008, respectively (WCGOP[16]). Based on these bycatch ratios, the estimated biomass of eulachon taken as bycatch in the Oregon ocean shrimp fishery was calculated at about 2.9 mt in 2004, 5.0 mt in 2005, and 7.7 mt in 2007—assuming total ocean shrimp catches of 5,534 mt (12.2 million lb), 7,167 mt (15.8 million lb), and 9,117 mt (20.1 million lb) in 2004, 2005, and 2007, respectively (Figure 31). Similar eulachon bycatch ratio and total biomass data for California ocean shrimp fisheries were only available for 2004; the eulachon bycatch ratio for that year was 0.0002 (WCGOP[17]) and the biomass of eulachon bycatch was estimated at 0.20 mt—based on a total ocean shrimp catch of 992 mt (2.2 million lb). These data were calculated by applying the yearly observed bycatch ratio of eulachon (observed biomass of eulachon/observed ocean shrimp biomass) to the total yearly Oregon or California ocean shrimp fishery landings (Figure 31).

[16] J. Majewski, unpublished data, NWFSC West Coast Groundfish Observer Program. Pers. commun., 14 October 2009.
[17] See footnote 16.

Unfortunately, no data are available on the level of eulachon bycatch that may be occurring in the Washington State ocean shrimp trawl fishery. In addition, due to sampling conditions and time constraints, not all smelt were identified to the species level in the Oregon and California ocean shrimp trawl fishery observer database and thus a portion of the bycatch in these fisheries was recorded as unidentified smelt. Estimated average biomass of unidentified smelt occurring as bycatch in the Oregon ocean shrimp trawl fishery was reported as 5.6 mt across the 3 years with observer data: 2004, 2005, and 2007 (NWFSC 2008, its Table 3).

Based on the portion of the smelt bycatch biomass identified to species in the Oregon ocean shrimp fishery by the WCGOP (NWFSC 2008), the unidentified smelt biomass was likely about 60% eulachon. NWFSC (2008, p. 24) calculated a eulachon bycatch rate of 0.0004 (±0.0030 SE) in the 2007 ocean shrimp trawl fishery north of 40°10′N latitude. Bellman et al. (2008, p. 38) used the ratio from NWFSC (2008) and total fleet landings of pink shrimp (mt, based on fish tickets) to calculate a bycatch of 4.7 mt of eulachon in the pink shrimp fishery north of 40°10′N latitude in 2007 including northern California, Oregon, and Washington. The depressed abundance of the southern DPS of eulachon may also be contributing to the above estimated levels of eulachon bycatch.

Presumably, most eulachon caught as bycatch in offshore ocean shrimp trawl fisheries off Oregon and California originate in the Columbia River, as apparent abundance of populations spawning to the south of the Columbia River have suffered severe declines. However, eulachon off California, Oregon, and Washington represent only a portion of the Columbia River eulachon subpopulation. Triennial groundfish trawl surveys conducted off the U.S. West Coast in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002) indicate that 80 to 90% of all the eulachon biomass in these surveys occurred in the Canadian portion of the Vancouver INPFC area (Table 4, Figure 4, and Figure 19), where eulachon are believed to be largely a mixture of Columbia River and Fraser River subpopulations (Beacham et al. 2005, DFO 2009d).

Genetic analyses of this stock mixture "indicated that there are continued stock proportions of approximately 60:40 Columbia:Fraser in these areas" (DFO 2009d, p. 14). The genetic composition of eulachon off northern California, Oregon, and Washington has not been studied, and it is not known whether eulachon ocean migratory patterns may be specific to certain genetically differentiated stocks, as has been shown for certain Chinook (Myers et al. 1998, Weitkamp 2010) and coho (Weitkamp and Neely 2002) salmon ESUs. Why some eulachon juveniles turn north and some turn south as they exit the Columbia River mouth is unknown, but if there is a genetic or stock specific component to this behavior, then threats to the smaller segment of the subpopulation that occurs south of the Columbia River would be of even greater concern.

As shown above, it is likely that the majority of eulachon originating in the Columbia River are subject to bycatch in the West Coast Vancouver Island shrimp trawl fishery. Offshore of west coast Vancouver Island, most eulachon occur in SMAs 23OFF, 21OFF, 124OFF, and 125OFF (Figure 21). According to DFO (2009c, p. 8) recent effort and shrimp catch are down, due to low demand for pink shrimp since "no machine peelers were operating in BC." Thus in SMAs 124OFF and 125OFF offshore of west coast Vancouver Island, where encounters with eulachon are high, "no shrimp trawl fishing occurred in … 2004 and very little effort has occurred in 2005, 2006, 2007, and 2008" (DFO 2009c, p. 11). The combination of reduced effort and required BRD use may be partly why the 1% eulachon action level has not been reached since the year 2000. The current 1% eulachon action level is 20 mt for SMAs 124OFF and 125OFF and 7.5 mt for the combination of SMAs 23OFF, 21OFF, and 23IN (DFO 2009a, p. 10) (Figure 21).

A recent workshop to determine research priorities for eulachon in Canada examined many hypotheses concerning threats to eulachon in British Columbia and concluded that eulachon bycatch in shrimp trawl fisheries was "potentially an important contributing factor in reducing recovery, along with temperature/food/hake, other harvest, but of uncertain or unknown magnitude" (Pickard and Marmorek 2007, p. 36). Hay and McCarter (2000) stated that "Although the shrimp trawl industry probably has not caused the recent decline in eulachons, we cannot rule out the possibility that it could be a factor in limiting the recovery of certain stocks."

Collateral BRD mortality

Although data on survivability of BRDs by small pelagic fishes such as eulachon are scarce, many studies on other fishes indicate that "among some species groups, such as small-sized pelagic fish, mortality may be high" and "the smallest escapees often appear the most vulnerable" (Suuronen 2005, p. 13–14). Results of several studies have shown a direct relationship between length and survival of fish escaping trawl nets, either with or without deflecting grids (Sangster et al. 1996, Suuronen et al. 1996, 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). A recent workshop (Pickard and Marmorek 2007, p. 31–33) to determine research priorities for eulachon in Canada recommended the need to research the effectiveness of BRDs and the need to estimate mortality, not just bycatch. It is difficult to evaluate the true effectiveness of BRDs in a fishery without knowing the survival rate of fish that are deflected by the BRD and escape the trawl net (Broadhurst 2000, Suuronen 2005, Broadhurst et al. 2006).

Nonindigenous species

Potential impacts and risks of nonindigenous aquatic species to native fish species include increased predation, increased competition for habitats and food, alteration of food webs, and transmission of new diseases and parasites (ISAB 2008). The negative impact of nonindigenous species is recognized as one of the leading factors causing imperilment of native North American freshwater aquatic species (Lassuy 1995, ISAB 2008) and was listed as a factor leading to the extinction of 40 North America fish species and subspecies, representing a full 68% of those lost over the past 100 years (Miller et al. 1989). NRC (2004) reported that 17 nonindigenous fish species inhabit the lower Klamath River basin, but their impact on eulachon has not been studied. Schade and Bonar (2005) estimated that the percent of total fish species that are nonnative in streams in California, Oregon and Washington, were 39.6%, 24.5%, and 18.4%, respectively.

Systma et al. (2004, p. 50) surveyed the lower Columbia River for nonindigenous species at 134 stations between 2001 and 2004 and found that:

> Of the 269 species identified, 54 (21%) were introduced, 92 (34%) were native, and 123 (45%) were cryptogenic [origin unknown]. … Over the past 10 years, a new [nonindigenous] invertebrate species was discovered about every 5 months [in the lower Columbia River].

By contrast, the rate of discovery of nonindigenous fish species in the lower Columbia River peaked in the 1950s (Systma et al. 2004). The Systma et al. (2004) survey identified 33 nonindigenous fish species in the lower Columbia River. Similarly, Pickard and Marmorek (2007, p. 41) stated that "Invasive, nonnative fish (carp, largemouth bass, crappie, catfish) have been increasing in the lower Fraser River." ISAB (2008) and Sanderson et al. (2009) recently documented the risks posed by nonindigenous species to native salmonids in the Columbia River basin and the Pacific Northwest, respectively. There is evidence that nonnative striped bass (*Morone saxatilis*) ate substantial numbers of adult eulachon in the Umpqua River when eulachon were abundant in that river in the late 1960s to early 1980s (see Umpqua River newspaper articles in Appendix B).

Bottom et al. (2005, p. xxii) examined the potential impacts of three prominent nonindigenous species on the lower Columbia River and stated that:

> Significant changes in the modern estuarine community through species introductions have not been assessed. However, the Asian clam, *Corbicula fluminea*, has expanded far into the lower mainstem reservoirs and tributary basins since its introduction into the estuary in 1938. *Pseudodiaptomus inopinus,* a calanoid copepod also introduced from Asia, has appeared prominently in the estuary since 1980, and American shad (*Alosa sapidissima*) has grown to a substantial population in the Columbia River since its introduction in 1885–1886. Fifteen other nonindigenous fishes are now common in the estuary. The specific impacts on the estuarine ecosystem … from any of these populations are speculative. However, given the tremendous abundance of *C. fluminea* and American shad (peak Bonneville Dam passage counts of 3×10^6), it is not unreasonable to expect that their consumption rates may have significantly modified the estuarine food web.

Cordell et al. (2008) documented the presence of several additional Asian copepods in the lower Columbia River and found that the calanoid copepod *P. inopinus* has largely been replaced by other Asian species, particularly *P. forbesi*. How these ongoing invasions of nonindigenous zooplanketers, mediated by ballast water exchange of large ships, will affect the estuarine food web is unknown, although the lower Columbia River may eventually come to resemble the San Francisco estuary, which "now has an East Asian copepod fauna" (Cordell et al. 2008).

Qualitative Threats Assessment

Although the question of how a DPS came to be at risk is important, a population or DPS that has been reduced to low abundance will continue to be at risk for demographic and genetic reasons until it reaches a larger size, regardless of the reasons for its initial decline. Furthermore, in some cases, a factor that was important in causing the original declines may no longer be an impediment to recovery. Unlike some ESA-listed species that face a single primary threat, eulachon face numerous potential threats throughout every stage of their life cycle. It is therefore relatively easy to simply list current and past potential threats to eulachon populations, but it is much more difficult to evaluate the relative importance of a wide range of interacting factors. The BRT also recognized that evaluating the degree to which factors for decline will continue to pose a threat generally requires consideration of issues that are more in the realm of social science than biological science—such as whether proposed changes will be funded, and, if funded, will be implemented effectively.

Nevertheless, the potential role that various threats have played in the decline of the southern DPS of eulachon was examined by the BRT in light of the question posed by the Northwest Region's Draft BRT Eulachon Instructions, articulated as follows:

> In [your] evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document your consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS, please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence.

The potential roles that 16 current threats may play in the decline of the southern DPS of eulachon were ranked according to severity in the Klamath, Columbia, and Fraser rivers and in that portion of the DPS along the mainland coast of British Columbia (Table 14 through Table 18). Also noted is the ESA factor for decline within which each threat falls (Table 14). The results of the BRT's analysis of the severity of threats to eulachon are presented in Table 15 through Table 18 in rank order from most severe to least severe for each geographical subset as determined by the mean BRT threat scores. Also presented in these tables are the standard deviation about the mean threat scores, the modal score, the range of scores, and the number of BRT members scoring the threat.

The BRT ranked climate change impacts on ocean conditions as the most serious threat to persistence of eulachon in all four subareas of the DPS: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp fisheries were also ranked in the top four threats in all subareas of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers filled out the last of the top four threats. In most categories, some portion of the BRT felt that insufficient data were available to score the threat severity (thereby marking the threat severity as unknown) as indicated by the number of BRT members voting (column N) in Table 15 through Table 18.

Table 14. Example worksheet for analysis of the severity of current threats to the southern DPS of eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. Insufficient data to score the threat severity is indicated by “u” for unknown. Threats that are not applicable to the area are indicated by NA. Threats are grouped within the four statutory listing factors: 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; and 4) other natural or man-made factors affecting its continued existence.

River basin	**Dams/water diversions**	**Dredging**	**Shoreline construction**	**Climate change impacts on ocean conditions**	**Climate change impacts on freshwater habitat**	**Water quality**	**Catastrophic events**	**Commercial harvest**	**Recreational harvest**	**Tribal/First Nations fisheries**	**Scientific monitoring**	**Disease**	**Predation**	**Competition**	**Eulachon bycatch**	**Nonindegenous species**
Klamath River		NA						NA			NA					
Columbia River																
Fraser River																
British Columbia coast								NA								
	Listing factor 1) The present or threatened destruction, modification, or curtailment of habitat or range							Listing factor 2) Over-utilization for commercial, recreational, scientific, or educational purposes				Listing factor 3) Disease or predation		Listing factor 4) Other natural or man-made factors		

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Table 15. Results of qualitative ranking by the eulachon BRT of severity of threats for Klamath River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

Threat	Mean	SD	Mode	Range	N
Climate change impacts on ocean conditions	4.2	0.6	4	3–5	10
Dams/water diversions	3.4	0.9	3	2–5	8
Eulachon bycatch	3.3	0.7	3	2–4	9
Climate change impacts on freshwater habitat	3.3	0.7	3	2–4	10
Predation	2.7	0.9	3	1–4	9
Water quality	2.5	1.1	3	1–4	10
Catastrophic events	2.3	1.8	1	1–5	8
Disease	2.3	1.9	1	1–5	4
Competition	2.0	0.8	2	1–3	7
Shoreline construction	1.9	1.1	1	1–4	9
Tribal/First Nations fisheries	1.7	0.8	1	1–3	10
Nonindigenous species	1.7	0.8	1	1–3	6
Recreational harvest	1.4	0.9	1	1–3	9

Table 16. Results of qualitative ranking by the eulachon BRT of severity of threats for Columbia River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

Threat	Mean	SD	Mode	Range	N
Climate change impacts on ocean conditions	4.3	0.7	4	3–5	10
Eulachon bycatch	3.8	0.7	4	3–5	9
Climate change impacts on freshwater habitat	3.4	0.5	3	3–4	10
Dams/water diversions	3.3	1.1	3	2–5	9
Water quality	3.0	0.7	3	2–4	10
Dredging	2.9	0.6	3	2–4	9
Predation	2.9	0.8	3	1–4	9
Catastrophic events	2.8	1.5	2	1–5	8
Commercial harvest	2.5	1.0	2	1–4	10
Shoreline construction	2.4	1.0	3	1–4	9
Disease	2.3	1.9	1	1–5	4
Competition	2.0	0.8	2	1–3	7
Recreational harvest	1.8	0.8	2	1–3	10
Tribal/First Nations fisheries	1.7	0.8	1	1–3	10
Nonindigenous species	1.7	0.8	1	1–3	6
Scientific monitoring	1.2	0.4	1	1–2	10

Table 17. Results of qualitative ranking by the eulachon BRT of severity of threats for Fraser River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

Threat	Mean	SD	Mode	Range	N
Climate change impacts on ocean conditions	4.1	0.6	4	3–5	9
Eulachon bycatch	3.7	0.7	3	3–5	9
Predation	3.1	0.4	3	3–4	8
Climate change impacts on freshwater habitat	3.1	0.6	3	2–4	9
Water quality	2.7	0.7	3	2–4	9
Commercial harvest	2.7	0.9	2	2–4	9
Dredging	2.6	0.7	2	2–4	8
Dams/water diversions	2.5	1.6	1	1–5	6
Shoreline construction	2.3	1.0	3	1–4	9
Catastrophic events	2.3	1.8	1	1–5	8
Disease	2.3	1.9	1	1–5	4
Competition	2.0	0.8	2	1–3	7
Tribal/First Nations fisheries	1.8	0.8	1	1–3	9
Recreational harvest	1.7	0.9	1	1–3	9
Nonindigenous species	1.7	0.8	1	1–3	6
Scientific monitoring	1.2	0.4	1	1–2	9

Table 18. Results of qualitative ranking by the eulachon BRT of severity of threats for eulachon in mainland British Columbia Rivers south of the Nass River. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

Threat	Mean	SD	Mode	Range	N
Climate change impacts on ocean conditions	4.1	0.6	4	3–5	9
Eulachon bycatch	3.6	0.9	4	2–5	9
Predation	3.1	0.4	3	3–4	8
Climate change impacts on freshwater habitat	2.9	1.2	3	1–4	9
Catastrophic events	2.4	1.7	2	1–5	8
Shoreline construction	2.3	0.9	2	1–4	8
Disease	2.3	1.9	1	1–5	4
Water quality	2.1	1.0	2	1–4	8
Competition	2.0	0.8	2	1–3	7
Tribal First Nations fisheries	1.9	0.8	2	1–3	9
Dam/water diversions	1.8	1.2	1	1–4	6
Dredging	1.7	1.0	1	1–4	9
Nonindigenous species	1.5	0.8	1	1–3	6
Recreational harvest	1.4	0.9	1	1–3	9
Scientific monitoring	1.2	0.4	1	1–2	9

Overall Risk Determination

The BRT's determination of overall risk to the species used these categories: at high risk of extinction, at moderate risk of extinction, or not at risk of extinction. Table 19 describes these qualitative reference levels of extinction risk. Quantitative and qualitative conservation assessments for other species have often used a 100-year time frame in their extinction risk evaluations (Morris et al. 1999, McElhany et al. 2000), and the BRT adopted this time scale as the period over which it had confidence in evaluating risk. The overall extinction risk determination reflected informed professional judgment by each BRT member. This assessment was guided by the results of the risk matrix analysis, integrating information about demographic risks with expectations about likely interactions with threats and other factors.

To allow individuals to express uncertainty in determining the overall level of extinction risk facing the species, the BRT adopted the likelihood point method, often referred to as the FEMAT method because it is a variation of a method used by scientific teams evaluating options under the Northwest Forest Plan (FEMAT 1993). Table 20 is an example worksheet and results. In this approach, each BRT member distributes 10 likelihood points among the 3 species extinction risk categories, reflecting their opinion of how likely that category correctly reflects the true species status. Thus if a member were certain that the species was in the not at risk category, he or she could assign all 10 points to that category. A reviewer with less certainty about the species' status could split the points among two or even three categories. This method has been used in all status review updates for anadromous Pacific salmonids since 1999, as well as in reviews of Puget Sound rockfishes (Stout et al. 2001b), Pacific herring (Stout et al. 2001a, Gustafson et al. 2006), Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), and black abalone (VanBlaricom et al. 2009).

Summary of Risk Conclusions for the Southern DPS of Eulachon

The BRT's scores for overall risk to the southern DPS of eulachon, throughout all of its range, were heavily weighted to moderate risk with this category receiving 60% of the likelihood points. High risk received 32% of the likelihood points and not at risk received 8% of the points. The BRT was concerned that, although eulachon are a relatively poorly monitored species, most of the available information indicates that the southern DPS of eulachon has experienced an abrupt decline in abundance throughout its range. The BRT was particularly concerned that two large spawning populations—in the Columbia and Fraser rivers—have declined to what appear to be historically low levels in the Fraser River and nearly so in the Columbia River. Overall risk scores for abundance ranged from 4 to 5 (see Table 13).

The BRT was concerned that there is very little monitoring data available for northern California eulachon, but determined that the available information suggests that eulachon in northern California experienced an abrupt decline several decades ago. The BRT was also concerned that recent attempts to estimate actual spawner abundance in some rivers in British Columbia that are known to have supported significant First Nations fisheries in the past have resulted in very low estimates of spawning stock. The BRT was also concerned that the current sizes of central and north coast British Columbia eulachon populations appear inconsistent with

Table 19. Description of reference levels for the BRT's assessment of the species' or DPS extinction risk.

	Qualitative reference levels of relative extinction risk
Continuum of decreasing relative risk of extinction	1). <u>Moderate risk</u>: A species or DPS is at moderate risk of extinction if it exhibits a trajectory indicating that it is more likely than not to be at a high level of extinction risk (see description of high risk below). A species/DPS may be at moderate risk of extinction due to projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or DPS is more likely than not to be at high risk depends on various case-specific and species-specific factors. For example, the time horizon may reflect certain life history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect the time frame or rate over which identified threats are likely to impact the biological status of the species or DPS (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence. Please explain the time scale over which the BRT has confidence in evaluating moderate risk.
	2. <u>High risk</u>: A species or DPS with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, or diversity that place its persistence in question. The demographics of a species/DPS at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species/DPS may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create such imminent demographic risks.
Extinct	A species or DPS is extinct when there is no longer a living representative.

the ethnographic literature that describes an extensive grease trading network based on eulachon catch (discussed by Hay, 2002, p. 103).

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

Of relevance to this issue are recent reviews of extinction risk in marine fishes illustrating that forage fish are not immune to risk of extirpation at the population scale (Dulvy et al. 2003, Reynolds et al. 2005). Hutchings (2000, 2001a, 2001b) and others (Dulvy et al. 2003, Mace and

Table 20. Example worksheet and results of the evaluation of the overall level of extinction risk for the southern DPS of eulachon using the likelihood point method (FEMAT 1993).

	Overall extinction risk category[a]		
	Not at risk	**Moderate risk**	**High risk**
Number of likelihood points[b]	8	60	32

Comments:

[a]These evaluations do not consider protective efforts, and therefore are not recommendations regarding ESA listing status.
[b]Each BRT member distributes 10 likelihood points among the 3 overall extinction risk categories. Placement of all 10 points in a given risk category reflect 100% certainty that level of risk reflects the true level of extinction risk for the species. Distributing points between risk categories reflects uncertainty in whether a given category reflects the true species status.

Hudson 1999, Hutchings and Reynolds 2004) cite empirical analyses indicating that marine fishes likely have similar extinction probabilities to those of nonmarine taxa. A number of inshore populations of Atlantic cod (*Gadus morhua*) and Atlantic herring (*Clupea harengus*) have either been extirpated or have not shown signs of recovery from depletions that are unprecedented in the historic record (Smedbol and Stevenson 2001). An example involves the disappearance of the Icelandic spring-spawning population of Atlantic herring (Beverton 1990), whose last known census population size in 1972 was 700,000 (Dulvy et al. 2004).

The BRT believes that high eulachon MVP sizes are necessary 1) to ensure that a critical threshold density of adult eulachon are available during breeding events for maintenance of normal reproductive processes, 2) to produce enough offspring to counteract high in-river egg and larval mortality and planktonic larval mortality in the ocean, and 3) to produce enough offspring to buffer against the action of local environmental conditions which may lead to random sweepstake recruitment events, where only a small minority of spawning individuals contribute to subsequent generations. In species with this life history pattern, the genetically effective population size can be several orders of magnitude lower than the census size (Hedgecock 1994, ICES 2004), and minimum viable census sizes may therefore be on the order of 50,000 to 500,000 (Dulvy et al. 2004). The BRT was concerned that in a number of subareas of the DPS (Klamath, Fraser, and Bella Coola rivers, Rivers Inlet, etc.), population sizes of eulachon are below what would be considered MVP sizes for highly fecund species.

The BRT noted that variable year-class strength in marine fishes with pelagic larvae is dependent on survival of larvae prior to recruitment and is driven by match-mismatch of larvae and their planktonic food supply (Hjort 1914, Lasker 1975, Sinclair and Tremblay 1984), oceanographic transport mechanisms (Parrish et al. 1981), variable environmental ocean conditions (Shepherd et al. 1984, McFarlane et al. 2000), and predation (Bailey and Houde 1989). The operation of these dynamic ocean conditions and their impacts on eulachon recruitment were amply illustrated in the Columbia River population where high larval densities were observed in 2000–2003, followed by lower than average adult returns in 2004, 2005, and 2006 (JCRMS 2007).

Failure to time spawning activity with river conditions conducive to successful fertilization and egg survival, and to the appearance of larval prey species in the oceanic environment, also contribute to high rates of environmentally driven egg and larval mortality. The BRT was concerned that there is evidence that climate change is leading to relatively rapid changes in both oceanic and freshwater environmental conditions that eulachon are unable to tolerate. Eulachon are basically a cold-water species adapted to feed on a northern suite of copepods in the ocean during the critical transition period from larvae to juvenile and much of their recent recruitment failure may be traced to mortality during this critical period. However, there have been recent shifts in the suite of copepod species available to eulachon that favor a more southerly species assemblage (Mackas et al. 2001, 2007, Hooff and Peterson 2006) and the BRT was concerned that climate change may be contributing to a mismatch between eulachon life history and prey species. It is also likely that pelagic fish with their shorter life cycles may be less resilient to long-term climatic changes than longer-lived demersal species.

However, the ability of the Columbia River eulachon stock to respond rapidly to the good ocean conditions of the late 1999–early 2002 period illustrates the species' resiliency, and the BRT viewed this resiliency as providing the species with a buffer against future environmental perturbations. The productivity potential or intrinsic rate of increase of eulachon (Musick et al. 2000) as indicated by life history characteristics such as low age-at-maturity, small body size, and planktonic larvae was recognized by the BRT as likely conferring eulachon with some resilience to extinction as they retain the ability to rapidly respond to favorable ocean conditions. However, the BRT was concerned that there is no empirical or theoretical grounds to conclude that high fecundity as a life history character confers resilience on a fish species in comparison to a species with lower fecundity (Sadovy 2001, Reynolds et al. 2005).

Overall, the BRT's risk scores for growth rate and productivity of the DPS ranged from 2 to 5 with a mean score of 3 (Table 13). Recent ocean conditions in the California Current Province in the fall of 2007 and spring-summer of 2008 were considered favorable for eulachon (PDO data online at http://jisao.washington.edu/pdo/ and http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/b-latest-updates.cfm), and the BRT postulated that this may indicate elevated eulachon returns may be expected starting with the 2011 run year. However, the BRT was concerned that these changes in the ocean, favorable to eulachon larval survival, may be of short-term duration, similar to the late 1998-early 2002 period.

In terms of threats related to diversity, the BRT was concerned that not only are eulachon semelparous (spawn once and die) but if recent estimates of age structure in eulachon are correct (Clarke et al. 2007), then spawning adults—particularly in southern areas such as the Columbia and Fraser rivers—may be limited to a single age class, which likely increases their vulnerability to perturbations and provides less of a buffer against year-class failure than species such as herring that spawn repeatedly and have variable ages at maturity.

The BRT was also concerned about the apparently very low abundance of the Klamath River subpopulation, which might be expected to have unique adaptations to conditions at the southernmost extent of the range, and about the potential loss of biocomplexity in Fraser River eulachon due to contraction of spawning locations, as documented by Higgins et al. (1987). The BRT noted some positive signs including observations that eulachon continue to display variation in spawn timing, age-at-maturity, and spawning locations and a high degree of biocomplexity (i.e., many spawning locations and spawn-timing variation) in Columbia River eulachon, which may buffer this stock from freshwater environmental perturbations. Overall, the BRT risk scores for diversity of the DPS ranged from 2 to 3 with a mean score of 2.6 (Table 13).

The BRT also had concerns about risks related to spatial structure and distribution. In particular, because the major spawning populations within the DPS appear to have declined substantially, the BRT was concerned that if some formerly significant populations, such as in the Klamath River, become extirpated, there will be less opportunity for successful recolonization. In addition, the apparent decline of populations in northern California may result in contraction of the southern portion of the DPS's range. The BRT also noted that several populations that used to support significant First Nations fisheries on the British Columbia coast have declined to very low levels (e.g., Bella Coola and Wannock rivers). Positive signs for spatial structure and connectivity noted by the BRT include considerations that eulachon appear to have the potential to recolonize given their apparent ability to stray from the natal spawning area, at least within rivers sharing the same estuary. In addition, the perceived historical spatial structure of the DPS, with the possible exception of the Klamath River, remains intact. Overall, the BRT scores for spatial structure and connectivity of the DPS ranged from 3 to 5 with a mean score of 3.7 (Table 13).

The BRT noted several recent events that appear likely to impact eulachon. Global patterns suggest the long-term trend is for a warmer, less-productive ocean regime in the California Current and the Transitional Pacific. The recent decline in abundance or relative abundance of eulachon in many systems coupled with the probable disruption of metapopulation structure may make it more difficult for eulachon to adapt to warming ocean conditions. In addition, warming conditions have allowed both Pacific hake (Phillips et al. 2007) and Pacific sardine (Emmett et al. 2005) to expand their distributions to the north, increasing predation on eulachon by Pacific hake and competition for food resources by both species. The recent and ongoing expansion of large numbers of jumbo squid into waters off Oregon, Washington, and British Columbia are also likely to have a significant impact on eulachon; however, ecosystem impacts of jumbo squid are uncertain (Zeidberg and Robison 2007, Holmes et al. 2008). Recent invasions of Asian copepods into the Columbia River estuary (Cordell et al. 2008) may have a negative influence on the Columbia River population. However, cold ocean conditions in spring 2008 suggest that this may have been a good year for eulachon recruitment. The effects of these recent positive and negative events are difficult to estimate; most members indicated that the net effect is likely to be negative.

Significant Portion of Its Range Question

The BRT concluded that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range and in effect answered the question in the affirmative as to whether the southern DPS of eulachon is at risk throughout a significant portion of its range.

Glossary

adipose fin. A fin without a bone or cartilage, located behind the dorsal fin.

ADFG. For *Alaska Department of Fish and Game*. Department that manages certain fisheries in the State of Alaska.

AFSC. For *Alaska Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

Allee effect. The circumstance of reduced population growth occurring at low population size. This can result from the impact of low spawner density on fertilization success or some other vital reproductive function.

allele. An alternative form of a gene that can occur at the same location (locus) on homologous (paired) chromosomes. A population can have many alleles for a particular locus, but an individual can carry no more than two alleles at a diploid locus.

anadromous. Species that spend their adult lives in the ocean but move into freshwater streams to reproduce or spawn (e.g., salmon).

anthropogenic. Caused or produced by human action.

ATU. For *accumulated thermal unit*. An ATU is a measurement that describes the accumulation of heat over time. One ATU is equal to one degree Celsius for one day. In water of 10°C, an organism would accumulate 10 ATUs per day.

BRD. For *bycatch reduction device*.

BRT. For *Biological Review Team*. The team of scientists who evaluates scientific information considered in a National Marine Fisheries Service status review.

bycatch. Animals caught by fishing that were not the intended target of the fishing activity. Such unwanted catch is often wasted. Both discarded and retained species can be considered bycatch.

CDFG. For *California Department of Fish and Game*. Department that comanages certain fisheries in the State of California.

comanagers. Federal, state, and tribal agencies that cooperatively manage fish in the Pacific Northwest.

CPUE. For *catch per unit effort*. A measure of the density or population size of an animal that is targeted by fishing. Large CPUEs indicate large populations, since many individuals are caught for every unit of fishing effort.

DFO. For *Department of Fisheries and Oceans Canada*. Department that manages fisheries in Canada.

DDT. For *dichlorodiphenyltrichloroethane* and its metabolites, including *p,p′*-DDT, *p,p′*-DDE, *p,p′*-DDD, *o,p′*-DDD, *o,p′*-DDE, and *o,p′*-DDT. These are banned organochlorine pesticides that were used to control insects that harm crops, as well as malaria-carrying mosquitoes. DDTs are still used in some parts of the world to control mosquitoes.

DPS. For *distinct population segment*. A DPS is a vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species. The Endangered Species Act provides for listing species, subspecies, or distinct population segments of vertebrate species.

DNA. For *deoxyribonucleic acid***.** DNA is a complex molecule that carries an organism's heritable information. DNA consists of a polysugar-phosphate backbone from which the bases (nucleotides) project. DNA forms a double helix that is held together by hydrogen bonds between specific base pairs (thymine to adenine, guanine to cytosine). Each strand in the double helix is complementary to its partner strand in terms of its base sequence. The two types of DNA commonly used to examine genetic variation are *mitochondrial DNA* (mtDNA), a circular molecule that is maternally inherited, and microsatellite (nuclear) DNA, which is organized into a set of chromosomes. See also **allele, microsatellite DNA, mitochondrial DNA**.

endangered species. A species in danger of extinction throughout all or a significant portion of its range, with respect to the Endangered Species Act. See also **ESA, threatened species**.

effective population size (Ne). The number of reproducing individuals in an ideal population that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration. Typically, Ne is less than either a population's total number of sexually mature adults present or the total number of adults that reproduced. Effective population can be defined in terms of the amount of increase in homozygosity (inbreeding effective number) or the amount of allele frequency drift (variance effective number).

ENSO. For *El Niño-Southern Oscillation*. Pattern of climate variability most clearly defined by year-to-year variations in sea surface temperature in the tropical equatorial Pacific Ocean in the zone extending from the South American coast to slightly west of the international date line.

ESA. For U.S. *Endangered Species Act* of 1973. Passed by Congress, it provides a means whereby the ecosystem on which threatened and endangered species depend may be conserved.

estuary. A semienclosed body of water having connections to the ocean at the downstream end and freshwater streams at the upstream end. Water in estuaries thus tends to be at an intermediate and variable salinity and temperature.

ESU. For *evolutionarily significant unit*. An ESU represents a distinct population segment of Pacific salmon under the Endangered Species Act that 1) is substantially reproductively isolated from nonspecific populations, and 2) represents an important component of the evolutionary legacy of the species.

fecundity. The potential reproductive capacity of an organism or population, measured by the number of gametes (eggs).

FEMAT. For *Forest Ecosystem Management Assessment Team*.

FL. For *fork length*. Length in millimeters from the tip of the snout to the center of the fork in the tail or caudal fin. Compare **SL** and **TL.**

genetic distance. A quantitative measure of genetic difference between a pair of samples.

haplotype. The collective genotype of a number of closely linked loci; the constellation of alleles present at a particular region of genomic or mitochondrial DNA.

INPFC. For *International North Pacific Fisheries Commission*.

ISAB. For *Independent Scientific Advisory Board*.

IUCN. For *International Union for the Conservation of Nature*. The full, legal name of the organization is the International Union for Conservation of Nature and Natural Resources. Online at http://www.iucn.org.

iteroparous. Said of an organism that reproduces several or many times during a lifetime. Compare **semelparous**.

JCRMS. For *Joint Columbia River Management Staff*. A joint undertaking of the Washington Department of Fish and Wildlife and the Oregon Department of Fish and Wildlife.

LC_{50}. The lethal concentration of a chemical or substance that kills 50% of the test organisms in a given time period, normally 96 hours for aquatic organisms.

LCFRB. For *Lower Columbia Fish Recovery Board*.

meristic trait. A discretely varying and countable trait (e.g., number of fin rays or basibranchial teeth).

metapopulation. An assembly of closely related subpopulations (usually spatially fragmented) that were established by colonists, survive for a while, send out migrants, and eventually disappear. The persistence of a subpopulation depends on the rate of colonization successfully balancing the local extinction rate.

microsatellite DNA. A class of repetitive DNA. Microsatellites are simple sequence repeats one to eight nucleotides in length. For example, the repeat unit can be simply "CA" and might exist in a tandem array (CACACACACA) 50 or more repeat units in length. The number of repeats in an array can be highly polymorphic. See also **DNA**.

mitochondrial DNA. The DNA genome contained within mitochondria and encoding a small subset of mitochondrial functions; mtDNA is typically circular and 15–20 kilobases in size, containing little noncoding information between genes. See also **DNA**.

morphometric trait. A discretely varying trait related to the size and shape of landmarks from whole organs or organisms analyzed by appropriately invariant biometric methods in order to answer biological questions.

MVP. For *minimum viable population*.

NMFS. For *National Marine Fisheries Service*. Also known as NOAA Fisheries Service

NWFSC. For *Northwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

ODFW. For *Oregon Department of Fish and Wildlife*. Department that comanages certain fisheries in the State of Oregon.

otolith. Crystalline calcium carbonate structure within the inner ear of fish. These structures have distinctive shapes, sizes, and internal and surface features that can be used for age determination and species identification.

ppb. For *parts per billion*. A unit of chemical concentration.

ppm. For *parts per million*. A unit of chemical concentration.

ppt. For *parts per thousand*. A unit of chemical concentration.

PDO. For *Pacific Interdecadal Oscillation*. A long-term pattern of North Pacific climate variability. PDO events persist for 20–30 years, while typical El Niño events persist for 6 to 18 months. The climatic indicators of the PDO are most visible in the North Pacific region.

phenotypic. Pertaining to the appearance (or other measurable characteristic) of an organism that results from interaction of the genotype and environment.

PCB. For *polychlorinated biphenyl***.** Persistent contaminants of aquatic sediments and biota that are very widespread. Commercial formulations of PCBs are mixtures of individual chlorinated biphenyls (congeners) varying according to the numbers of chlorines and their ring positions on the biphenyl. Prior to the 1975 congressional ban on PCB manufacture, various mixtures of some 209 individual PCBs were used extensively in electrical transformers, capacitors, paints, waxes, inks, dust control agents, paper, and pesticides.

PAH. For *polycyclic aromatic hydrocarbon***.** PAHs are widely distributed throughout the marine environment and commonly occur in sediments in urban coastal and estuarine areas. Sources include crude oil, petroleum products, and residues from combustion of fossil fuels. They are composed of fused benzene rings, with or without alkyl substituents (e.g., methyl groups).

population. A group of individuals of a species living in a certain area that maintain some degree of reproductive isolation.

Puget Sound. A coastal fjord-like estuarine inlet of the Pacific Ocean located in northwest Washington State between the Cascade and Olympic mountains and covering an area of more than 9,000 km^2 including 3,700 km of coastline.

semelparous. Said of an organism that reproduces but once during its lifetime. Compare **iteroparous**.

SL. For *standard length***.** Length in millimeters from the tip of the snout to the base of the caudal peduncle. Compare **FL** and **TL**.

SMA. For *shrimp management area*.

SWFSC. For *Southwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

species. Biological: A small group of organisms formally recognized by the scientific community as distinct from other groups. Legal: Refers to joint policy of the USFWS and NMFS that considers a species as defined by the ESA to include biological species, subspecies, and DPSs.

SRS. For *sediment retention structure*.

Strait of Georgia. A strait between Vancouver Island and the mainland Pacific coast of British Columbia. It is approximately 220 km long, averages 35 km wide, and has a surface area of approximately 6,900 km^2. Archipelagos and narrow channels mark each end of the Strait of Georgia, including the Gulf Islands and San Juan Islands in the south and the Discovery Islands in the north. The main channels to the south are Haro Strait and Rosario Strait, which connect the Strait of Georgia to the Strait of Juan de Fuca. In the north, Discovery Passage is the main channel connecting the Strait of Georgia to Johnstone Strait.

SWFSC. For *Southwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

threatened species. A species not presently in danger of extinction but likely to become so in the foreseeable future, with respect to the Endangered Species Act. See also **endangered species, ESA**.

TL. For *total length*. Length in millimeters from the tip of the snout to the tip of the farthest lobe of the tail or caudal fin. Compare **FL** and **SL**.

trophic. Pertaining to nutrition. A trophic migration would be a movement of fish to a feeding area.

USACE. For *U.S. Army Corps of Engineers*.

USFWS. For *U.S. Fish and Wildlife Service*.

viable salmonid population. An independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a long time frame (McElhany et al. 2000).

WDFW. For *Washington Department of Fish and Wildlife***.** Department that comanages certain fisheries in Washington State. The agency was formed in the early 1990s by combining the Washington Department of Fisheries and Washington Department of Wildlife.

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Appendix A: Life History Tables

This appendix contains the following tables:

Table A-1. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

Eulachon spawning areas	Spawning regularity	Estuary	Reference
California			
Sacramento River	Single fish		Vincik and Titus 2007
Gualala River	Anecdotal		Fry 1979
Jacoby and Jolly Giant creeks	Rare	Humboldt Bay	Jennings 1996
Mad River	Irregular		Moyle et al. 1995, Moyle 2002
Redwood Creek	Irregular		Moyle et al. 1995, Moyle 2002
Klamath River	Regular		Moyle et al. 1995, Moyle 2002
Smith River	Rare		Moyle et al. 1995, Moyle 2002
Oregon			
Winchuk River	Unknown		Willson et al. 2006
Chetco River		Chetco Estuary	WDFW and ODFW 2008
Pistol River	Unknown		Willson et al. 2006
Hunter Creek	Unknown		Willson et al. 2006
Rogue River	Unknown		Roffe and Mate 1984
Euchre Creek	Unknown		Willson et al. 2006
Elk River	Unknown		Willson et al. 2006
Sixes River	Unknown	Sixes Estuary	Reimers and Baxter 1976
Coquille River	Unknown		Gaumer et al. 1973, Kreag 1979
Coos Bay/ River	Unknown	Coos Bay	Cummings and Schwartz 1971
Umpqua River	Unknown	Umpqua Estuary	OFC 1970, Johnson et al. 1986
Tenmile Creek (drains lake system)	Unknown		Willson et al. 2006
Siuslaw River	Unknown		Willson et al. 2006
Tenmile Creek	Irregular		WDFW and ODFW 2008
Yaquina River	Unknown		Borgerson et al. 1991, Willson et al. 2006
Clatskanie River	One-time	Columbia River	Williams 2009
Sandy River	Irregular	Columbia River	WDFW and ODFW 2008
Tanner Creek	One-time	Columbia River	WDFW and ODFW 2008
Hood River	Anecdotal	Columbia River	Smith and Saalfeld 1955
Washington			
Columbia River mainstem	Regular	Columbia River	Smith and Saalfeld 1955, WDFW and ODFW 2001, 2008
Grays River	Regular	Columbia River	WDFW and ODFW 2001, 2008
Skamokawa Creek	Irregular	Columbia River	WDFW and ODFW 2001, 2008

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

Eulachon spawning areas	Spawning regularity	Estuary	Reference
Washington, continued			
Elochoman River	Irregular	Columbia River	WDFW and ODFW 2001, 2008
Cowlitz River	Regular	Columbia River	Smith and Saalfeld 1955, WDFW and ODFW 2001, 2008
Toutle River	Occasional	Columbia River	WDFW and ODFW 2008
Kalama River	Regular	Columbia River	WDFW and ODFW 2001, 2008
Lewis River	Regular	Columbia River	WDFW and ODFW 2001, 2008
Washougal River	Unknown	Columbia River	WDFW and ODFW 2008
Klickitat River	Anecdotal	Columbia River	Smith and Saalfeld 1955
Bear River	Occasional	Willapa Bay	WDFW and ODFW 2001, 2008
Naselle River	Occasional	Willapa Bay	WDFW and ODFW 2001, 2008
Nemah River	Unknown	Willapa Bay	Smith 1941, WDFW and ODFW 2001, 2008
Wynoochie River	Unknown		WDFW and ODFW 2001, 2008
Quinault River	Occasional		WDFW and ODFW 2001, 2008
Queets River	Occasional		WDFW and ODFW 2001, 2008
Quillayute River	Unknown		WDFW and ODFW 2008
Elwha River	Occasional		Shaffer et al. 2007
Puyallup River	Unknown		Miller and Borton 1980
British Columbia			
Fraser River	Regular	Fraser Estuary	Hay and McCarter 2000, Hay 2002, Moody 2008
Squamish River	Irregular	Howe Sound	Hay and McCarter 2000, Hay 2002, Moody 2008
Homathko River	Irregular	Bute Inlet-Johnstone Strait	Hay and McCarter 2000, Hay 2002, Moody 2008
Stafford/Apple rivers	Unknown	Loughborough Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Port Neville	Unknown	Johnstone Strait	Hay and McCarter 2000, Hay 2002
Franklin River	Unknown	Knight Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Klinaklini River	Regular	Knight Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Kakweiken River	Unknown	Thompson Sound-Johnstone Strait	Hay and McCarter 2000, Hay 2002, Moody 2008
Kingcome River	Regular	Kingcome Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Nekite River	Unknown	Smith Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Hardy Inlet	Unknown	Rivers Inlet	Hay and McCarter 2000, Hay 2002
Clyak River	Unknown	Moses Inlet-Rivers Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Wannock River	Regular	Rivers Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

Eulachon spawning areas	Spawning regularity	Estuary	Reference
British Columbia, continued			
Chuckwalla/Kilbella rivers	Regular	Rivers Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Kwatna River	Unknown	Burke Channel-Kwatna Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Quatlena River	Unknown	Burke Channel-Kwatna Inlet	Moody 2008
Cascade Inlet	Unknown	Dean Channel	Hay and McCarter 2000, Hay 2002
Skowquiltz River	Unknown	Dean Channel	Hay and McCarter 2000, Hay 2002
Taleomy River	Unknown	Dean Channel-South Bentinck Arm	Hay and McCarter 2000, Hay 2002, Moody 2008
Noeick River	Unknown	Dean Channel-South Bentinck Arm	Hay and McCarter 2000, Hay 2002, Moody 2008
Aseek River	Unknown	Dean Channel-South Bentinck Arm	Moody 2008
Kimsquit River	Regular	Dean Channel	Hay and McCarter 2000, Hay 2002, Moody 2008
Dean River	Regular	Dean Channel	Hay and McCarter 2000, Hay 2002, Moody 2008
Necleetsconay River/Paisla Creek	Regular	Dean Channel-North Bentick Arm	Moody 2008
Bella Coola River	Regular	Dean Channel-North Bentick Arm	Hay and McCarter 2000, Hay 2002, Moody 2008
Kainet or Lard Creek	Unknown	Kynoch Inlet-Mathieson Channel	Hay and McCarter 2000, Hay 2002
Aaltanhash River	Unknown	Princess Royal Channel-Aaltanhash Inlet	Hay and McCarter 2000, Hay 2002
Khutze River	Unknown	Princess Royal Channel-Khutze Inlet	Hay and McCarter 2000, Hay 2002
Kemano/Wahoo rivers	Regular	Gardner Canal-Kemano Bay	Hay and McCarter 2000, Hay 2002, Moody 2008
Kowesas River	Regular	Gardner Canal-Chief Matthew's Bay	Hay and McCarter 2000, Hay 2002, Moody 2008
Kitlope River	Regular	Gardner Canal	Hay and McCarter 2000, Hay 2002, Moody 2008
Foch Lagoon	Irregular	Douglas Channel	Hay and McCarter 2000, Hay 2002
Giltoyees Inlet	Irregular	Douglas Channel	Hay and McCarter 2000, Hay 2002
Kildala River	Regular	Douglas Channel-Kitimat Arm	Hay and McCarter 2000, Hay 2002, Moody 2008

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

Eulachon spawning areas	Spawning regularity	Estuary	Reference
British Columbia, continued			
Kitimat River	Regular	Douglas Channel-Kitimat Arm	Hay and McCarter 2000, Hay 2002, Moody 2008
Skeena River	Regular	Chatham Sound	Hay and McCarter 2000, Stoffels 2001,Hay 2002
Ecstall River	Unknown		Stoffels 2001, Moody 2008
Khyex River	Unknown		Stoffels 2001, Moody 2008
Scotia Creek	Unknown		Stoffels 2001
Khtada Creek	Unknown		Stoffels 2001
Kasiks River	Unknown		Stoffels 2001
Gitnadoix River	Unknown		Stoffels 2001
Nass River	Regular	Portland Inlet	Hay and McCarter 2000, Hay 2002, Moody 2008
Southeast Alaska			
Wilson / Blossom rivers		Smeaton Bay	Willson et al. 2006
Chickamin River			Willson et al. 2006
Unuk/Klahini/Eulachon rivers	Regular	Burroughs Bay	Willson et al. 2006
Stikine River			Womble 2003,Willson et al. 2006
Hulakon River, Grant Creek		Bradfield Canal	Willson et al. 2006
Bradfield River			Willson et al. 2006
Speel/Whiting rivers		Port Snettisham	Womble 2003,Willson et al. 2006
Taku River			Womble 2003,Willson et al. 2006,Flory 2008b
Mendenhall River			Willson et al. 2006
Eagle River			Willson et al. 2006
Berners/Lace/Antler rivers	Regular	Berners Bay	Womble 2003, Willson et al. 2006
Katzehin River		Chilkoot Inlet	Womble 2003, Willson et al. 2006
Skagway River		Chilkoot Inlet	Willson et al. 2006
Taiya River		Chilkoot Inlet	Womble 2003, Willson et al. 2006
Chilkoot/Ferebee rivers	Regular	Chilkoot Inlet	Womble 2003, Willson et al. 2006
Chilkat River	Regular	Chilkat Inlet	Womble 2003, Willson et al. 2006
Endicott River			Womble 2003, Willson et al. 2006
Excursion River			Womble 2003, Willson et al. 2006
Adams Inlet		Glacier Bay	Womble 2003, Willson et al. 2006
Yakutat area, Alaska			
Dixon River			Womble 2003, Willson et al. 2006

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

Eulachon spawning areas	Spawning regularity	Estuary	Reference
Yakutat area, Alaska, continued			
Fairweather Slough			Willson et al. 2006
Sea Otter Cr.			Willson et al. 2006
Doame R.			Willson et al. 2006
Alsek R., Clear Cr.		Dry Bay	Womble 2003, Willson et al. 2006
Dangerous/Italio/Akwe rivers			Willson et al. 2006
Situk/Ahrnklin rivers/Tawah Cr.			Willson et al. 2006
Lost R.			Willson et al. 2006
Southcentral Alaska			
Pillar Cr., Kalsin R. (Kodiak Island)			Willson et al. 2006
Martin R., Alaganik Slough, Ibeck Slough, Eyak R., Scott R., Copper R. (Copper River Delta)			Willson et al. 2006
Resurrection R.		Resurrection Bay	Willson et al. 2006
Twentymile R., Portage Cr., Placer R., Chickaloon R., Virgin Cr.		Turnagain Arm	Willson et al. 2006
Susitna R., Yentna R., Beluga R., Kenai R.		Cook Inlet	Willson et al. 2006
Western Alaska			
Kametolook R.	Unknown	Gulf of Alaska	Willson et al. 2006
Three Star R.	Unknown	Gulf of Alaska	Willson et al. 2006
King Salmon R.	Unknown	Bristol Bay	Willson et al. 2006
Meshik R.	Unknown	Bristol Bay	Moffitt et al. 2002, Willson et al. 2006
Sandy R.	Unknown	Bristol Bay	Moffitt et al. 2002, Willson et al. 2006
Bear R./Milky R.	Unknown	Bristol Bay	Moffitt et al. 2002, Willson et al. 2006
Unnamed river on Unimak Island	Unknown	Bristol Bay	Moffitt et al. 2002, Willson et al. 2006
King Salmon R.	Unknown	Bristol Bay	Willson et al. 2006
Nushagak R.	Unknown	Bristol Bay	Willson et al. 2006

Table A-2. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

Estuary	Reference no. and occurrence	Personal communication	Reference source
Skagit Bay	260 rare	D. Penttila, Washington Dept. Fisheries, Seattle	260. Miller, B. S., and S. F. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. 3 Volumes. Washington Sea Grant Program and Washington State Dept. Ecology, Seattle.
Hood Canal	260 not found	D. Penttila, Washington Dept. Fisheries, Seattle	260. Miller and Borton 1980 (Complete listing above.)
Puget Sound	260, 452 rare		260. Miller and Borton 1980 (Complete listing above) 452. Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington, University of Washington Press, Seattle.
Grays Harbor	96	R. Brix, Washington Dept. Fisheries, Montesano	96. Deschamps, G., S. G. Wright, and R. E. Watson. 1971. Fish migration and distribution in the lower Chehalis River and upper Grays Harbor. *In* Grays Harbor cooperative water quality study 1964-1966, p. 1–55. Tech. Rep. No. 7. Washington Dept. Fisheries, Olympia.
Willapa Bay		R. Brix, Washington Dept. Fisheries, Montesano	
Columbia River	118, 269	R. McConnell, NMFS, Hammond, OR	118. EPA (U.S. Environmental Protection Agency). 1971. Columbia River thermal effects study. Vol. 1: Biological effects studies. EPA, U.S. Atomic Energy Commission, and National Marine Fisheries Service. 269. Misitano, D. A. 1977. Species composition and relative abundance of larval and post-larval fishes in the Columbia River estuary, 1973. Fish. Bull. 75(1):218–222.
Nehalem Bay	Not found	G. Cailliet, Moss Landing Marine Laboratories, Moss Landing, CA	

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

Estuary	Reference no. and occurrence	Personal communication	Reference source
Tillamook Bay	39, 131 not found		39. Bottom, D. L., and B. Forsberg. 1978. The fishes of Tillamook Bay. Federal Aid Progress Rep., Fish. Oregon Dept. Fish and Wildlife, Corvallis. 131. Forsberg, B. O., J. A. Johnson, and S. M. Klug. 1977. Identification, distribution, and notes on food habits of fish and shellfish in Tillamook Bay, Oregon. Federal Aid Progress Rep., Fish. Oregon Dept. Fish and Wildlife, Corvallis.
Netarts Bay	399 not found	A. Chung, Oregon State Univ., Corvallis	399. Stout, H. (ed.). 1976. The natural resources and human utilization of Netarts Bay, Oregon. Oregon State Univ., Corvallis.
Siletz River	384 not found	G. Stewart, Oregon Dept. Fish and Wildlife, Newport	384. Starr, R. 1979. Natural resources of Siletz estuary. Oregon Dept. Fish and Wildlife, Corvallis.
Yaquina Bay	Not found	J. Butler, Oregon Dept. Fish and Wildlife, Newport W. DeBen, U.S. EPA, Newport, OR G, Stewart, Oregon Dept. Fish and Wildlife, Newport	
Alsea River	Not found	J. Butler, Oregon Dept. Fish and Wildlife, Newport G. Stewart, Oregon Dept. Fish and Wildlife, Newport	
Siuslaw River	197 rare	J. McCleod, Oregon Dept. Fish and Wildlife, Florence	197. Hutchinson, J. M. 1979. Seasonal distribution of fishes in Siuslaw Bay. Oregon Dept. Fish and Wildlife, Corvallis.

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

Estuary	Reference no. and occurrence	Personal communication	Reference source
Umpqua River	200, 277, 323	J. Johnson, Oregon Dept. Fish and Wildlife, Reedsport	200. Johnson, J., D. P. Liscia, and D. M. Anderson. 1986. The seasonal occurrence and distribution of fish in the Umpqua estuary April 1977 through January 1986. Information Rep. 86-6. Oregon Dept. Fish and Wildlife, Corvallis. 277. Mullen, R. 1977. The occurrence and distribution of fish in the Umpqua River estuary, June through October 1972. Information Rep. 77-3. Oregon Dept. Fish and Wildlife, Corvallis. 323. Ratti, F. 1979b. Natural resources of Umpqua estuary. Estuary Inventory Rep. 2(5). Oregon Dept. Fish and Wildlife, Corvallis.
Coos Bay	91, 193, 337, 429 rare	W. Mullarkey, Oregon Dept. Fish and Wildlife, Charleston	91. Cummings, E, and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Information Rep. 70-11. Fish Commission of Oregon, Portland. 193. Hostick, G. A. 1975. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Information Rep. 74-11, Fish Commission of Oregon, Portland. 337. Roye, C. 1979. Natural resources of Coos Bay estuary. Oregon Dept. Fish and Wildlife, Corvallis. 429. Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, W. G. Mullarkey, N. T. Richmond, and T. J. Rumreich. 1988. Coos Bay fish management plan. Draft No. 3, Oregon Dept. Fish and Wildlife, Corvallis.
Rogue River	322 rare	A. Riikula, Oregon Dept. Fish and Wildlife, Gold Beach	322. Ratti, F. 1979a. Natural resources of Rogue Estuary. Estuary Inventory Rep. 2(8). Oregon Dept. Fish and Wildlife, Corvallis.

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

Estuary	Reference no. and occurrence	Personal communication	Reference source
Klamath River	138	T. Kisanuki, U.S. Fish and Wildlife Service, Arcata, CA M. Orcutt, Hoopa Valley Tribe, Hoopa, CA. M. Pisano, California Dept. Fish and Game, Arcata R. Warner, California Dept. Fish and Game, Eureka	138. Fry Jr., D. H. 1979. Anadromous fishes of California. Calif. Dept. Fish and Game, Sacramento.
Humboldt Bay	165, 454 rare	R. Barnhart, U. S. Fish and Wildlife Service, Coop. Fish. Research Unit, Arcata, CA C. Toole, Univ. California Cooperative Extension, Eureka R. Warner, California Dept. Fish and Game, Eureka	165. Gotshall, D. W., G. H. Allen, and R. A. Barnhart. 1980. An annotated checklist of fishes from Humboldt Bay, California. Calif. Fish Game 66(4):220–232. 454. Young, J. S. 1984. Identification of larval smelt (Osteichthes: Salmoniformes: Osmeridae) from northern California. Master's thesis. Humboldt State Univ., Arcata, CA.
Eel River	270, 313 not found		270. Monroe, G. W., F. Reynolds, B. M. Browning, and J. W. Speth. 1974. Natural resources of the Eel River delta. Coastal Wetland Series No. 9, California Dept. Fish and Game, Sacramento. 313. Puckett, L. K. 1977. The Eel River estuary observations on morphometry, fishes, water quality, and invertebrates. Memo. Rep. California Dept. Fish and Game, Sacramento.

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

Estuary	Reference no. and occurrence	Personal communication	Reference source
Tomales Bay	22, 264, 292 not found		22. Bane, G. W., and A. W. Bane. 1971. Bay fishes of northern California with emphasis on the Bodega Tomales Bay area. Mariscos Publications, Hampton Bays, NY. 264. Miller, D. J.,and R. N. Lea. 1972. Guide to the coastal marine fishes of California. California Dept. Fish Game. Fish Bull. 157. 292. Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. Calif. Fish Game 50(4):305–307.
Central San Francisco/ Suisun/San Pablo bays	264, 292 not found		264. Miller and Lea 1972 (Complete listing above.) 292. Odemar 1964 (Complete listing above.)
South San Francisco Bay	Not found, 292, 294		292. Odemar 1964 (Complete listing above.) 294. Oregon Dept. Fish and Wildlife and Washington Dept. Fisheries. 1987. Status report: Columbia River fish runs and fisheries 1960–1986. ODFW, Portland, and WDF, Olympia.
Elkhorn Slough	Not found, 264, 292		264. Miller and Lea 1972 (Complete listing above.) 292. Odemar 1964 (Complete listing above.)
Morro Bay	Not found, 264, 292		264. Miller and Lea 1972 (Complete listing above.) 292. Odemar 1964 (Complete listing above.)
Santa Monica Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

Estuary	Reference no. and occurrence	Personal communication	Reference source
San Pedro Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)
Alamitos Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)
Anaheim Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)
Newport Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)
Mission Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)
San Diego Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)
Tijuana Bay	Not found, 264		264. Miller and Lea 1972 (Complete listing above.)

Table A-3. Documented occurrence of eulachon in northern California rivers (see Appendix B for transcription of cited newspaper articles).

Run year	Month	Klamath River	Redwood Creek	Mad River	Humboldt Bay tributaries	Source
1908	April-May		X			San Francisco Call, San Francisco, CA
1916	February	X				Calif. Academy of Sciences ichthyology collection
1919	February	X				San Jose Mercury Herald, San Jose, CA
1947	March	X				Calif. Academy of Sciences ichthyology collection
1952	February	X				Humboldt Standard, Eureka, CA
1955	February		X			Calif. Academy of Sciences ichthyology collection
1963	March	X				Calif. Academy of Sciences ichthyology collection
	April	X	X	X		Humboldt Standard, Eureka, CA; Odemar 1964
1965	April	X				Humboldt Standard, Eureka, CA
1967	April		X			The Times-Standard, 14 March 1968, Eureka, CA
1968	March	X				The Times-Standard, Eureka, CA
1969	April	X				The Times-Standard, Eureka, CA
1971	March	X				Humboldt Standard, Eureka, CA
1972	—	X				Humboldt Standard, Eureka, CA
1976	April	X	X	X		Humboldt Standard, Eureka, CA
1977	May				X	Jennings 1996
1978	April	X	X			Young 1984
1979	March	X				Young 1984
	April	X				
1980	March	X				Young 1984
	April	X				
1988	December	X				Larson and Belchik 1998
1989	May	X				Larson and Belchik 1998

Table A-4. Latitudinal and depth distribution of eulachon in fishery-independent upper continental slope and continental shelf bottom trawl surveys of groundfish on the U.S. West Coast.

Year	Total no. of hauls	No. hauls with eulachon	Eulachon frequency in hauls	Survey depth range (m)	Survey latitudinal range (dd.mm)	Depth (m)			Latitudinal range (dd)		Source
						Mean	Min	Max	South	North	
Upper continental slope											
1989–1993	401	25	0.06	183–1,280	38.20–48.10	330	194	589	40.40	47.51	Lauth et al. 1997
1995	106	None	—	183–1,280	40.30–43.00	—	—	—	—	—	Lauth 1997a
1996	203	2	0.01	183–1,280	43.00–48.10	377	366	387	44.56	46.17	Lauth 1997b
1997	182	2	0.01	183–1,280	34.30–48.10	319	259	379	46.17	47.11	Lauth 1999
1999	199	2	0.01	183–1,280	34.30–48.10	291	242	339	42.07	46.17	Lauth 2000
2000	330	10	0.03	183–1,280	35.00–48.10	291	186	608	41.82	45.81	Keller et al. 2005
2001	334	1	<0.01	183–1,280	34.15–48.10	214	214	214	45.03	45.03	Keller et al. 2006a
2002	427	9	0.02	183–1,280	32.30–48.10	250	189	390	44.69	46.28	Keller et al. 2006b
Continental shelf triennial survey											
1989	539	222	0.41	55–366	34.30–49.40	141	60	333	34.36	49.35	Weinberg et al. 1994a
1992	501	196	0.39	55–366	34.30–49.40	139	59	348	40.44	49.25	Zimmerman et al. 1994
1995	522	88	0.17	55–500	34.30–49.40	137	66	328	41.24	49.34	Wilkins et al. 1998
1998	527	45	0.08	55–500	34.30–49.40	147	79	322	42.24	49.14	Shaw et al. 2000
2001	506	130	0.26	55–500	34.30–49.40	147	62	466	42.25	49.05	Weinberg et al. 2002
Continental slope and shelf											
2003	574	29	0.05	55–1,280	32.30–48.10	126	51	237	33.97	48.40	Keller et al. 2007a
2004	508	40	0.08	55–1,280	32.30–48.10	119	55	220	34.51	48.23	Keller et al. 2007b
2005	675	19	0.03	55–1,280	32.30–48.10	130	96	169	42.00	47.90	Keller et al. 2008

Table A-5. Latitudinal, longitudinal, and depth distribution of eulachon in AFSC fishery-independent bottom trawl surveys of groundfish in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. Data available online at http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm.

Year	No. hauls with eulachon	Depth (m)			Latitudinal range (dd.mm)		Longitudinal range (dd.mm)	
		Mean	Min.	Max.	South	North	East	West
Gulf of Alaska								
1984	178	188	27	393	54.40	60.28	134.23	162.40
1987	226	170	26	402	54.42	60.25	132.94	162.65
1990	284	184	20	432	54.49	60.27	133.07	162.96
1993	294	181	20	351	54.35	60.32	133.33	162.60
1996	272	165	28	474	53.80	60.19	132.90	166.39
1999	277	172	16	409	53.54	60.20	132.82	166.63
2001	117	174	62	297	52.64	59.87	146.97	165.43
2003	230	173	31	566	52.77	60.30	132.89	169.00
2005	259	169	23	548	53.66	60.21	132.88	164.78
2007	237	165	32	516	54.24	60.30	132.83	162.10
Eastern Bering Sea								
1982	29	103	40	159	55.00	56.68	159.76	168.20
1983	43	91	29	159	55.00	59.65	158.42	176.56
1984	30	108	49	163	54.98	57.34	159.67	170.07
1985	19	126	101	157	55.00	56.83	166.31	170.49
1986	38	106	49	155	54.99	57.01	160.37	170.07
1987	27	114	33	155	55.00	57.98	159.76	168.20
1988	17	95	31	155	55.01	58.09	158.42	167.04
1989	21	114	49	159	54.82	58.00	162.79	172.20
1990	25	102	18	159	55.01	60.32	158.32	170.07
1991	23	119	49	155	55.00	57.69	162.82	167.64
1992	27	109	27	155	55.00	60.36	161.00	170.07
1993	20	95	22	148	55.32	59.68	159.06	171.52
1994	40	92	16	154	54.99	60.00	159.09	171.53
1995	38	97	29	143	54.99	57.01	159.08	172.66
1996	38	104	35	155	54.99	57.98	158.32	172.63
1997	38	100	39	157	55.01	57.68	159.76	168.87
1998	56	94	34	154	54.99	57.99	158.97	170.49
1999	39	106	53	155	55.01	57.01	162.80	168.26
2000	46	98	37	153	55.00	60.34	159.07	171.41
2001	62	90	46	153	54.99	58.00	159.02	168.90
2002	44	91	32	153	55.00	58.67	158.40	168.30
2003	36	103	32	156	55.00	60.00	158.42	175.27
2004	39	102	25	156	54.99	59.32	158.35	174.46
2005	36	101	24	154	55.00	61.00	159.12	176.24
2006	37	98	36	146	55.33	58.02	158.97	170.70
2007	48	96	21	155	55.00	59.00	160.36	172.86
2008	37	100	44	156	54.99	61.32	160.37	174.89
Aleutian Islands								
1986-1997	13	170	62	404	51.90	53.76	166.96	176.46
2000-2006	12	164	89	197	53.58	53.78	166.77	167.37

Table A-6. Age distribution of selected adult eulachon populations as determined by reading otolith increments. NR = data not recorded, N = number aged, proportions in bold indicate the mode for that year.

			Proportion of fish in each age class								
Year	**Sex**	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Reference**
Columbia River											
1984	NR	104			<0.11	**0.50**	0.27	0.08	<0.05		Dammers 1988
1985	NR	100			0.02	0.25	**0.48**	0.20	0.03	0.02	Dammers 1988
1986	NR	144		0.04	**0.35**	**0.35**	0.15	0.10	0.01	<0.01	Dammers 1988
1992	NR	NR			0.26	**0.49**	0.25				WDFW and ODFW 2001
1993	NR	NR			**0.39**	**0.39**	0.22				WDFW and ODFW 2001
1994	NR	NR			**0.66**	0.28	0.006				WDFW and ODFW 2001
1995	NR	NR			0.41	**0.46**	0.13				WDFW and ODFW 2001
1996	NR	NR			**0.56**	0.39	0.05				WDFW and ODFW 2001
1997	NR	NR			**0.60**	0.33	0.07				WDFW and ODFW 2001
1998	NR	NR			**0.56**	0.37	0.07				
Frazier River											
1986	NR	20				0.40	**0.45**	0.10	0.05		Higgins et al. 1987
Kemano River											
1988	M	76			0.24	**0.45**	0.29	0.03			Lewis et al. 2002
1989	M	101		0.01	0.15	0.29	**0.43**	0.13			Lewis et al. 2002
1990	M	143			0.15	**0.48**	0.33	0.03			Lewis et al. 2002
1992	M	158			0.28	**0.37**	0.33	0.02			Lewis et al. 2002
1993	M	213			0.31	**0.37**	0.31	0.01			Lewis et al. 2002
1994	M	152			**0.41**	0.40	0.19				Lewis et al. 2002
1995	M	124			0.13	**0.39**	0.32	0.15	0.01		Lewis et al. 2002
1996	M	135			0.21	**0.45**	0.23	0.10			Lewis et al. 2002
1997	M	171		0.05	**0.55**	0.28	0.11	0.01			Lewis et al. 2002
1998	M	86			0.26	0.31	**0.43**				Lewis et al. 2002
1988	F	120			0.16	**0.42**	0.39	0.03			Lewis et al. 2002
1989	F	111		0.09	0.26	**0.32**	0.28	0.05			Lewis et al. 2002
1990	F	144			0.17	**0.41**	0.34	0.08			Lewis et al. 2002
1992	F	96			**0.47**	0.39	0.14	0.01			Lewis et al. 2002
1993	F	192			**0.45**	0.38	0.18				Lewis et al. 2002
1994	F	175			**0.51**	0.36	0.13				Lewis et al. 2002

Table A-6 continued. Age distribution of selected adult eulachon populations as determined by reading otolith increments. NR = data not recorded, N = number aged, proportions in bold indicate the mode for that year.

			Proportion of fish in each age class								
Year	**Sex**	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Reference**
1995	F	118			0.14	**0.37**	0.36	0.12			Lewis et al. 2002
1996	F	140			0.17	**0.52**	0.24	0.06			Lewis et al. 2002
1998	F	91		0.01	0.19	**0.54**	0.26				Lewis et al. 2002
Kitimat River											
1993	F	59			**0.75**	0.20	0.02	0.03			Pederson et al. 1995
Nass River											
1969	NR	53			0.15	**0.83**	0.02				Langer et al. 1997
1970	NR	256			0.38	**0.56**	0.06				Langer et al. 1997
1971	NR	378		0.04	**0.68**	0.24	0.04				Langer et al. 1997
Copper River delta											
Eyak River											
2002	NR	445			0.01	**0.97**	0.02				Moffit et al. 2002
Alaganik Slough											
1998	NR	460			0.01	0.08	**0.91**				Moffit et al. 2002
2000	NR	99			**0.73**	0.27					Moffit et al. 2002
Ibeck Creek											
2001	NR	1,215			0.04	**0.96**	<0.01	<0.01			Moffit et al. 2002
Copper River											
Flag Point Channel											
1998	NR	2,591			<0.01	0.09	**0.90**	<0.01			Moffit et al. 2002
2000	NR	1,338		<0.01	**0.48**	**0.48**	0.40	<0.01			Moffit et al. 2002
2001	NR	1,699		<0.01	**0.56**	0.43	0.01				Moffit et al. 2002
2002	NR	1,290			0.01	**0.98**	0.01				Moffit et al. 2002
60-km Bridge											
2002	NR	812			0.01	**0.98**	0.01				Moffit et al. 2002
Twentymile River											
2000	M	235		0.09	**0.51**	0.36	0.04				Spangler et al. 2003
2001	M	585		0.06	**0.83**	0.01					Spangler et al. 2003
2000	F	49	0.02	0.23	**0.57**	0.14	0.04				Spangler et al. 2003
2001	F	425		0.08	**0.88**	0.04					Spangler et al. 2003

Table A-7. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NR = not recorded, NS = not sexed, FL = fork length, SL = standard length, NA = not applicable.

Location (river basin)	Date	Age	Method	Male length (mm) Mean	SD	SE	Range	No.	Female length (mm) Mean	SD	SE	Range	No.
Alaska													
Susitna River	1982[a]	—	NR, NS	213.0	—	—	—	—	—	—	—	—	—
	1983[a]	—	NR, NS	206.0	—	—	—	—	—	—	—	—	—
Twentymile River	1976[b]	—	NR	228.0	—	—	209–249	22	224	—	—	210–246	40
	1977[c]	—	NR	228.0	—	—	162–270	—	223	—	—	202–255	408
													Total
	2000[d]	—	FL	215.0	—	0.9	166–242	222	202	—	3.0	143–234	49
	2001[d]	—	FL	209.0	—	0.5	100–241	585	203	—	0.6	99–253	425
Copper River delta													
Eyak River	2002[e]	3	SL	180.0	—	4	—	4	—	—	—	—	—
		4	SL	187.0	—	0	—	430	187	—	12	—	2
		5	SL	192.0	—	3	—	9	—	—	—	—	—
Ibeck Creek	2001[e]	3	SL	180.0	—	2	—	40	164	—	4	—	2
		4	SL	177.0	—	0	—	1,089	171	—	1	—	75
		5	SL	186.0	—	3	—	5	—	—	—	—	—
		6	SL	182.0	—	3	—	4	—	—	—	—	—
	2003[f]	—	SL	179.0	—	10	138–207	1,249	173	—	9	154–206	101
Alaganik Slough	1998[e]	3	SL	179.0	—	3	—	6	—	—	—	—	—
		4	SL	175.0	—	2	—	35	172	—	2	—	2
		5	SL	179.0	—	0	—	377	175	—	2	—	40
	2000[e]	3	SL	160.0	—	1	—	47	160	—	2	—	25
		4	SL	174.0	—	3	—	21	173	—	9	—	6
Copper River													
Flag Point Channel	1998[e]	3	SL	179.0	—	3	—	7	181	—	1	—	2
		4	SL	182.0	—	1	—	151	175	—	1	—	96
		5	SL	183.0	—	0	—	1,848	177	—	0	—	478
		6	SL	176.0	—	2	—	7	186	—	10	—	2
	2000[e]	2	SL	182.0	—	NA	—	1	—	—	—	—	—
		3	SL	174.0	—	0	—	534	168	—	1	—	109
		4	SL	176.0	—	0	—	547	172	—	1	—	99

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NS = not sexed, FL = fork length, SL = standard length, NA = not applicable.

Location (river basin)	Date	Age	Method	Male length (mm)					Female length (mm)				
				Mean	SD	SE	Range	No.	Mean	SD	SE	Range	No.
Flag Point Channel		5	SL	183.0	—	2	—	43	164	—	5	—	5
(continued)		6	SL	192.0	—	NA	—	1	—	—	—	—	—
	2001[e]	2	SL	—	—	—	—	—	154	—	NA	—	1
		3	SL	174.0	—	0	—	643	167	—	1	—	306
		4	SL	180.0	—	0	—	571	172	—	1	—	155
		5	SL	179.0	—	2	—	21	166	—	3	—	2
	2002[e]	3	SL	178.0	—	3	—	16	185	—	6	—	2
		4	SL	183.0	—	0	—	1,081	178	—	1	—	175
		5	SL	188.0	—	3	—	15	190	—	NA	—	1
60-km Bridge	2002[e]	3	SL	181.0	—	8	—	3	176	—	4	—	7
		4	SL	186.0	—	0	—	575	181	—	1	—	218
		5	SL	191.0	—	3	—	9	—	—	—	—	—
Southeast Alaska													
Stikine River[g]	1979	2	FL	180.0	—	—	141–197	—	—	—	—	—	—
		3	FL	190.0	—	—	165–210	—	—	—	—	—	—
		4	FL	194.0	—	—	173–211	—	—	—	—	—	—
	1980	2	FL	172.0	—	—	155–179	—	—	—	—	—	—
		3	FL	186.0	—	—	162–208	—	—	—	—	—	—
		4	FL	201.0	—	—	195–208	—	—	—	—	—	—
British Columbia													
Nass River[h]	1970	3	SL	173.0	11.3	—	—	87	171	16.2	—	—	11
		4	SL	179.0	11.2	—	—	123	181	11.8	—	—	19
		5	SL	188.0	6.1	—	—	12	192	3.5	—	—	4
	1971	2	SL	155.0	10.9	—	—	5	144	6.9	—	—	9
		3	SL	167.0	52.3	—	—	74	157	16.2	—	—	183
		4	SL	174.0	10.2	—	—	33	171	10.3	—	—	60
		5	SL	188.0	19.8	—	—	7	183	11.3	—	—	7
Skeena River	2003[i]	—	FL, NS	189.0	—	2	—	52					
Kitimat River	1993[j]	3	SL	—	—	—	—	—	169	—	1.5	149–187	44
		4	SL	—	—	—	—	—	175	—	1.5	165–181	12

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, SL = standard length, NA = not applicable.

Location				Male length (mm)					Female length (mm)				
(river basin)	Date	Age	Method	Mean	SD	SE	Range	No.	Mean	SD	SE	Range	No.
Kitimat River (cont.)		5	SL	—	—	—	—	—	184	—	NA	NA	1
		6	SL	—	—	—	—	—	170	—	9.5	160–189	2
	1997[k]	2	SL	173.0	9.9	—	—	2	162	0.0	—	—	1
		3	SL	176.0	14.4	—	—	28	180	9.9	—	—	25
		4	SL	175.0	12.9	—	—	16	174	11.6	—	—	37
		5	SL	184.0	15.6	—	—	13	183	12.7	—	—	10
		6	SL	182.0	0.0	—	—	1	178	17.7	—	—	2
Kemano River	1988[l]	3	FL	168.0	—	—	—	—	165	—	—	—	—
		4	FL	175.0	—	—	—	—	174	—	—	—	—
		5	FL	187.0	—	—	—	—	186	—	—	—	—
		6	FL	195.0	—	—	—	—	196	—	—	—	—
	1989[l]	2	FL	190.0	—	—	—	—	181	—	—	—	—
		3	FL	188.0	—	—	—	—	181	—	—	—	—
		4	FL	189.0	—	—	—	—	184	—	—	—	—
		5	FL	189.0	—	—	—	—	181	—	—	—	—
		6	FL	183.0	—	—	—	—	176	—	—	—	—
	1990[l]	3	FL	177.0	—	—	—	—	182	—	—	—	—
		4	FL	188.0	—	—	—	—	187	—	—	—	—
		5	FL	196.0	—	—	—	—	194	—	—	—	—
		6	FL	206.0	—	—	—	—	194	—	—	—	—
	1992[l]	3	FL	177.0	—	—	—	—	173	—	—	—	—
		4	FL	187.0	—	—	—	—	182	—	—	—	—
		5	FL	196.0	—	—	—	—	198	—	—	—	—
		6	FL	207.0	—	—	—	—	214	—	—	—	—
	1993[l]	3	FL	176.0	—	—	—	—	170	—	—	—	—
		4	FL	187.0	—	—	—	—	186	—	—	—	—
		5	FL	198.0	—	—	—	—	195	—	—	—	—
		6	FL	207.0	—	—	—	—	—	—	—	—	—
	1994[l]	3	FL	169.0	—	—	—	—	166	—	—	—	—
		4	FL	182.0	—	—	—	—	181	—	—	—	—

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NS = not sexed, FL = fork length, SL = standard length.

Location (river basin)	Date	Age	Method	Male length (mm) Mean	SD	SE	Range	No.	Female length (mm) Mean	SD	SE	Range	No.
Kemano River (cont.)		5	FL	186.0	—	—	—	—	186	—	—	—	—
	1995[l]	3	FL	171.0	—	—	—	—	174	—	—	—	—
		4	FL	181.0	—	—	—	—	182	—	—	—	—
		5	FL	183.0	—	—	—	—	181	—	—	—	—
		6	FL	190.0	—	—	—	—	195	—	—	—	—
		7	FL	201.0	—	—	—	—	—	—	—	—	—
	1996[l]	3	FL	188.0	—	—	—	—	185	—	—	—	—
		4	FL	192.0	—	—	—	—	185	—	—	—	—
		5	FL	195.0	—	—	—	—	186	—	—	—	—
		6	FL	193.0	—	—	—	—	195	—	—	—	—
	1998[l]	2	FL	—	—	—	—	—	175	—	—	—	—
		3	FL	177.0	—	—	—	—	172	—	—	—	—
		4	FL	174.0	—	—	—	—	172	—	—	—	—
		5	FL	181.0	—	—	—	—	174	—	—	—	—
	2003[i]	—	FL, NS	196.0	—	3	—	36	—	—	—	—	—
Fraser River	1986[m]	—	FL	182.0	13.3	—	129–212	325	164	21.6	—	124–200	95
	1995[n]	—	SL	158.0	11.0	—	—	311	158	10.4	—	—	352
	1996[n]	—	SL	156.0	10.4	—	—	241	155	10.7	—	—	218
	1997[n]	—	SL	161.0	12.0	—	—	254	158	10.4	—	—	259
	1998[n]	—	SL	158.0	12.6	—	—	260	158	15.6	—	—	156
	2000[n]	—	SL	162.0	10.4	—	—	108	163	9.3	—	—	93
	2001[n]	—	SL	160.0	6.4	—	—	50	156	5.3	—	—	50
	4/25/2001[o]	—	FL, NS	171.0	7.2	—	117–186	138	—	—	—	—	—
	5/2/2001[o]	—	FL, NS	171.0	7.4	—	154–195	47	—	—	—	—	—
	5/3/2002[o]	—	FL, NS	181.0	22.0	—	116–206	20	—	—	—	—	—
	2003[i]	—	FL, NS	183.0	—	3	—	45	—	—	—	—	—
	2009[p]	—	—	192.0	—	—	—	77	180	—	—	—	171
Washington													
Columbia River	3/2/1962[q]	—	FL	155.0	—	—	132–180	99					
	1968	—	FL	153.0	—	—	—	—	—	—	—	—	—

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed, NA = not applicable.

Location (river basin)	Date	Age	Method	Male length (mm) Mean	SD	SE	Range	No.	Female length (mm) Mean	SD	SE	Range	No.
Columbia River (cont.)	1969	—	FL, NS	161.0	—	—	—	—	—	—	—	—	—
	1978[r]	—	FL	183.0	13.1	—	142–250	674	178	12.9	—	153–205	59
	1984[s]	3	FL, NS				134–158	11	—	—	—	—	—
		4	FL, NS	—	—	—	125–167	52	—	—	—	—	—
		5	FL, NS	—	—	—	115–185	28	—	—	—	—	—
		6	FL, NS	—	—	—	156–189	8	—	—	—	—	—
		7	FL, NS	—	—	—	148–191	5	—	—	—	—	—
	1985[s]	3	FL, NS	—	—	—	148–150	2	—	—	—	—	—
		4	FL, NS	—	—	—	153–183	25	—	—	—	—	—
		5	FL, NS	—	—	—	156–196	48	—	—	—	—	—
		6	FL, NS	—	—	—	170–204	20	—	—	—	—	—
		7	FL, NS	—	—	—	178–188	3	—	—	—	—	—
		8	FL, NS	—	—	—	192–203	2	—	—	—	—	—
	1986[s]	2	FL, NS	—	—	—	134–145	5	—	—	—	—	—
		3	FL, NS	—	—	—	133–198	50	—	—	—	—	—
		4	FL, NS	—	—	—	125–201	50	—	—	—	—	—
		5	FL, NS	—	—	—	165–211	22	—	—	—	—	—
		6	FL, NS	—	—	—	182–220	14	—	—	—	—	—
		7	FL, NS	—	—	—	201–209	2	—	—	—	—	—
		8	FL, NS	217.0	—	—	NA	1	—	—	—	—	—
	1992[t]	3	FL, NS	169.4	—	—	—	—	—	—	—	—	—
		4	FL, NS	189.3	—	—	—	—	—	—	—	—	—
		5	FL, NS	190.8	—	—	—	—	—	—	—	—	—
	1993[t]	3	FL, NS	164.4	—	—	—	—	—	—	—	—	—
		4	FL, NS	159.4	—	—	—	—	—	—	—	—	—
		5	FL, NS	149.0	—	—	—	—	—	—	—	—	—
	1994[t]	3	FL, NS	178.7	—	—	—	—	—	—	—	—	—
		4	FL, NS	177.4	—	—	—	—	—	—	—	—	—
		5	FL, NS	164.8	—	—	—	—	—	—	—	—	—
	1994[r]	2	FL	181.0	16.8	—	151–201	12	—	—	—	—	—

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed, TL = total length, NA = not applicable.

Location				**Male length (mm)**					**Female length (mm)**				
(river basin)	**Date**	**Age**	**Method**	**Mean**	**SD**	**SE**	**Range**	**No.**	**Mean**	**SD**	**SE**	**Range**	**No.**
Columbia River (cont.)		3	FL	181.0	11.6	—	163–205	25	179	13.2	—	163–193	7
		4	FL	179.0	15.8	—	156–209	16	168	10.6	—	160–175	2
		5	FL	168.0	7.5	—	160–178	5	150	NA	—	NA	1
	1995[t]	3	FL, NS	171.3	—	—	—	—	—	—	—	—	—
		4	FL, NS	181.0	—	—	—	—	—	—	—	—	—
		5	FL, NS	197.5	—	—	—	—	—	—	—	—	—
	1996[t]	3	FL, NS	168.5	—	—	—	—	—	—	—	—	—
		4	FL, NS	179.4	—	—	—	—	—	—	—	—	—
		5	FL, NS	170.2	—	—	—	—	—	—	—	—	—
	1997[t]	3	FL, NS	165.4	—	—	—	—	—	—	—	—	—
		4	FL, NS	170.5	—	—	—	—	—	—	—	—	—
		5	FL, NS	162.8	—	—	—	—	—	—	—	—	—
	1998[t]	3	FL, NS	173.5	—	—	—	—	—	—	—	—	—
		4	FL, NS	181.5	—	—	—	—	—	—	—	—	—
		5	FL, NS	175.9	—	—	—	—	—	—	—	—	—
	2003[i]	—	FL, NS	175.0	—	3	—	25	—	—	—	—	—
Cowlitz River	2/21/1962[q]	—	FL	162.0	—	—	138–195	100	—	—	—	—	—
	3/17/1962[q]	—	FL	157.0	—	—	133–191	100	—	—	—	—	—
	3/19/1962[q]	—	FL	159.0	—	—	143–185	50	163	—	—	121–198	98
	3/31/1962[q]	—	FL	164.0	—	—	134–196	99	160	—	—	121–197	98
	4/5/1962[q]	—	FL	153.0	—	—	128–180	100	150	—	—	118–185	95
	4/7/1962[q]	—	FL	161.0	—	—	134–193	97	—	—	—	—	—
Elochoman River	3/28/1962[q]	—	FL	153.0	—	—	126–190	96	159	—	—	136–194	95
Elwha River[u]	2005	—	TL	180.0	10.1	—	171–195	7	166	28.5	—	125–250	18
Oregon													
Tenmile Creek[v]	1992	—	FL, NS	189.0	—	—	—	24	—	—	—	—	—
	1993	—	FL, NS	170.0	—	—	—	6	—	—	—	—	—
	1994	—	FL, NS	155.0	—	—	—	1	—	—	—	—	—
	2001	—	FL, NS	177.0	—	—	—	23	—	—	—	—	—
	2003	—	FL, NS	208.0	—	—	—	3	—	—	—	—	—

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed.

Location				Male length (mm)					Female length (mm)				
(river basin)	Date	Age	Method	Mean	SD	SE	Range	No.	Mean	SD	SE	Range	No.
Tenmile Creek (cont.)	2005	—	FL, NS	165.0	—	—	—	7	—	—	—	—	—
	2007	—	FL, NS	170.0	—	—	—	1	—	—	—	—	—
	2008	—	FL, NS	182.0	—	—	—	1	—	—	—	—	—

[a]Barrett et al. 1984 (as reprinted in Willson et al. 2006)
[b]Kubik and Wadman 1977
[c]Kubik and Wadman 1978
[d]Spangler 2002
[e]Moffit et al. 2002
[f]Joyce et al. 2004
[g]Franzel and Nelson 1981 (in Willson et al. 2006, their Table 2b)
[h]Langer et al. 1977
[i]Clarke et al. 2007
[j]Pedersen et al. 1995
[k]Kelson 1997
[l]Lewis et al. 2002
[m]Higgins et al. 1987
[n]Hay et al. 2002 (their Table 3)
[o]Stables et al. 2005
[p]Plate 2009
[q]DeLacy and Batts 1963
[r]Data provided by Brad James, WDFW, Vancouver, WA, 2008
[s]Dammers 1988
[t]WDFW and ODFW 2001
[u]Shaffer et al. 2007
[v]WDFW and ODFW 2008

Table A-8. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured, NA = not applicable.

Location (river basin)	Year	Age	Male weight (g) Mean	SD	SE	Range	No.	Female weight (g) Mean	SD	SE	Range	No.
Alaska												
Susitna River	1982[a] Not sexed	—	72.0	—	—	—	—	—	—	—	—	—
	1983[a] Not sexed	—	64.0	—	—	—	—	—	—	—	—	—
Twentymile River	1976[b]	—	66.0	—	—	41–91	200	68.0	—	—	45–95	40
	1977[c]	—	90.7	—	—	45.4–127	—	86.2	—	—	54.4–127	408
	2000[d]	—	69.9	—	1.0	26.5–104	222	60.0	—	2.8	29–101	49
	2001[d]	—	65.8	—	0.5	6-106	585	60.1	—	0.5	28–122	425
Copper River delta												
Eyak River	2002[e]	3	43.0	—	2.0	—	4	—	—	—	—	—
		4	55.0	—	0.0	—	430	50.0	—	10.0	—	2
		5	58.0	—	2.0	—	9	—	—	—	—	—
Ibeck Creek	2001[e]	3	53.0	—	2.0	—	40	38.0	—	2.0	—	3
		4	50.0	—	0.0	—	1,089	46.0	—	1.0	—	75
		5	60.0	—	5.0	—	5	—	—	—	—	—
		6	52.0	—	4.0	—	4	—	—	—	—	—
	2003[f]	—	56.0		10.0	23–89	1,249	47.0	—	9.0	31–82	101
Alaganik Slough	1998[e]	3	53.0	—	4.0	—	6	—	—	—	—	—
		4	44.0	—	1.0	—	35	34.5	—	1.0	—	2
		5	48.0	—	0.0	—	377	39.9	—	1.0	—	40
	2000[e]	3	37.0	—	1.0	—	47	35.0	—	2.0	—	25
		4	48.0	—	3.0	—	21	43.0	—	6.0	—	6
Copper River												
Flag Point channel	1998[e]	3	52.0	—	2.0	—	7	56.0	—	8.0	—	2
		4	57.0	—	1.0	—	151	49.6	—	1.0	—	96
		5	55.0	—	0.0	—	1,848	51.1	—	0.0	—	478
		6	52.0	—	3.0	—	7	67.0	—	14.0	—	2
	2000[f]	2	55.0	—	NA	—	1	—	—	—	—	—
		3	47.0	—	0.0	—	534	43.0	—	1.0	—	109
		4	47.0	—	0.0	—	547	47.0	—	1.0	—	99

Table A-8 continued. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured, NA = not applicable.

Location (river basin)	**Year**	**Age**	**Male weight (g) Mean**	**SD**	**SE**	**Range**	**No.**	**Female weight (g) Mean**	**SD**	**SE**	**Range**	**No.**
Flag Point Channel		5	53	—	2.0	—	43	39.0	—	3.0	—	5
(cont.)		6	60	—	NA	—	1	—	—	—	—	—
	2001[f]	2	—	—	—	—	—	37.0	—	NA	—	1
		3	48	—	0.0	—	643	45.0	—	1.0	—	306
		4	52	—	0.0	—	571	48.0	—	1.0	—	155
		5	52	—	2.0	—	21	47.0	—	3.0	—	2
	2002[f]	3	53	—	3.0	—	16	47.0	—	2.0	—	2
		4	57	—	0.0	—	1,081	52.0	—	1.0	—	175
		5	62	—	3.0	—	15	66.0	—	NA	—	1
60-km Bridge	2002[f]	3	57	—	7.0	—	3	51.0	—	3.0	—	7
		4	62	—	0.0	—	575	58.0	—	1.0	—	218
		5	68	—	3.0	—	9	—	—	—	—	—
Southeast Alaska												
Stikine River[g]	1979	2	38	—	—	18–50	—	—	—	—	—	—
		3	46	—	—	28–60	—	—	—	—	—	—
		4	52	—	—	34–58	—	—	—	—	—	—
	1980	2	35	—	—	30–42	—	—	—	—	—	—
		3	46	—	—	32–60	—	—	—	—	—	—
		4	58	—	—	52–64	—	—	—	—	—	—
British Columbia										—	—	—
Skeena River	2003[h]	—	48.7	—	1.7	—	52	—	—	—	—	—
	Not sexed											
Kitimat River	1993[i]	3	—	—	—	—	—	43.0	—	1.5	27–71	44
		4	—	—	—	—	—	50.5	—	2.0	40–60	12
		5	—	—	—	—	—	52.0	—	NA	NA	1
		6	—	—	—	—	—	40.2	—	7.8	48–80	2
	1997[j]	2	42.4	5.9	—	—	2	33.8	NA	—	—	1
		3	46.2	11.3	—	—	28	44.9	10.5	—	—	25
		4	45.6	11.0	—	—	16	41.9	9.1	—	—	37
		5	55.0	16.6	—	—	13	48.6	12.6	—	—	10
		6	50.4	N/A	—	—	1	47.2	19.7	—	—	2

Table A-8 continued. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured.

Location (river basin)	Year	Age	Male weight (g) Mean	SD	SE	Range	No.	Female weight (g) Mean	SD	SE	Range	No.
Kemano River	1988–1998[k]	—	47.5	10.9	—	—	1,110	44.2	10.7	—	—	1,433
	2003[h]	—	57.5	—	2.3	—	36	—	—	—	—	—
	Not sexed											
Fraser River	1986[l]	—	46.3	10.7	—	13.8–81	325	34.7	14.5	—	12.9–63.7	95
	1995[m]	—	42.8	10.9	—	—	311	44.3	9.6	—	—	352
	1996[m]	—	40.8	9.5	—	—	241	42.8	9.9	—	—	218
	1997[m]	—	38.1	9.1	—	—	254	38.0	7.1	—	—	259
	1998[m]	—	36.7	8.6	—	—	260	37.0	9.9	—	—	156
	2000[m]	—	43.2	9.0	—	—	108	46.2	8.4	—	—	93
	2001[m]	—	36.7	5.0	—	—	50	37.4	3.5	—	—	50
	2003[h]	—	47.2	—	1.6	—	45	—	—	—	—	—
	Not sexed											
	2009[n]	—	59.0	—	—	—	77	51.0	—	—	—	171
Washington												
Columbia River	1978[o]	—	42.0	9.9	—	20–76.1	674	39.6	10.6	—	20.5–64.3	59
	2003[h]	—	37.3	—	1.8	—	25	—	—	—	—	—
	Not sexed											
Elwha River[p]	2005	—	40.3	5.8	—	36–49	7	28.9	12.2	—	11–58	18

[a]Barret et al. 1984 (as reprinted in Willson et al. 2006)
[b]Kubic and Wadman 1977
[c]Kubic and Wadman 1978
[d]Spangler 2002
[e]Moffit et al. 2002
[f]Joyce et al. 2004
[g]Franzel and Nelson 1981 (in Willson et al. 2006, their Table 2b)
[h]Clarke et al. 2007
[i]Pederson et al. 1995
[j]Kelson 1997
[k]Lewis et al. 2002
[l]Higgins et al. 1987
[m]Hay et al. 2002, their Table 3
[n]Plate 2009
[o]Data provided by Brad James, WDFW, Vancouver, WA, 2008
[p]Shaffer et al. 2007

Table A-9. Range (gray) and peak (black) timing of documented river entry or spawn timing for eulachon.

Basin	December	January	February	March	April	May	June
California							
Mad River[a]							
Redwood Creek[a]							
Klamath River[a]							
Oregon							
Tenmile Creek[b]							
Columbia Basin							
Columbia River[c]							
Cowlitz River[c]							
Sandy River[b]							
Washington							
Elwha River[d]							
British Columbia							
Fraser River[e]							
Kingcome River[f]							
Kemano River[g]							
Bella Coola River[h]							
Kitimat River[i]							
Skeena River[j]							
Nass River[k]							
Alaska							
Stikine River[l]							
Taku River[m]							
Berners River[n]							
Chilkat River[f, o]							
Chilkoot River[o]							
Copper River[p, q]							
Alaganik River[p, q]							
Eyak River[p]							
Ibeck Creek[p, q]							
Twentymile River[r]							
Susitna River[s]							

[a]References in Table A-3.
[b]WDFW and ODFW 2008
[c]WDFW and ODFW 2001
[d]Shaffer et al. 2007
[e]Ricker et al. 1954, Hart 1943, Hart and McHugh 1944
[f]Mills 1982
[g]Lewis et al. 2002
[h]Moody 2008
[i]Pedersen et al. 1995, Kelson 1996 (cited in Moody 2008).
[j]Lewis 1997
[k]Langer et al. 1977
[l]Franzel and Nelson 1981
[m]Flory 2008b, Berry and Jacob 1998
[n]Marston et al. 2002, Eller and Hillgruber 2005
[o]Betts 1994
[p]Joyce et al. 2004
[q]Moffitt et al. 2002
[r]Kubik and Wadman 1977, 1978, Spangler et al. 2003
[s]Barrett et al. 1984 (cited in Spangler et al. 2003).

Table A-10. Documented avian predators on spawning runs of eulachon.

Avian predator	River system			
	Twentymile River[a]	Copper River delta[b]	Berner's Bay[c, d]	Columbia River[e]
Gulls (*Larus* spp.)	X			
Herring gull (*Larus argentatus*)		X	X	X
Thayer's gull (*L. thayeri)*			X	X
Glaucous-winged gull (*L. glaucescens*)		X	X	X
Glaucus gull (*L. hyperboreus*)				X
Mew gull (*L. canus*)		X	X	
Western gull (*L. occidentalis*)				X
California gull (*L. californicus*)				X
Bonaparte's gull (*L. philadelphia*)		X	X	X
Ring-billed gull (*L. delawarensis*)				X
Terns (*Sterna* spp.)			X	
Bald eagle (*Haliaeetus leucocephalus*)	X	X	X	X
Marbled murrelet (*Branchyrhamphus marmoratus*)			X	
Cormorants (*Phalacrocorax* spp.)				X
Mergansers (*Mergus* spp.)			X	X
Grebes (*Podiceps* spp.)			X	
Scoters (*Melanitta* spp.)			X	
Loons (*Gavia* spp.)			X	
Corvids			X	
Common raven (*Corvus corax*)		X		
Northwestern crow (*C. caurinus*)		X		
Black-billed magpie (*Pica hudsonia*)		X		

[a]Spangler 2002
[b]Maggiulli et al. 2006
[c]Willson and Marston 2002
[d]Marston et al. 2002
[e]WDFW and ODFW 2001

Table A-11. Temperatures at the time of river entry and spawning for eulachon in different river systems.

Location	Temperature	Incubation time	Reference
Columbia River	6.5°–9.0°C	≈ 21 days	Parente and Snyder 1970
Cowlitz River	4.5°–7.0°C	30–49 days	Smith and Saalfeld 1955
Fraser River	4.0°–5.0°C	≈ 28 days	Hay and McCarter 2000
Fraser River	4.4°–7.2°C	30–40 days	Hart 1973
Kemano River	1.1°–6.5°C	50 days	Lewis et al. 2002
Kitimat River	4.0°–7.0°C	≈ 42 days	Willson et al. 2006, their Table 4
Nass River	0.0°–2.0°C	Unknown	Langer et al. 1977

Appendix B: Selected Accounts of Eulachon in Local Newspapers

[*Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting obvious typographical errors without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncracies of spelling and phrasing in the older works are generally preserved. Some of the excerpts are market ads.*]

Table B-1. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

Newspaper	City, state	Keywords searched	Start date	End date	Database and online URL
Oregon Spectator	Oregon City, Oregon Territory	Smelt, eulachon	2-5-1846	3-1855	Oregon Spectator Index, 1846–1855, Vol. 1 and 2
Oregonian	Portland, Oregon Territory	Smelt, eulachon	12-4-1850	1-28-1850	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Morning Oregonian	Portland, OR	Smelt, eulachon	8-19-1861	4-23-1890	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Weekly Oregonian	Portland, OR	Smelt, eulachon	2-4-1854	11-15-1862	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Daily Oregonian	Portland, OR	Smelt, eulachon	7-19-1869 8-11-1869 8-19-1869 8-23-1869 10-2-1875		Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Oregonian	Portland, OR	Smelt, eulachon	2-4-1861	12-31-1922	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db
Democratic Standard	Portland, Oregon Territory	Smelt, eulachon	8-30-1854	2-16-1859	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db
Eugene Register-Guard	Eugene, OR	Umpqua smelt	1912	2007	Online at news.google.com
Vancouver Register	Vancouver, Wash. Territory	Visual search for smelt	10-7-1865	9-14-1867	Historic Newspapers in Washington. http://www.secstate.wa.gov/ history/newspapers.aspx
			2-15-1868	3-7-1868	
			6-6-1868	0-9-1869	
Olympia Record	Olympia, WA	Smelt, eulachon	5-13-1902	1-3-1923	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db
Morning Olympian	Olympia, WA	Smelt, eulachon	3-15-1891	12-31-1922	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db
Tacoma Daily News	Tacoma, WA	Smelt, eulachon	8-25-1890	12-31-1898	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db
Bellingham Herald	Bellingham, WA	Smelt, eulachon, hooligan, candlefish	10-2-1903	12-30-1922	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db
Centralia Chronicle	Centralia, WA	Smelt, eulachon	8-1-1889	6-26-1890	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
			2-7-1902	6-13-1902	

Table B-1 continued. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

Newspaper	**City, state**	**Keywords searched**	**Start date**	**End date**	**Database and online URL**
Centralia Daily Chronicle	Centralia, WA	Smelt, eulachon	5-1-1908	1-11-1913	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
			9-2-1918	2-28-1920	
			7-14-1928	12-31-1937	
Centralia Daily Chronicle-Examiner	Centralia, WA	Smelt, eulachon	1-13-1913	12-31-1913	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
			7-1-1914	12-31-1915	
Centralia News-Examiner	Centralia, WA	Smelt, eulachon	9-23-1904	2-23-1910	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
			12-28-1911		
			10-3-1912		
			10-21-1912		
			12-29-1912		
			12-11-1913		
			4-11-1916	05-18-1916	
Centralia Weekly Chronicle	Centralia, WA	Smelt, eulachon	11-9-1910	10-2-1912	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Chehalis Bee-Nugget	Chehalis, WA	Smelt, eulachon	10-28-1921	5-24-1938	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Chehalis Bee	Chehalis, WA	Smelt, eulachon	5-21-1897		Newspaper ARCHIVE.com. http://www.kcls.org/databases/
			7-16-1897		
			7-23-1897		
Kalama Beacon	Kalama, Wash. Territory	Visual search	5-19-1871	2-10-1874	Univ. Washington Library, Microfilm A-48
Eureka Humboldt Standard	Eureka, CA	Smelt, candlefish, candle fish, eulachon	1-1-1958	05-31-1967	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Humboldt Standard	Eureka, CA	Smelt, candlefish, candle fish, eulachon	1-1-1952	12-31-1957	Newspaper ARCHIVE.com. http://www.kcls.org/databases/
Times-Standard	Eureka, CA	Smelt, candlefish, candle fish, eulachon	6-1-1967	12-31-1977	Newspaper ARCHIVE.com. http://www.kcls.org/databases/

Table B-1 continued. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

Newspaper	**City, state**	**Keywords searched**	**Start date**	**End date**	**Database and online URL**
San Francisco Call	San Francisco, CA	Smelt, candlefish, candle fish, eulachon	1895	1910	California Digital Newspaper Collection. http://cbsr.tabbec.com/
San Francisco Bulletin	San Francisco, CA	Smelt, candlefish, candle fish, eulachon	10-8-1855	12-31-1891	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db
San Jose Mercury News	San Jose, CA	Smelt, candlefish, candle fish, eulachon	11-5-1861	12-31-1922	America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db

Oregon (Columbia River)

Morning Oregonian (Portland), Saturday, 6 April 1867, p. 4, col. 2

> Smelt—Holman & Co. of the Union Fish Market have just received a fine lot of smelt, halibut, etc. They keep on hand the best and freshest fish of the season. Call on them on Washington Street near Second.

Morning Oregonian (Portland), Thursday, 9 April 1868, p. 4, col. 6

Fish! Fish!
At the Franklin Fish Market!
134 First St., Portland
Just Received Fresh from the Fisheries, Smelt by the Million

Morning Oregonian (Portland), Friday, 15 January 1869, p. 2, col. 4

New To-Day, Oak Point Smelt!
At the Franklin Fish Market, 134 First Street.
Just Received by the Str. Ranger—large supply.

Morning Oregonian (Portland), Thursday, 21 January 1869, p. 2, col. 4

Fresh Oak Point Smelt at the Franklin Fish Market by the Steamer "Okanagan"

Morning Oregonian (Portland), Tuesday, 25 January 1870, p. 2, col. 4

New Today, Fresh Smelt, Three Pounds for 25 Cents
Arrived last night at the "Union Fish Market," Washington Street between First and Second
Hotels and Restaurants Supplied Cheap—J. Quinn.

Daily Oregonian (Portland), Saturday, 28 January 1871, p. 2, col. 3

New To-Day, Fresh Smelt
A Fresh Lot Arrived Last Night for Sale at Quinn's Union Fish Market on Waddington Street.
Hotels and Restaurants Supplied at Low Rates.

Daily Oregonian (Portland), Wednesday, 1 February 1871, p. 4, col. 1

Local Brevities

> Six tons of smelt arrived from down the river on Monday night, and the market may be said to be full and terms in favor of the buyer.

Daily Oregonian (Portland), Saturday, 20 January 1872, p. 3, col. 2

Local Brevities

> The first smelt of the season appeared in the market last evening.
>
> The First Smelt at Quinn's—Quinn, of the Union Market, Washington Street, is, as usual, the first on hand with the delicacies of the season. This time he has the first catch of smelt. Call early, if you would make sure of a mess.

Daily Oregonian (Portland), Friday, 16 February 1872, p. 3, col. 3

> Smelt—Quinn, of the Union Fish Market, has sufficient quantity of smelt now to supply all demands. The prices are so low that everybody can eat 'em. … Don't go home without a mess of smelt.

Daily Oregonian (Portland), Tuesday, 8 December 1874, p. 2, col. 2

First Smelt!
The First Lot of Smelt of the Season!
At Quinn's, 3 lbs for 25 Cents

Daily Oregonian (Portland), Wednesday, 17 March 1875, p. 3, col. 3

> Smelt—the first of the season—from the Columbia River in large quantities at Malarkey's, Second Street, between Stark and Washington. Get a mess.

Daily Oregonian (Portland), Tuesday, 22 February 1876, p. 2, col. 5

Columbia River Smelt!
First of the Season of 1876
At C. A. Malarkey's New York Market, S.E. Cor. Stark and Second streets

Daily Oregonian (Portland), Friday, 25 February 1876, p. 3, col. 3

1,000 Pounds Fresh Columbia River Smelt, for Sale Wholesale and Retail by C. A. Malarkey, S.E. Corner Stark and Second streets.

Daily Oregonian (Portland), Wednesday, 1 March 1876, p. 2, col. 4

Fresh Columbia River Smelt. I received last night the largest lot that has come to market this season. 3 lbs for 25 cts. C. A. Malarkey New York Market, S. E. Cor. Stark and Second streets.

Daily Oregonian (Portland), Saturday, 4 March 1876, p. 2, col. 3

Caution.

> Fresh Columbia River Smelt. The public are cautioned against buying Puget Sound Smelt for Columbia River Smelt. Come to headquarters for the latter.

> Large lot received again last night. C. A. Malarkey, New York Market, S. E. Cor. Stark and Second.

Daily Oregonian (Portland), Saturday, 2 February 1878, p. 2, col. 3

Columbia River Smelt!
First of the Season of 1878!
Wholesale and Retail at Chas. A. Malarkey's New York Market
S.E. Cor. Stark and Second sts., Portland

Daily Oregonian (Portland), Saturday, 2 February 1878, p. 2, col. 3

Hurra! Hurra!
First Columbia River Smelt of the Season
Smelt! Smelt! Smelt!
At 5 Cents per Pound
Wholesale and Retail at Dougherty & Browne's Washington Market
Corner Fourth and Washington streets

Daily Oregonian (Portland), Thursday, 22 January 1880, p. 2, col. 3

Smelt, Smelt, Columbia River Smelt
First of the season 1880
At C. A. Malarkey's New York Market, Stark Street between First and Second

Morning Oregonian (Portland), Thursday, 5 February 1880, p. 1, col. 4

> Smelt fishermen are making good wages on the river now. Some make $40 a night with dip nets. Hapgood Cannery at Waterford has put up 8,000 pounds. There is a big run.

Daily Oregonian (Portland), Thursday, 12 February 1880, p. 3, col. 1

> Dead Smelt—A gentlemen who came up the river from Astoria yesterday, informs us that millions of smelt are dying from some unknown cause in the Columbia and floating ashore. In the vicinity of Pillar Rock the bank is lined with these little fish for some distance, and hundreds of voracious sea gulls are constantly devouring them.

Morning Oregonian (Portland), Saturday, 8 January 1881, p. 2, col. 3

Smelt, Columbia River Smelt, Season 1881
A Fine Lot just Received by C. A. Malarkey, New York Market
N.E. Corner Oak and Second Street
Country Orders Promptly Filled

Morning Oregonian (Portland), Wednesday, 27 February 1882, p. 3, col. 1

C. A. Malarkey, Second and Oak, Will Receive this Morning a Choice Lot of Columbia River Smelt.

Morning Oregonian (Portland), Tuesday, 6 March 1883, p. 2, col. 4

New To-Day, Smelt, First of the Season
At Williams & Sons General Market

Morning Oregonian (Portland), Tuesday, 13 March 1883, p. 3, col. 7

Smelt! Smelt! Columbia River Smelt!
These Most Delicious Fish Are Now Being Received by C. A. Malarkey Daily
Orders from the Country Will Be Filled Promptly.
C. A. Malarkey, New York Market, N.E. Corner Oak and Second St.

Morning Oregonian (Portland), Monday, 25 February 1884, p. 1, col. 8

Smelt, Smelt, Columbia River Smelt!
First of the season of 1884 have now arrived
Send your orders to Chas. A. Malarkey, N.W. Corner Fourth and Morrison streets

Morning Oregonian (Portland), Tuesday, 4 March 1884, p. 2, col. 4

Smelt, Smelt, Columbia River Smelt!
The Most Delicious of All Fish are Now Coming to Market
Country Customers Will Find It to their Advantage to Order from C. A. Malarkey, Fourth and Morrison sts

Morning Oregonian (Portland), Friday, 13 February 1885, p. 3, col. 1

Columbia River Smelt

> These delicious little fish have made their appearance at Astoria, and C. A. Malarkey corner of Fourth and Morrison has made arrangements to receive a full supply during the season. He expects the first lot to-day. Call early and leave your order.

Morning Oregonian (Portland), Friday, 13 February 1885, p. 3, col. 3

Local and General

> The Little Fish Coming—Polish up your frying pan, for Malarkey says he is going to have Columbia River smelt to-day. These little fish have become of considerable importance to fishermen and several boats have been kept on the lookout for their advent for the past two weeks. The advance guard of the immigration came up the river a little way some days since, but smelling the snow

in eastern Oregon, took a wheel back. The ones behind are shoving on the ones before, and countless millions of smelt are crossing in over the bar, anxious to reach the Cowlitz or the Sandy.

Oregonian (Portland), Wednesday, 25 February 1885, p. 3, col. 1

Brief Mention

Considerable anxiety has been expressed about the Columbia River smelt fleet now overdue here and anxiously awaited by all good citizens. It is now stated that the smelt are hovering off the bar waiting for a pilot.

Oregonian (Portland), Friday, 27 February 1885, p. 3, col. 2

Fish In Supply. … The first box of Columbia River smelt, so long looked for, was received by J. W. and V. Cook last evening. It contained about 20 pounds—the result of a night's fishing by five men. There will be plenty in a few days, sure.

Daily Oregonian (Portland), Friday, 13 March 1885, p. 3, col. 2

Local and General

No Hope For Smelts—Fishermen generally have about given up hope of a smelt harvest this year. In speaking of the matter yesterday, a pioneer, who resided for many years on the lower Columbia, says that there were no smelt or oolachan, as they were called by Indians, in the Columbia from the time he came here till in 1863, when they appeared in vast numbers about the middle of February, and have been plentiful every season since. In Irving's "Astoria" mention is made of the great quantities of smelt in the Columbia in 1826. Shortly after they forsook the river entirely and did not return till 1863, having been absent nearly 40 years. It would be interesting to know why the smelt deserted the river and in what ocean wilderness they wandered all these 40 years. If they have gone again to stay 40 years, most of us may as well say good-bye to them for we'll eat no more Columbia River smelt unless the doctrine of transmogrification is true, in which case if a fellow is changed into a seal or a sturgeon he may have a chance at them once more.

Morning Oregonian (Portland), Sunday, 31 January 1886, p. 5, col. 1

There is a great rivalry just now among the fish dealers. The first smelt are now in the market. Malarkey went down the river yesterday, met the steamer as she was coming up and secured all the smelt, which were piled up last night triumphantly on his tables.

Morning Oregonian (Portland), Tuesday, 2 February 1886, p. 3, col. 1

Wm. McGuire & Co., corner Third and Morrison streets, corralled all of the smelt that came to town yesterday, consequently they have the only fresh smelt in the city. They received 25 large boxes—over 4,000 pounds—and are prepared to furnish everybody at reasonable prices. They are prepared to fill all orders from the country at lowest rates and guarantee perfect satisfaction. Send in your orders. Telephone 371.

Morning Oregonian (Portland), Sunday, 7 February 1886, p. 5, col. 6

Columbia River Smelt

Wm. McGuire & Co., Third and Morrison, have made arrangements to receive large supplies of fresh smelt daily and are prepared to fill all orders from the country at lowest rates. Send in your orders early.

Morning Oregonian (Portland), Tuesday, 10 February 1886, p. 2, col. 4

Smelt And Salmon

Columbia River smelt and genuine Chinook salmon received daily and for sale in any quantity from one pound to one ton by C. A. Malarkey, corner of Fourth and Morrison streets.

Morning Oregonian (Portland), Saturday, 11 December 1886, p. 5, col. 1

The first Columbia River smelt of the season came up yesterday to George Ginstin, of the Baltimore Market, No. 290 First.

Morning Oregonian (Portland), Wednesday, 19 January 1887, p. 3, col. 2

Local and General

A Few Good Fish— … Vin Cook says they had a mess of Columbia River smelt down at Clifton the other day, but have not been able to catch any since. It will not be long till these delicious little fish are here.

Oregonian (Portland), Friday, 28 January 1887, p. 3, col. 2

Local and General

Fish In Demand— … while [another fisherman] proudly exhibited a sample of genuine Columbia River smelt. Vin Cook has a party on the lookout for the arrival of these anxiously awaited little fish, and they yesterday sent him up several pounds. The advance of the main school of smelt may be expected any day now. It was about this time last year that the first shipment came up.

Oregonian (Portland), Thursday, 24 February 1887, p. 5, col. 2

Local and General

Fishing For Smelt—No doubt many people once in a while give a thought to the Columbia River smelt, which would have been in market before now but for the cool spell, but probably very few have any idea of the number who are keeping a sharp lookout along the Columbia for the advent of these little fish. Although the Columbia from the mouth of the Willamette for a long way up has been frozen for some time and there has been snow all along down the river, not a day has passed for the last three weeks but what seines have been put out and dip nets plied at various points in vain search for the smelt. At Oak Point two men in the employ of a fish dealer here have been going out twice every day for the past three weeks and probing the Columbia with dip nets, but nary a smelt have they caught. As the ice is now going out the fish may be expected any day.

Morning Oregonian (Portland), Monday, 1 March 1887, p. 3, col. 4

Fish dealers were all on hand when the [steamer ship] Telephone arrived yesterday, expecting to see a shipment of Columbia River smelt. They were disappointed, but the little fish will be here soon or not at all.

Morning Oregonian (Portland), Saturday, 5 March 1887, p. 3, col. 3

Brief Mention

The prospect is that we are to have no Columbia River smelt this season.

Oregonian (Portland), Wednesday, 9 March 1887, p. 3, col. 3

Local and General

Coming Up on the Rise—People had about given up all idea of seeing any Columbia River smelt this season, but it appears that they have not deserted us but were only lying off the mouth of the river waiting for the water to become decently warm in order to swarm to their spawning place in the Cowlitz and Sandy. Deep sea fishermen at Astoria report that the cod and groupers caught by them of late have been literally filled with smelt and they predict a large run. The late heavy warm rains have put the schools a motion and in a few days it will perhaps be possible to walk across the Sandy on the backs of the smelt. …

Smelt at Last—Late last night McGuire & Co., fish dealers, corner o' Third and Morrison streets, received a telegram from down the river stating that several boxes of Columbia River smelt would arrive on the [steamer ship] Telephone today for them. These will be the first smelt of the season and as the steamer will arrive about 2:30 everybody can have smelt for dinner by leaving orders early today.

Morning Oregonian (Portland), Thursday, 10 March 1887, p. 5, col. 3

Local and General

The Smelt Here—The first lot of smelt of the season arrived on the [steamer ship] Telephone yesterday, and very fine they were, being much larger and plumper than the first to arrive usually are. A number of them were evidently caught by Indians in the old-fashioned way by sweeping a stick armed with sharp pointed nails through the water and impaling the smelts thereon.

Morning Oregonian (Portland), Friday, 11 March 1887, p. 3, col. 3

And now the smelt come in earnest. C. A. Malarkey came up the river last evening having secured the entire catch of these delicious fish along the Columbia for the day some two tons in all. He is prepared to furnish all both great and small, and as he has the only smelt in the city orders should be left early this forenoon.

Sunday Oregonian (Portland), 26 February 1888, p. 5, col. 3

Fish and Fishing

… The smelt season is about over apparently. They have not come above the Cowlitz as yet, and are not likely to visit the Sandy this season. They have gone so far up the Cowlitz now that there is trouble to get them and boxes of them which a few days ago could be bought for 50 cents have jumped to $3.

Sunday Oregonian (Portland), 11 March 1888, p. 5, col. 2

In and About Portland

Large quantities of smelt still continue to be sent up from the Cowlitz. Nothing has been heard of them reaching the Sandy yet.

Morning Oregonian (Portland), Thursday, 13 December 1888, p. 8, col. 1

Picked Up About the Town

The First, Lone Smelt—Mr. Calper, who has a salmon fishery on Lewis River, a day or two since caught a fine large Columbia River smelt, which in some manner became entangled in his net. This is the first smelt of the season, and it comes to hand unusually early, as they generally put in an appearance some time in February. It is also a little strange that the first smelt heard from should be taken in Lewis River, as for the three past seasons the shoals of these fish have not come any farther up than the Cowlitz. It will hardly be worth while for our epicures to make up their mouths for smelt yet awhile. One swallow does not make it summer, nor does one smelt make it spring, and in all probability we shall have a cold snap before we shall see smelt in the market.

Morning Oregonian (Portland), Thursday, 27 December 1888, p. 5, col. 2

Portland and Vicinity

Smelt for Christmas Dinner—Last evening a gentleman marched into the reporter's room of The Oregonian office and left a parcel with the compliments of Vin Cook. On opening the package it was found to be a cigar box filled with genuine Columbia River smelt, which glistened in the lamplight like silver. A short time since a notice was published in The Oregonian of a single smelt having been caught by Mr. Calper in his salmon seine in Lewis River. Mr. Cook, who is at Clifton, seeing this, sent out a boat to drift for smelt and enough was caught to make a course for the Christmas dinner for all hands at Clifton and some left to send to The Oregonian. It is hardly probable that any one in this region ever had Columbia River smelt for dinner on Christmas before. The smelt usually arrive in February and what they mean by coming so much earlier than usual this year it is impossible to say. They have some queer ways, as only a few years since they forgot to come up entirely. It may be that they have had some premonition that there would be no winter this time and if so the chances are ten to one that they will find themselves fooled. If the weather should "come off" warm with rain it is not unlikely that there will be smelt in the market very soon.

Morning Oregonian (Portland), Saturday, 12 January 1889; p. 8, col. 1

Gathered by Reporters
First Shipment for the Season of Columbia River
Smelt Quickly Disposed Of

Nothing Too Rich For Us—The first shipment of Columbia River smelt of this season arrived here yesterday. There were only 35 pounds of them, and they were all disposed of by McGuire & Co. before they arrived for 50 cents per pound, that being the price fixed by the fishermen, who have been out drifting for several nights in hopes of making a haul. The price made no difference, and many more could have been sold. Wealthy people at the East think nothing of paying a dollar a pound or more for the first salmon or trout of the season, and our wealthy people are not going to be left on the first Columbia River smelt, no matter what the price is.

Morning Oregonian (Portland), Thursday, 21 February 1889, p. 5, col. 1

Columbia River Smelt—Columbia River smelt are coming in plentiful and Malarkey & Co., corner of Fourth and Morrison streets, have enough to supply everybody at cheaper prices than ever before. The run will not last long and if you want a mess of these delicious little fish now is the time to get them. This firm makes a specialty of shipping these fish and orders from the country for any quantity will be promptly filled.

Morning Oregonian (Portland), Friday, 22 February 1889, p. 4, col. 3

Smelt, Smelt

Columbia River Smelt are now growing plentiful and cheap. Parties wishing to procure smelt for salting down can buy them by the box at a low price. Remember that the run lasts but a short time. Malarkey & Co., Fourth and Morrison streets.

Morning Oregonian (Portland), Wednesday, 18 December 1889, p. 6, col. 7

The Very First of the Season
A Small Lot of Smelt Have Put in an Appearance in the City

A small lot of genuine Columbia River smelt were displayed at C. A. Malarkey & Co.'s market yesterday. They were, it is needless to say, the first of the season, and as the fisherman who sent them up wrote, "they are the earliest smelt that ever went into Portland market." J. B. Johnson captured them near Quinn's Landing, and the 25 pounds represent three night's work out in the cold. He has got ahead of Vin Cook this year, and broken the record, for no living man has ever seen Columbia River smelt here so early before. They generally arrive about the 1st of January, and when they come it is considered that winter is over. Many who saw the smelt yesterday, said "well winter is over," but it is more probable that the smelt have made a mistake. Many things have been mentioned as tending to indicate that we are to have a hard winter, but the arrival of these smelt is the first thing which seems to indicate that winter is over, and we might as well cling to the hope till it is dispelled.

Morning Oregonian (Portland), Monday, 23 December 1889, p. 5, col. 1

Something about Early Smelt—Mr. James Quinn, formerly a well-known resident of this city, but for years a resident at Quinn's Landing on the lower Columbia, demurs to the statement published in these columns a few days since, to the effect that some Columbia River smelt received here on that day were, as the man who caught them claimed, the earliest smelt ever seen in the Portland market. Mr. Quinn says he had fresh Columbia River smelt in his market on Washington Street, on the 8th of December, 1869. From this it appears that Mr. Johnson in 1889 was 10 days behind Mr. Quinn in 1869 in getting smelt to this market. It is the belief of many fishermen that smelt and Chinook salmon both are in the river all winter, and could be taken if fished for, but the game would hardly be worth the candle.

Morning Oregonian (Portland), Friday, 22 January 1892, p. 5, col. 2

The Smelt as a Weather Prophet—The shoals of smelt which have been in the Columbia River for the past month or six weeks have struck into the Cowlitz. Over a ton of these fish were sent up from the Cowlitz Wednesday evening, and it was supposed that they would continue to be plentiful, but the next day only a small lot arrived, and it is feared that the shoals will soon go up the river out of reach, and the smelt season will be over. The fact that the smelt have started up for their spawning grounds is considered by many to indicate that winter is over. It is scarcely probable that there will be any ice or snow this winter.

Morning Oregonian (Portland), Monday, 28 November 1892, p. 6, col. 2

Columbia Smelt. An Unusually Early Catch of the Dainty Little Fish

A lot of Columbia River smelt were received in this city Saturday, and very fine ones they were. This is the earliest time of year that smelt have ever been caught. They were taken by J. B. Johnson, near Eagle Cliff, and the first sales were made at 75 cents per pound, which is the highest price ever paid for the delicious little pan fish.

The Columbia River smelt did not put in an appearance formerly, as a general thing, till about the 1st of February, and if there happened to be a cold winter and ice in the Columbia, they did not materialize until after the ice had gone out, when they arrived in the Cowlitz in immense shoals, and shortly after in the Sandy in like numbers. For several years past fishermen have been using dip nets in the Columbia, searching for smelt, and last year and the year before at Christmastime they caught small lots right along. The first man who got a shipment into market received a high price, as every market man was anxious to have the first lot, which he had no trouble in disposing of at 50 cents per pound. The price would soon drop to 25 cents, then to a bit, and when the shoals of fish got into the Cowlitz they would sell for 5 cents. Soon they would be shipped all over the country, and then there would be many more smelt than could be got rid of at any price.

The fact that the smelt were to be found in the river in December led some to imagine that they were there all winter, staying in deep water. If such is the case, Mr. Johnson, who made this early catch and broke the record, has probably found one of their haunts. Some people think that the freshet in the Columbia—if a rise of five feet at Vancouver can be called a freshet—has brought the fish up the river. There is no probability, however, of their going up the Cowlitz to their spawning grounds till the snow is gone out of the mountains at the headwaters of that stream.

The Columbia River smelt is what is called farther north the oolihan, or candlefish, and is esteemed as one of the most delicious little fish caught. Salmon and trout have no superiors in their season, but the smelt comes at a season when other fish are scarce, and so is most esteemed. If it is going to come at this season and mix itself up with Sound smelt and all the other fish in the market, its good qualities will have to submit to the test of comparison.

Morning Oregonian (Portland), Monday, 1 January 1893, p. 5, col. 1

Smelt Have Returned—The Columbia River smelt, which arrived earlier this season than ever before so far as known, and were well along on their way up the

Cowlitz River to their spawning grounds when the snow storm came on and drove them back, have re-entered the Cowlitz and will for a time be plentiful in the local market. They re-entered the Cowlitz last Friday, and a man who happened to be loafing along the bank of the river saw them pouring up the stream in a solid column about two feet in width. He hastily secured a dip net, worked with a will for two hours, caught the boat coming to this city and sold his catch for $25. He was much elated with his success, and expressed his intention of devoting the remainder of his life to fishing.

Morning Oregonian (Portland), Wednesday, 2 January 1895, p. 9, col. 1–2

Great Quantities of Smelt

The Columbia River smelt, the most delicious of panfish, during the past year commenced coming to market in October, more than a month earlier than ever known before. Small quantities have been received almost daily ever since, but within the past week the shoals have entered the Cowlitz River, on their way to their spawning grounds, and they have been taken in large quantities. The change in the weather has been so slight as hardly to check them, although ice or snow might send them back into the deep waters of the Columbia. With the first rains, the immense shoals of these fish will swarm the Cowlitz and tons of them will be coming to market, and they will be shipped to all parts of the country. No method has yet been discovered of preserving the delicate flavor of these fish, which are so fat as to be known to the Indians as the candle fish. Large quantities might be put up yearly if any process could be discovered which would preserve their good qualities.

Morning Oregonian (Portland), Thursday, 28 March 1895, p. 8, col. 3–4

The Big Run of Smelt

The enormous run of smelt in the Sandy River is attracting wide attention. If all the statements of those who have been out there are true, and they seem to be verified by the wagonloads of smelt taken, the run is the biggest that has been seen in the Sandy for the past 15 years. When the O. R. & N. railroad was in course of construction, and there was a large encampment on the river, the water suddenly came alive with the fish, and the railroad employees feasted on smelt for several days. Great wagonloads were taken. The next run occurred six years ago, it is claimed by those who know, but the run was comparatively small, and was soon over. There are now hundreds of people catching smelt by the tons. A wagon may be filled in half an hour. The wagon is driven into the shallow water, and the fish are scooped into the wagon by means of a small scoop net. It is stated some of the farmers are catching the fish in wagonloads and distributing them over their farms for fertilizing purposes, where some are smoking them, and many are being packed in salt. The fish move along close to the shore. The females come with the first run, and the males afterward. One can put his hands in the water and feel the fish bumping against them. Mr. Joseph Paquet was down the river several days ago and saw indications that the fish were going up the river. They were followed by droves of seagulls, watching, apparently, to catch the fish which happen to come near the surface. They were on the way to spawning-ground. The habits of the smelt are rather peculiar. They have usually appeared in the Cowlitz River, and not in the Lewis River, but this year they have entered the Lewis and very few in the Cowlitz. The run went on past the Willamette and entered the turbid and always discolored waters of the Sandy River. W. F. Allen, who was on the Sandy in all the smelt runs for the past 30 years, will go out today and see how the present run sizes up with what he saw in the long ago.

Morning Oregonian (Portland), Monday, 1 April 1895, p. 5, col. 4–5

All Fished for Smelt
Large Number of Portlanders Visit the Sandy to Enjoy the Sport

The banks of the Sandy River for many miles were the scene of great activity all day yesterday, made so by the presence of hundreds of pleasure seekers, bent upon catching smelt or watching others catch them. A gentleman who has made a careful estimate, from personal observation, states that the catch during the week has fully averaged 100 tons per day. It is thought that this run is the greatest that has occurred for over 30 years, and of the longest duration. The runs do not usually last over five or six days, but the fish were still running very thick yesterday, the eighth day. It is thought the run will now dwindle down, as all fish now going up are males. The females go up to the spawning grounds first and they are followed by the males. It is inferred that the run is almost over, as the males have already been running since the middle of the week. As far as could be ascertained yesterday no females were caught, all being males, very firm and plump. A few of the fish gave evidence of some hard knocks during their trip up the river. If the gentleman who estimated the catch at 100 tons a day is right the entire catch during the run will foot up a 1,000 tons.

All yesterday vehicles of every sort, loaded with families, well supplied with boxes and sacks and dip nets, prepared to catch smelt, poured to the banks of the Sandy. The favorite place was at the county bridge. The river has here cut a deep channel through the slightly wooded uplands, and winds its sinuous ways like a thread of silver to blend with the majestic Columbia, a few miles below. Where the bridge spans the river there is a sort of open space, and to the southeast the river makes a gentle curve, sweeping around a gravel and sandbar of about five acres in extent. A full view of the bridge and surroundings may be had from the county road to the westward, just before it plunges down a winding grade to the bridge. The gravel was covered with fishermen and women, both great and small. With long poles, on which were suspended dip nets made of most anything that will allow the water to run off, they were constantly dipping out the sluggish smelt. Toward the point of the gravel bank, which the water sweeps around swiftly, a dozen or more of wagons had been backed into the stream up to the hub, and these were being filled by means of nets of larger size. It was an interesting sight to see these wagons fill up and others take the place. The men swung the nets with monotonous regularity, and rarely ever failed to bring up from a dozen to half a dozen wriggling fish. The smelt seemed to run around this point in more condensed bunches than below, along the margin of the gravel bank. The experienced fisherman was provided with a sort of metal funnel, well perforated with holes, on the end of a light pole, about eight feet long. But it was comparatively an easy matter to catch in a few minutes all anyone would care to take of them.

From a sportsman's point of view the taking of fish in this manner cannot be regarded as very exhilarating exercise, still it is a sort of change. One good thing about it is that no one went home without a fine string, or rather sack of fish. The smelt caught in the Sandy were very plump and firm. At this time of year the river is very clear and cold. Evidence of prodigality and waste was apparent from the piles of half-dried fish near the bridge. And yet, with all the millions which were taken from the river, millions went on to the spawning ground. On their return trip they keep well in the center of the river and move faster than when on the way up.

A large number of people went out from the city in carriages and on bicycles merely to see the fishing. It was a day that will not soon be forgotten in the interior of the county, and if there is a family within 10 miles of the Sandy that has not had a feast of fish last week, it has not been because they could not be had in unlimited quantities.

Morning Oregonian (Portland), Wednesday, 4 December 1895, p. 12, col. 3

First Smelt Arrive
But They're Mighty Dear—Wait, and They'll Soon Be Cheaper.

Among the various species of fish which form the great harvest of the mighty Columbia, none is more eagerly looked for or more highly appreciated than the smelt, the Columbia River smelt, or "candle-fish," being considered by many people of this section the prince of all pan fish. Ten or a dozen years ago, they did not appear in this market as a general thing till after the cold weather was past, in February or March, or as soon as the main school began crowding up the Cowlitz and other tributaries of the Columbia to their breeding grounds. Of late years fishermen have taken to fishing for them with seines in the Columbia, and it has been found that they are in the river nearly all winter, and year after year they have been coming earlier and earlier to market, the fishermen who gets in the first lot reaping a rich reward for his trouble. The first lots have sold for 50 cents per pound, and, as they become more plentiful, the price goes down to 25 cents, then to 15 cents, and finally to 5 cents, when they come in by scores of bushels at a time, till finally they are so plentiful that there is no sale for them.

Last year the smelt arrived just before Christmas, and the run lasted a long time, the quantity of little fish disposed of here being probably much greater than in any previous year and yielding a handsome return to the fishermen. This was the earliest the smelt ever came to market; but the record has been beaten this season, as a small lot, just a few pounds, were received here yesterday. This is positively the earliest arrival of smelt known, and unless freezing weather comes on and drives them back, or to the bottom, it may be expected that the fish will soon arrive in quantities. They were held at 75 cents per pound, as they were looked upon more as a curiosity than as an article of merchandise.

The sturgeon, which, until within the past year or two, thronged the Columbia and devoured enormous quantities of smelt, are now very scarce, and this will probably result in an increase in the shoals of smelt, which, however, have always been immense.

Morning Oregonian (Portland), Tuesday, 29 December 1896, p. 9, col. 4

The Story of Smelt
How It Is Mentioned by an Early Visitor to Oregon

A gentleman of this city, who has a copy of "Francheve's Narrative," which is the diary of Gilbert Francheve [Franchère], of Montreal, who was a clerk in the trading company of John Jacob Astor, and who visited the Columbia in 1811, is of the opinion that Francheve makes the first mention of the Columbia River smelt. He says:

"February brings a small fish about the size of a sardine. It has an exquisite flavor, and is taken in immense quantities by means of a scoop net, which the Indians, seated in canoes, plunge into the schools, but the season is short, not even lasting two weeks."

The season for smelt has grown much longer within the past few years, since fishermen have made it a business of going out hunting for the advance guards of the schools. Some years since, they were seldom seen in market until February, when the great schools began pushing their way up the Cowlitz and Sandy to their spawning grounds, and in a short time the run was over, or the fish had become soft and not fit for food. Last year the first smelt caught in the Columbia in drift nets came to market in December, and the season lasted nearly three months, the fish being good all the time till after they were well on their way to the spawning grounds.

It is probable that mention has been made of the vast schools of smelt entering the Columbia before Francheve [Franchère] wrote his diary, as the smelt were always here, and the earliest residents along the river have described how the Indians caught them by means of a long rod, through which nails had been driven, forming a sort of comb, or rake, which they moved swiftly through the schools of smelt, bringing up many impaled upon these nails. Smelt fishing now brings in considerable money to the fishermen, owing to the greater length of the season. Late in the season the price gets very low, but then the only limit to the catch is the amount that can be disposed of. Many are salted by farmers along the river, and some are smoked, but the fish is best in a fresh state, and for the pan has no superior on the coast.

Morning Oregonian (Portland), Saturday, 7 December 1907, p. 12, col. 1–2

Good Things in Portland Markets, by Lilian Tingle

> Columbia River smelt cost 50 cents [per pound].

Morning Oregonian (Portland), Saturday, 14 December 1907, p. 12, col. 1–2

Good Things in Portland Markets, by Lilian Tingle

> Columbia River smelt … are 20 to 25 cents per pound.

Morning Oregonian (Portland), Saturday, 29 February 1908, p. 5, col. 1–2

Good Things in Markets, by Lilian Tingle

> I saw even more varieties of fish in the market than there were last week. Columbia River smelt were 12½ cents a pound, and scarce at that, when I inquired about it, but more may be in today.

Morning Oregonian (Portland), Saturday, 7 March 1908, p. 12, col. 1–2

Good Things in Markets, by Lilian Tingle

> Columbia River smelt was selling at two pounds for 25 cents ….

Morning Oregonian (Portland), Saturday, 19 December 1908, p. 10, col. 2

What the Markets Offer, by Lilian Tingle

> Columbia River smelt are more plentiful and are to be had at a reasonable price.

Morning Oregonian (Portland), Saturday, 24 December 1908, p. 15, col. 2

What the Markets Offer, by Lilian Tingle

> The cold weather has kept the price of Columbia River smelt up to 30 and 35 cents a pound.

Morning Oregonian (Portland), Saturday, 9 January 1909, p. 8, col. 2

Good Things in Markets

> Columbia River smelt was about 10 cents a pound yesterday, but the supply is of course affected by the weather.

Morning Oregonian (Portland), Tuesday, 2 February 1909, p. 9, col. 2

> The Run Is On—Fresh Columbia River smelt, 5 cents a pound. Maces Market, 151 Fourth Street.

Morning Oregonian (Portland), Saturday, 13 February 1909, p. 12, col. 4

Good Things in Markets

> Columbia River smelt was selling at 4 and 5 cents a pound earlier in the week, but cost 7 to 10 cents when I inquired; and no man would risk a statement as to whether it was likely to be down again today or up higher.

Morning Oregonian (Portland), Friday, 24 December 1909, p. 10, col. 2

Good Things in Markets

> The fish market is exceedingly well supplied with the sea dainties for which Portland is famous … Columbia River smelt, 40 to 50 cents [per pound].

Morning Oregonian (Portland), Saturday, 12 February 1910, p. 12, col. 2

Good Things in Portland Markets, by Lilian Tingle

> Columbia River smelt may be considered the most interesting feature of the market this week, of interest alike to epicure and economist. At 5 cents a pound, or six pounds for a quarter, this dainty fish is within the reach of everyone. Many thrifty housekeepers take advantage of the season of plenty, and buying smelt by the box at about 3 cents a pound. Proceed to secure inexpensive future breakfast or luncheon dishes by salting, smoking, pickling or canning this “violet of the waters.”

Sunday Oregonian (Portland), 13 February 1910, p. 9, col. 4–5

Smelt Cannery Offered
Kelso Owners Seek Someone to Operate Plant
Heavy Catches Are Accompanied by No Diminution of Supply—Cowlitz Yields Well

> Owners of an idle canning plant in Kelso are seeking someone who will engage in the packing of Columbia River smelt in that city.
>
> F. L. Stewart, a banker of Kelso, who is in Portland, expresses the conviction that the opportunities are good for using the plant for smelt canning in winter and fruit and vegetable canning in the spring and summer. The cannery was started as a cooperative venture, but has been idle about two years.
>
> Although the smelt, now so generously in the Portland markets, bear the name “Columbia River,” the great preponderance of them is taken in the vicinity of Kelso from the Cowlitz River. Kelso this season has shipped out approximately

15,000 boxes. Each box contains 50 pounds and the fish average eight to the pound. The catch, so far, therefore represents approximately 6,000,000 fish.

In spite of the heavy catches there is apparently no diminution in the yearly runs of fish and at the height of the season they get down to a low figure.

At the beginning of the present season fishermen got $3 a box for the first run, but the price, as the run increased, dropped rapidly until now the fishermen realize about 25 cents a box. Last year the price went as low as 15 cents. The largest catch reported this season was 45 boxes, taken between 7 and 11 a.m., by two men in one boat.

Some of the residents of Kelso smoke the fish as they would herring and find that smoked smelt are a delicacy. The cannery plan, however, would be to put them up in form similar to sardines.

Morning Oregonian (Portland), Thursday, 17 February 1910, p. 8, col. 4

Cowlitz Full of Smelt
Big Run May Presage Prosperous Salmon Season Later On

Astoria, Ore., Feb. 16—The largest run of smelt for years in the Cowlitz River is now in progress. The river has never been known to contain so many smelt in the memory of the oldest fisherman.

This may bode good for the coming fishing season in the Columbia, as it is said that a good run of smelt has always been followed by a good run of salmon.

Sunday Oregonian (Portland), 27 February 1910, Section 5, p. 8

Smelt Fishing on the Cowlitz
How an Army of Men Catch the Biggest Run Known in the Last 20 Years
By R. G. Callvert

A hobo the other day wandered along the fringe of the riverbank that lies between the floating docks and the railroad track at Kelso, picking up discarded smelt for an easy meal.

"Here, drop those rotten fish and come down and get some fresh ones," shouted a fisherman from a float where smelt were being packed into boxes for shipment.

Discarded fish may look good to a tramp in most countries, but in Kelso during the smelt run only a stranger with a most aggravated antipathy to exertion need go without the freshest product of the Cowlitz River.

Had the tramp known it and been inclined toward the effort, an old can tied at the end of a stick plunged into the water from a nearby log boom would have brought him up in one sweep all the smelt he could eat in a day. Or by lying on the log boom he could have pulled out enough fish with his bare hands for a square meal.

There is not much romance connected with the taking of the smelt that are so plentiful in the markets of Portland and the Northwest during four or five months of each winter. There is no battling with waves and storms such as are encountered by the hardy herring fishermen of the Atlantic. For the sportsman, smelt fishing would be just about as exciting as clam digging and the amount of skill required about the same. Smelt fishing furnishes tales, however, that are novelties among fish stories in that while almost unbelievable they are nevertheless true.

During the smelt runs fish are so plentiful that even the voracious seagull becomes almost sated. When the gulls are at all hungry the fishermen sometimes find amusement tossing smelt into the air, which the birds catch before they reach the water. A seagull on the wing will seize a fish perhaps by the tail and reverse it with a toss in the air and gulp it head first in the twinkling of an eye.

So plentifully do the smelt run that frequently children bail them out of the water with tin cans securing half fish and half water. When the water is shallow enough the smelt can be taken with the bare hands, for the skin of the fish is not slimy when in the water.

While the Cowlitz River is the only known spawning ground for smelt where the fish may be taken year by year, they have been known to run up the Lewis River and also up the Sandy. At the time the smelt ran up the Lewis River, 14 years ago, there was only a small run of male smelt in the Cowlitz and the fishermen transferred their operations to the Lewis. When smelt run in numbers up the river it is apparently independently of the Cowlitz run and it is said to occur in the Sandy about once in eight years. It is truthfully related that at the time of the last run up the Sandy a party of Portland young men went out with dip nets on a fishing expedition. One man lost his dip net, but luckily found an old, rusty, discarded birdcage. This he attached to the end of a pole and successfully kept pace with his more fortunate companions. This is the only record in fishing annals of successful fishing with a birdcage, although if the novelty of the experiment invites one it can undoubtedly be successfully duplicated in the Cowlitz River any day between now and April 1.

During the last big smelt run in the Sandy farmers drove their wagons to stream, filled them with dip nets and used the fish for fertilizing fruit trees. An unusually large quantity of pork with a fishy taste sold in the markets some months afterwards revealed the fact that some of the farmers had utilized the fish surplus in feeding their hogs.

This season the Cowlitz River is the spawning ground of the greatest run of smelt ever known by fishermen who have been engaged in the business for 20 years. It is now estimated that by the close of the season the river will have yielded 300,000 boxes of smelt, each box weighing 50 pounds. This will represent an output of 10,000,000 pounds or 5,000 tons and a smelt average about eight fish to the pound means the marketing of 80,000,000 fish.

The smelt has peculiarities of his own, as pronounced as those of the salmon. What is known commercially as the “Columbia River smelt” is caught in paying quantities regularly year by year only in Cowlitz River, which is a tributary of the Columbia River rising in the State of Washington.

The main fishing grounds of the river extend over an area during the season of not more than eight or 10 miles as a rule. Like those of the salmon the smelt runs come in from the sea through the mouth of the Columbia River. In the earliest catches, when smelt bring from $3.50 to $3 per box, the fish are taken in limited numbers in the Columbia.

In the Columbia some fish are caught in the early season by gillnetters, but when the season is well along the gillnetter cannot compete with the regular smelt fisherman, for the former has to pick the fish out one by one from the meshes of his net. The latter uses a dip net attached to a long pole, and after locating a school of fish simply bails them out of the river and into his boat, sometimes getting as many fish as he can lift out of the water.

The smelt lie in schools close to the bottom of the river and are therefore found at varying depths. The fisherman prospects for the schools with the reverse end of his pole, and if the end of the pole is plunged into an accumulated number of fish, the wriggles of the small bodies that results is communicated to the hands of the fisherman.

Most of the fishing is done at night, for the light of day seems to scatter the fish, yet even in daylight hours the fishermen are able to pursue their occupation with good results.

Before Kelso accumulated a variety of industries along its waterfront, one of the best fishing points was opposite the Northern Pacific depot, from where one can toss a stone into the water. The driving of piles, however, seems to have driven the fish farther up the stream, and this season they have been found most plentifully about one and one-half miles above the town. Between the small floating docks and the fishing grounds boats are continually plying, going upstream empty and returning ladened with fish. Fully 500 boats are utilized in the industry and of these about 75 are powerboats.

As a rule there are two men to each boat and the crafts are filled in almost an incredibly short space of time. Last Tuesday night J. A. Sprague, one of the principal shippers of Kelso, and one companion loaded his launch to its capacity in 45 minutes. This represents a catch of 45 boxes, or one 50-pound box a minute. Last year a catch of 125 boxes for two men held the record for a night's fishing. This year there have been frequent occasions when two men brought in 200 boxes to represent a day's work.

To the ordinary fisherman who has no regular market to supply, a catch of 200 boxes of smelt in the height of the season is worth about $50. On the Cowlitz River; however, there are a number of men who ship direct to retail markets, maintain boats of their own and buy from other fishermen. Portland wholesalers have buyers at Kelso and probably the greater portion of the retail trade is supplied through Portland. At Kelso, however, smelt have been shipped direct as far East as Wisconsin.

The output of the river, say the fishermen, could be greatly increased if the market demands were sufficient to justify more men engaging in the industry. Kelso has no facilities for shipping fish in cold storage. A cold storage plant is one of the enterprises the town wants, for it is believed that the market can be broadened and a demand created in the Far Eastern states. Canning in the form of sardines is also suggested, and in Kelso there is a cannery that was utilized as a cooperative plant by fruit and vegetable growers until last year, that will be turned over to any experienced man who will engage in the business.

Kelso has a group of enterprising citizens who have done much to build up the town to its present population of 2,800. Practically the same group of businessmen established the electric light plant and city waterworks, built a $15,000 opera house, erected a drawbridge across the Cowlitz River, which they afterwards sold to the county, established a newspaper office, invested in the cooperative cannery mentioned and have aided and encouraged several other enterprises.

They are now seeking to put the smelt fishing on a basis where it will pay better returns to the fishermen and increase the number of men engaged in the industry. This effort is apparently justified, for though the output of smelt is slowly growing year by year, the increasing inroads upon the schools of fish do not seem to diminish their number.

Cowlitz River fishermen are now advocating the licensing of persons engaged in commercial smelt fishing. Frequently, during the season, schoolboys will go out, load up a few boats with fish and become easy marks for the buyers. The result is a demoralizing market, the boys being content with enough money to buy candy or a few toys. Often too, groups of Greeks or Italians will come up the Cowlitz in boats, remain at the fishing grounds for a few days and sell their catches for whatever they can get, again upsetting the prices paid the regular fishermen. The men who are regularly engaged in the industry want the protection of a reasonable license, which, they believe, will cut out the itinerant fisherman.

It is a saying among fishermen that a big run of smelt presages a big run of salmon. If this is true, the salmon fisheries of the Columbia should have a prosperous season this year, for the smelt run is unprecedented in volume.

Morning Oregonian (Portland), Thursday, 8 December 1910, p. 21, col. 6

Smelt in the River
Good Hauls Looked For in about 10 Days

Astoria, Ore., Dec. 7— … Two days ago a few smelt were seen at the mouth of Grays River, showing that they are beginning to come in, and good hauls of this class of fish may be looked for in about 10 days or two weeks.

Morning Oregonian (Portland), Thursday, 5 January 1911, p. 21, col. 1

Run of Smelt is Small

Astoria, Ore., Jan 4.—(Special)—Quite a few smelt have been caught during the last few days in the vicinity of Clifton, but none has been taken as yet in the Grays River. It is said the water in that stream is too low and a freshet must come before the smelt will be attracted that way.

Morning Oregonian (Portland), Saturday, 7 January 1911, p. 12, col. 4

Good Things in Markets

Columbia River smelt, though less costly than on its first appearance, sold yesterday at 25 cents a pound, but will probably soon reach the lower prices we are accustomed to.

Morning Oregonian (Portland), Saturday, 11 February 1911, p. 8, col. 4

Good Things in Markets

The day of very cheap Columbia River smelt is not yet, though any market man will tell you it may be expected at any time now. Smelt were selling yesterday at 10 to 12½ cents a pound, and were quite scarce at that, though earlier in the week they were to be had at three pounds for 25 cents.

Morning Oregonian (Portland), Friday, 18 February 1911, p. 10, col. 3

Good Things in the Market

The smelt are here! The run is sufficiently strong to reduce the price to 5 cents a pound, and at every dealer's the fish are on hand in boxfuls.

Morning Oregonian (Portland), Wednesday, 22 February 1911, p. 18, col. 2

Marine Notes

First of the season's catch of smelt in the Cowlitz River, amounting to 35 tons was brought to Portland on the steamer Lurline. Another consignment was transported by the steamer Joseph Kellogg.

Morning Oregonian (Portland), Saturday, 25 February 1911, p. 12, col. 2

Good Things in Markets, by Lilian Tingle

The heavy run of Columbia River smelt has come in earnest this week. The delicious little fish are selling at three pounds for a dime, 10 pounds for a quarter, or one dollar a box, and there is enough for every one.

Morning Oregonian (Portland), Saturday, 2 December 1911, p. 11, col. 2

First Columbia River Smelt of the Season at Mace's Market

Morning Oregonian (Portland), Saturday, 27 January 1912, p. 4, col. 3

Good Things in Markets

> Columbia River smelt is not really plentiful, but is to be had at 6 to 8 cents a pound.

Morning Oregonian (Portland), Saturday, 10 February 1912, p. 12, col. 4

Good Things in Markets, by Lilian Tingle

> Columbia River smelt are still the leading feature in the fish markets, and are selling at about 8 cents a pound.

Morning Oregonian (Portland), Tuesday, 2 April 1912, p. 7, col. 3

Smelt Run Now On
Millions of Small Fish Enter the Sandy River
Sunday Crowds Active

> Troutdale, Ore., April 1—(Special)—This thriving little city should have been named Smeltdale, as there isn't a trout anywhere near it. But the dainty little smelt is just now the attraction that has made the town the Mecca of thousands who are all returning home laden down with all the fish they care to take away with them.
>
> The great run of smelt from the Columbia River began on Thursday last and was at its greatest yesterday. An ideal day and the prospect of unlimited catches, together with the exciting sport of taking them, brought people from every direction. The banks were lined with teams from all over the county and automobiles from the city, and the entire day was spent in a vain effort to deplete the Sandy River of its finny denizens.
>
> Millions Will Die [subhead]
>
> Thousands were caught but millions got away, only to swim against the strong current for a few days longer and then float back dead, dying or exhausted, when the greatest run known will all be over.
>
> Nine years ago there was a similar run of smelt in the Sandy. This is the only river, excepting the Cowlitz that is ever entered by them from the Columbia. No one can ever predict when they are coming. It is only when the water is seen to be fairly alive with them that the word goes out and for a few days all other business is suspended while the people from far and near lay in a big supply.
>
> Birdcages Used as Nets [subhead]

Yesterday's sport was exciting enough. It was attended with many involuntary baths and much mirth. The fishing appliances consisted of nets tied to long poles and every scoop into the water brought up fish.

In place of the regulation net there were to be seen improvised scoops made of wire gauze, coal oil cans and even birdcages. A motion picture outfit made films and every sort of a water craft did a rushing business all day long.

The great run will cease as suddenly as it began.

Morning Oregonian (Portland), Saturday, 23 November 1912, p. 16, col. 4

Smelt Are Running Early
Fish Caught Close to Ocean Bring Fancy Prices

ASTORIA, Ore., Nov. 22—(Special)—Smelt are entering the river earlier this year than ever before. Last night one man who was fishing for herring in the lower river not far from Sand Island caught a pound and a half of smelt in his net, and as a result he is going out with a regular smelt net.

Columbia River smelt are considered the most toothsome fish found on the coast, and when caught close to the ocean are exceptionally fine, those taken early in the season often selling as high as a dollar a pound.

Sunday Oregonian (Portland), 15 December 1912, p. 14, col. 4

Good Things in Markets

Columbia River smelt is the "newest thing" in the fish market and is available, in small quantities only, at 25 cents a pound.

Sunday Oregonian (Portland), 2 February 1913, p. 16, col. 5

Good Things in Markets

Columbia River smelt again is in the market, in generous supply, and can now be had at six pounds for 25 cents.

San Jose Evening News (San Jose, CA), Monday, 14 April 1913, p. 5, col. 4–5

Unusual Run of Smelt near Portland—Farmers Carry Fish by Wagonloads for Fertilizer

Portland, Ore., April 14—A run of smelt which promises to break all records has come into the Sandy River, a tributary of the Columbia, 12 miles from Portland.

An army of farmers and people from the city are busy scooping out the little fish in water buckets, dip nets, inverted birdcages and with pitchforks. The supply is so far beyond the demands of the markets that farmers are hauling them off by the wagonload and distributing them over their plowed lands as fertilizer.

One cent a pound is the market price for smelt along the Sandy, with but scant demand, since people there and in Portland have become surfeited with them.

Heavy runs of smelt in the Sandy appear at intervals of several years, but this one is denominated a freak. The run is both ahead of time and unusually heavy.

Morning Oregonian (Portland), Saturday, 29 November 1913, p. 12, col. 1

Good Things in Portland Markets

The first Columbia River smelt of the season is on the market this week at $1 a pound.

Morning Oregonian (Portland), Friday, 5 December 1913, p. 14, col. 4

Columbia Smelt on Sale
Weather Makes Fish Scarce and Retail Price is 25 Cents a Pound

Columbia River smelt have appeared in the market. The run, so far, has been a small one, and as long as the present kind of weather continues, the fish will not be plentiful, but warm rains and higher water in the river will bring them in abundance.

The big run, which is due later, will be in the Cowlitz River. Smelt are retailing in the markets at 25 cents a pound.

Morning Oregonian (Portland), Wednesday, 14 January 1914, p. 14, col. 2

Marine Notes

First of the smelt caught this season in the Cowlitz River arrived yesterday on the steamer Joseph Kellogg, the shipment consisting of 60 boxes. Owing to high water in that stream the catch is regarded as light.

Sunday Oregonian (Portland), 18 January 1914, p. 6, col. 6

Columbia River smelt are so plentiful as to confound the price jugglers.

Morning Oregonian (Portland), Thursday, 5 February 1914, p. 16, col. 6

Marine Notes

It was estimated that the deliveries of smelt from the Cowlitz River and lower Columbia district yesterday were between 1,200 and 1,500 boxes. The launch Frolic brought 425 cases from the Cowlitz.

Morning Oregonian (Portland), Friday, 27 February 1914, p. 14, col. 3–4

Good Things in Markets

> Columbia River smelt is still at flood tide and is expected to be abundant [in the fish market] until possibly the middle of March.

Morning Oregonian (Portland), Tuesday, 31 March 1914, p. 10, col. 6

Smelt Are Destroyed
Prosecutions May Follow Use of Fish as Fertilizer
Mr. Finley Says Law against Wanton Waste of Food Will Be Enforced against Sandy River People

> The smelt running in the Sandy River are attracting many people to that locality. Inasmuch as the fish are extremely plentiful, it is no trouble at all to catch them in nets or makeshift scoops. The fact that the fish are so abundant has led many persons to catch them without limit.
>
> "The State Board of Fish and Game Commissioners desire to give public notice that the law passed as the last session of the Legislature concerning the wanton waste of fish will be strictly enforced," said William L. Finley. "The Columbia River smelt is one of our most valuable commercial fish. The fact that it comes in great numbers into Cowlitz, the Sandy and certain other streams at about this time of the year, leads some people to believe that the supply is inexhaustible.
>
> "These fish come in from the sea and go into the rivers to spawn. We have to depend upon our future supply from the natural spawning of these fish. At the present time many people living in the vicinity of Troutdale are catching far greater numbers of these fish than they have any use for; in fact, they are loaded into gunny sacks and into wagons and not used in any way except as a fertilizer.
>
> "It is an economic waste and an outrage that such a fine pan fish as the smelt should be wantonly destroyed and wasted. There is nothing governing the amount of these fish that can be caught or the method of catching them, yet there is a strict law against the wanton waste of food of this kind. If it is not observed, complaints will be sworn out and arrests will follow."

Morning Oregonian (Portland), Saturday, 2 January 1915, p. 5, col. 4

Kelso Prepares for Smelt Run

> Kelso, Wash., Jan. 1—(Special)—The Columbia River Smelt Company is erecting a new dock near the depot at Kelso to facilitate the work of handling and shipping the smelt catch during the approaching season. It is now almost time for the arrival of the fish and old fishermen expect the run to start as soon as the river rises. The fish never start their run until the river is muddied by rains. Plans are

being made to open an Eastern market on a more extensive scale than last year when shipments in refrigerator cars were made for the first time.

Morning Oregonian (Portland), Saturday, 9 January 1915, p. 8, col. 6–7

Good Things in Markets

In the fish market: Variety is considerable this week still and the ripple on the surface is caused by a run of smelt up the Columbia River. They are in the Cowlitz strong and here in Portland are selling at two pounds for 25 cents, with every prospect of rapid descent in price.

Morning Oregonian (Portland), Monday, 15 February 1915, p. 9, col. 6–7

Cowlitz Has No Smelt

Vancouver, Wash., Feb. 14—(Special)—That some person desiring to keep the smelt from running up the Cowlitz River at Kelso dumped several barrels of lime in the mouth of the river, just as the smelt were beginning to run, is a story told at Kelso.

It is known that for two or three days the smelt passed the Cowlitz River and went into the Kalama River, the first time since 1847. There is not a great deal of current at the mouth of the river where it is said the lime was dumped into the river. Many persons say, however, that it was just a whim of the smelt themselves to select the Kalama River. It is reported that another big run of smelt has started in at the mouth of the Columbia River.

Morning Oregonian (Portland), Wednesday, 8 March 1915, p. 11, col. 1

New Run Fresh Columbia River Smelt, 75c for 50-lb Box, Order Shipped Promptly
Sanitary Fish Co., First and Washington

Morning Oregonian (Portland), Tuesday, 9 March 1915, p. 5, col. 4–5

Smelt in Lewis on Wane
Gulls Prey on Third Run that is Wakened by Swift Current

Vancouver, Wash., March 8—(Special)—The third run of smelt in the Lewis River at Woodland is beginning to wane and the price has dropped. The smelt, which are said not to eat after they leave salt water, are dying by thousands, and may be seen floating downstream. Many are weak and cannot swim against the current.

Seagulls by the thousands hover over the Columbia River and follow the smelt from the time the smelt enter the mouth of the Columbia River. They refuse to eat the dead smelt. So thick are the smelt in the Lewis River that they are dipped out in bunches from 50 to 75 pounds. One man made a dip yesterday that weighed 68 pounds.

Morning Oregonian (Portland), Friday, 31 December 1915, p. 9, col. 4

Smelt Are Becoming Plentiful

Kelso, Wash., Dec. 20—(Special)—Columbia River smelt are being taken in increasing numbers in the mouth of the Cowlitz and along the Columbia by the gillnetters, and fishermen are expecting a large enough supply of the fish so as to permit of dip net fishing at almost any time. Many boxes of smelt are leaving the Kelso depot daily, and the fishermen are securing good prices for their catches.

Morning Oregonian (Portland), Friday, 31 December 1915, p. 12, col. 3–4

Good Things in the Market

The fish market is enlivened by the intelligence that a considerable run of Columbia River smelt appeared in the Cowlitz on Wednesday, and consequently the price has dropped to 15 cents a pound.

Morning Oregonian (Portland), Friday, 28 January 1916, p. 11, col. 1–2

Good Things in the Market

The influx of Columbia River smelt has been completely checked by the cold, but frozen stock sells at 12½ cents a pound.

Morning Oregonian (Portland), Tuesday, 7 March 1916, p. 16, col. 6

Marine Notes.

Smelt shipments delivered here yesterday aboard the launch Beaver, which came from the Cowlitz River, numbered 212 boxes.

Morning Oregonian (Portland), Saturday, 21 December 1918, p. 18, col. 7

Columbia River Smelt 15c per lb. Single frozen, properly packed to arrive in good condition in 5-pound to 15-pound lots, within 150 miles of Portland. Write for quotations on larger quantities. Northwest Fish Products Co., 205 Yamhill St., Portland, Ore. Phone Main 4760.

Morning Oregonian (Portland), Wednesday, 5 February 1919, p. 13, col. 6

Run of Smelt Begins
Farmers Join Fishermen in Cowlitz River Catches

The annual run of smelt in the Cowlitz River has started, according to reports received in Portland yesterday. Farmers and people living in the vicinity of the river have joined with the smelt fishermen in catching the fish, which are said to be running in large schools.

As a result of the commencement of the run, prices of Columbia River smelt dropped to 4 and 5 cents per pound in Portland. It will be several months before the smelt can be expected in the Sandy River, although the fish do not ply through this stream every year. However, for the past two years Portland people have made large smelt catches in the Sandy.

Morning Oregonian (Portland), Monday, 17 February 1919, p. 8, col. 6

Disappearance of Smelt Feared
Pioneer Cowlitz Fishermen Deplores Lack of Protective Laws

KALAMA, Wash., Feb. 13—(To the Editor.)—I have been fishing smelt since 1879 and for over 25 years after that date never saw the Cowlitz River without a big run of smelt. Some winters they would come as early as January and sometimes as late as March. Then they would come so thick that a fish boat could be loaded with a small dip net in a few hours.

For the last eight years I have noticed the large runs have disappeared; for three years, or three winters, the most smelt have been caught in the Kalama, Lewis and Sandy rivers, and it looks like the smelt were done for in the Cowlitz forever.

This winter we got a surprise. A big run of smelt entered the Cowlitz after the markets had been well supplied from the smelt caught by gill nets in the lower Columbia. As soon as the smelt entered the Cowlitz several hundred launches loaded up. My boy caught a ton and one-half in five or six hours and expected to make a stake out of it. He went over to Rainier, but the smelt buyers were blocked, and also in Kelso. At least 150 fish boatloads at two tons each have been dumped overboard inside of three days and a big troller loaded and bound for a lower river port with seven tons of smelt got foul of a bootlegger just after being loaded and bound out of the Cowlitz, and struck the sandbar in the mouth of the Cowlitz. He kept driving ahead and drove her high and dry. The river falling about his launch, he was compelled to jettison his cargo overboard, as nobody wanted his smelt for nothing.

The whole thing is a disgrace. Every fisherman and cannery man knows that the smelt is the natural food for the Chinook salmon. The young salmon, after leaving the spawning ground and hatcheries, feed on the young smelt, and the large salmon fatten on the grown smelt. This run of smelt, most likely the last big run ever to come into the Cowlitz, will be followed up by launches to the very spawning grounds. My boy was offered a contract by one of our big smelt merchants at $8 per boatload of 2⅓ tons, a trifle over ⅛ of a cent per pound.

There is no law against dumping a few hundred tons of these fine fish overboard, but we should have a law to protect the smelt, as well as the salmon. Our lawmakers in Salem and Olympia are not all to blame, but the fish law agitators in both houses, who fight all kinds of battles between themselves on how to protect the salmon, let the salmon starve and don't think of feeding this royal fish. I am sure that in less than 15 years from now smelt will be as scarce as the elk in the mountains. These plentiful launches with the big scoop nets will soon finish the smelt business. I am able to see it. It is my trade and business. The smelt-buying merchants about Kelso and Kalama consist of about a dozen, and get discharged sailors and soldiers to dip the smelt at from $3 to $5 a ton. They get fat on the destruction of the smelt. Whatever can be dumped fresh on the market at 75 cents to $1 a box goes. Several hundred tons may go into cold storage and be retailed later from 10 to 12½ cents per pound. It would be wise and easy to draft a law that would be of benefit to the salmon, the fishermen and the children. —Charles Wood

Morning Oregonian (Portland), Tuesday, 1 April 1919, p. 10, col. 5

Those Who Come and Go

Run of smelt in the Sandy River attracted scores of guests from the hotels yesterday. To the easterners and people from California the sight was wonderful. "About everyone in the hotels has gone out to the Sandy River," said Clerk J. J. O'Brien, at the Hotel Portland. "Those who went yesterday came back so excited and talked so much about the fish that they caused others to go out today. One easterner declared there was more fish than water in the river."

Morning Oregonian (Portland), Saturday, 1 January 1920, p. 1, col. 2

Smelt on Market Here
First Shipments of Cowlitz River Run Are Received

Portland markets yesterday were selling the first of the new run of Columbia River smelt, the fish having been shipped from Cowlitz River, where the run is said to be quite heavy. The fish are what is known as the "widow" run, being the forerunners of the main run, which starts generally in February. About 20 boxes of the fish were received yesterday from the Cowlitz by the Portland Fish Company, which reports that they will continue to receive consignments daily until the run ceases. Heavy catches generally reduce the "widow" run within a short time, it is stated, and smelt are off the market until the main run starts.

The wholesale price for the smelt yesterday was 13 cents a pound, and the retail price at most of the markets was 20 cents. When the main run begins the fish are caught in such quantities that the price generally drops much lower.

Morning Oregonian (Portland), Tuesday, 27 April 1920, p. 10, col. 6

Those Who Come and Go

When A. N. Ward gets back to the Hot Stove Club at Malden, Mass., [he] will have a fish story to tell that his fellow townsmen will probably not believe and will stamp it as a traveler's tale. When Mr. Ward recounts that he saw a river so filled with fish that the stream was virtually one solid mass of fish for miles, and contained millions of smelt, the Maldenites will sniff with suspicion. When he says that in five minutes he, or anyone, could gather enough fish from the Sandy River with his coat, or auto robe, or any old thing, to fill a car to overflowing, they'll be certain that he is drawing the long bow. And yet, those were the things which Mr. Ward saw when he toured the Columbia River highway yesterday. He saw the great smelt run and saw miles upon miles of parked cars, while their drivers were filling gunny sacks, cans, buckets, tubs, boxes and any container they could secure, with smelt. At home Mr. Ward is an undertaker, and with his wife he is at the Multnomah, returning from the profiteer belt of California.

Morning Oregonian (Portland), Wednesday, 28 April 1920, p. 15, col. 4–5

Smelt Run Biggest Ever
Prow of Boat Turns Up Hundreds All Night Long

"My observation is that this is the biggest smelt run that has ever come up the Columbia River," was the statement made yesterday by State Game Warden Carl D. Shoemaker after he spent Monday night on the river in a motorboat. "We found early this morning that the seagulls are following the smelt all the way from Vancouver Bridge to the mouth of Sandy and that a solid wave of smelt is coming upstream between these points, or a distance of about 10 miles. The prow of our boat turned up hundreds of them all night long."

Mr. Shoemaker says there are no indications of the run slacking and that tons of fish are being shipped to Oregon and Washington points and many are going into local cold-storage plants. It is found that female smelt predominate over males in the present run, indicative of another heavy one next year.

Morning Oregonian (Portland), Monday, 3 May 1920, p. 4, col. 2

Smelt Run Nears End
School in Sandy Keeps over Spawning Beds
Within Next Few Days Dipnetters Will Be Hard Put to Get a Meal from Waters

The record run of smelt, so far as the Sandy River is concerned, is all but over. Within the next few days the gulls and the dipnetters will be hard put to find a meal in the deeps and shallows that aforetime held smelt by the billion. But few fish were obtained yesterday and the disappointments were in keeping—for not more than 50 fishermen were congregated at the Troutdale Bridge at any one time during the day.

Most of the dipnetters, however, managed to get a sack or so, by watching for the stray fringes of the now depleted and rapidly vanishing school. The main body of the run held well to the center of the stream, over the spawning beds, and only the commercial fishermen, with improvised piers and rowboats, were able to reach the profitable coigns of vantage.

The Sandy River smelt run, more than a month overdue by comparison with previous seasons, began 10 days ago and within half a week had attained unheard of proportions. Launches in the Columbia River outside, near the mouth of the

Sandy, ploughed through pools of smelt so dense that the curving wave at the bow was a cascade of shining fish. The smelt even drove far past the Sandy and as far up the river as Bonneville.

Morning Oregonian (Portland), Wednesday, 5 May 1920, p. 10, col. 2

Like the Sands of the Sea

Take all the hyperbolic similes expressive of vastitude of numbers, stir them well together, segregate the triple-extracted essence and confine it in a humdinger of extravagant comparison, and one will but have paid tribute to the fringes of the Columbia River smelt run. Naught save deity could give it census, for the count would worst mortal mathematics as that science is ordinarily employed. These observations are by way of preface to the statement that a Portland resident has been arrested on the count of wasting food fish, because he sought to fertilize his fruit trees with passé smelt.

There are those who will charge the game department with mulish conformance to law, asserting that the statute invoked was never intended to deal with billions upon billions of silver "hooligans," swimming up the Columbia just as they did on the morning Captain Gray's visit, ever and ever so long ago. To chirk up a cherry tree or two with half a peck from that seemingly inexhaustible measure, the sea, would to many commend itself not only as a trifling tithe on nature's largess but as a most sensible procedure.

When the grandfathers of the present were the boys of yesterday, back in Ohio, Michigan, Minnesota, Wisconsin, and New York, along the entire Atlantic coast and well into the middle-west, the flight of passenger pigeons was an annual event comparable to the smelt run of the Columbia. On sunny days, with the spring mornings all golden and green, when those epochal pilgrimages were on the wing, it is recorded that the face of the sky was darkened as by a heavy cloud—a living veil of plumage that swept on and on, and endured till dusk. And thus for many days. They narrate, those same grandsires, that one might feed a bullet to the muzzle-loading squirrel rifle and fire at random upward, through the hurtling avalanche of pigeons. Not one but several birds would fall to that hazard, it is recounted. Yet the passenger pigeon is gone, and wealth would reward the man who could prove the existence of a single flock, a single bird. The species is with the great auk and the dodo, and while it may have perished in some stormy passage between the northern and southern continents, there is abundant evidence against the market hunter and the game assassin.

Natural history is replete with tragedies in which man plays the role of villain. Ethically and economically—and merely, for an additional reason, because all waste is wicked—the game department is fortified in its enforcement of the law with respect to the smelt run.

Morning Oregonian (Portland), Friday, 7 May 1920, p. 10, col. 7

Habits of Smelt Little Known
Study Made of Fish which Authorities Know under Several Names

Portland, May 6—(To the Editor)—Please publish the following information, and any other interesting facts, about the smelt. How long until they hatch, and how long do they stay in fresh water after hatching? How long before they come back to spawn? Do all that come up the river die, and what becomes of them when dead? What is their correct name? Are there such fish other places than the Columbia River? —A Subscriber

The scientific name of the Columbia River smelt is Thaleichthys pacificus. It is described in encyclopedias and dictionaries under "candlefish." The Indians called it "oolachan," sometimes spelled "eulachon," which has been corrupted by whites into "hooligan." It is common in Alaska and British Columbia streams, as well as in the Columbia.

R. E. Clanton, master fish warden, is authority for the statement that the longevity and habits of the Columbia River smelt have never been made the subject of exhaustive study, and that this season is the first in which trained observation has been directed.

The present attempt includes a study of the reproductive organs of the female smelt, to discover whether nature has provided for a second spawning. It is not known at present whether smelt return to the ocean or perish in the rivers—as does the salmon after visiting the spawning beds.

If the billions of smelt in an ordinary run were to die in freshwater, it is contended, the evidence of such demise would be prevalent, even to the point of pollution, of so mighty a stream as the Columbia. On the other hand, the return of the smelt run to salt water, if it does return, never has been observed. Fish commission officials, including Master Warden Clanton and Secretary Carl Shoemaker, of the fish commission, expect to make tests this week toward solving the riddle.

The journey of the smelt fry to the ocean is another phase of the life cycle that is darkness. None has seen, so far as the records show, the migration of the infant fish from the birthplace river to salt water. Their numbers must be uncounted myriads, and even if the fry were even an inch in length the passage of the infant smelt would be plainly discernible. It is conjectured that the fry run to sea when extremely small.

But all this is guesswork. An attempt is now launched to learn more of the actual life history of the Columbia River smelt. Specimens now held at Bonneville hatchery will be kept under observation to determine whether they are subject to demise after spawning, while an attempt will also be made, with nets, to discover whether any portion of the recent heavy run has retraced its course to the Pacific.

Morning Oregonian (Portland), Thursday, 20 January 1921, p. 4, col. 2

Smelt Enter Cowlitz River

Kelso, Wash., Jan. 19—(Special)—For the first time this season smelt were dipped in the Cowlitz River today. A few smelt had been gillnetted in the Cowlitz earlier this winter before the freshet, and for the last two weeks the Columbia River gillnetters have been getting smelt on the lower Columbia. It is thought that the present run is what is known as the early winter run and that the main run of the little fish will not be here for several weeks more.

Morning Oregonian (Portland), Friday, 18 February 1921, p. 11, col. 1

Lewis River Rises

Woodland, Wash., Feb. 17—(Special)—Warm winds and melting snow in the mountains have caused a decided rise in the Lewis River. The water has already reached within a foot of the high-water record. Muddy water is driving the run of smelt out of the river into the Columbia.

Morning Oregonian (Portland), Saturday, 19 February 1921, p. 13, col. 1–2

Many Fruits in Season

Columbia River smelt retailed at two pounds for 15 cents yesterday.

Morning Oregonian (Portland), Saturday, 19 March 1921, p. 13, col. 2

Fish for Lent Plenty

Prices will cover all the stages between 5 cents a pound for Columbia River smelt to 50 cents a pound for lobster shipped from the Atlantic seaboard.

Morning Oregonian (Portland), Saturday, 24 December 1921, p. 12, col. 1

Smelt Put in Appearance

Columbia River smelt have appeared for the holiday season in large quantities. They are being dipped up with nets and selling retail here at 15 cents a pound, in comparison with 25 cents a pound, which was the price until yesterday.

Morning Oregonian (Portland), Saturday, 14 January 1922, p. 10, col. 2–3

Did the Smelt Neglect their Tryst?

If nature forgot us for a single season, in all her bounties, we should be like so many children squalling in the dark. Quite helpless, very hungry and probably petulant. Occasionally the good dame does forget, neglecting some customary gift, and men puzzle themselves to discover the reason. They do not always find an answer. Why was it, as was recorded 25 years ago, that there had been noted long periods during which the smelt run deserted the Columbia River? For 20 years, so these observers asserted, the pleasing little eulachon was—to put it tritely—conspicuous by his absence.

The drying racks of the Indians were not laden, and the residents along the great river and its tributaries scanned the streams vainly for the return of their favorite fish, who was wont to be as punctual as April. There is no record of the year in which the run reappeared, nor is there more than the testimony of a few individuals, as preserved in news reports, to substantiate the disappearance. Undoubtedly it was the ancient and continuous custom of the smelt to frequent the Columbia as spawning time. Captain Robert Gray, whose good ship lent its name to the river, found them plentiful in 1792, and did not neglect to pay his compliments. It is to be regretted that the record of their truancy is not more specific, better verified, for instances in which anadromous fish fail to keep their natural appointments are more than rare.

Regarded across a third of a century, the claim is doubtful, and one cannot but incline to an opinion that the smelt were punctual, but unobserved. It might have been that the run, lengthy as it is, passed the specific points of observation at periods of high and murky water, to spawn far upstream. The weakness of this theory, which is otherwise entirely tenable, is that such conditions would scarcely be repeated annually over a long period of years. An instance that proves how easy it is to overlook the presence of the run is that of the appearance of the smelt in the Sandy River last spring. Unusually high water prevailed at the time the run was expected, and all observers were confident that the hordes of smelt had not entered the stream. Later they revised their opinion, for schools of infant smelt were noticed in early summer, and it became apparent that the fish had arrived and fulfilled their destiny without a single person glimpsing the millions of adult fish in the muddy current. Yet, as has been said, it is a bit far-fetched to fancy that such conditions could be indefinitely repeated.

The habits of anadromous fish are definite and precise. They return from the sea at well established seasons to the waters of their own birth to deposit their eggs. In this impulse the smelt are one with the salmon, whose cousins they are, and the confirmed belief is that such runs do not fail until the run itself is obliterated. With salmon this has repeatedly been proved. It is logical to assume that the multitudinous smelt conform to the same law, and that those early observers confused loose report and limited observation with fact until they had for themselves established a tradition. This may not be true, but if it is not true one of ocean's mysteries remains unsolved, and it is to be regretted that the record is so imperfectly preserved.

Morning Oregonian (Portland), Monday, 6 February 1922, p. 6, col. 2

Smelt Run in Cowlitz Small

Kelso, Wash., Feb. 5—(Special)—A small run of Columbia River smelt is in the Cowlitz River and the fishermen are making small catches of the little fish, which are a great table delicacy throughout the northwest. Boats can get but three or four boxes a night. It may be several weeks before a heavier run arrives, say those familiar with smelt fishing operations, as few fish have been caught by the Columbia River gillnetters.

Morning Oregonian (Portland), Saturday, 11 February 1922, p. 12, col. 1

A large supply of Columbia River smelt is available at 15 cents a pound, and in some places at two pounds for 25 cents.

Morning Oregonian (Portland), Tuesday, 21 February 1922, p. 7, col. 6

Smelt Run Again Enters Cowlitz

Kelso, Wash., Feb. 20—(Special)—What is thought to be the main run of Columbia River smelt entered the Cowlitz River last night and large catches of smelt were made by the fishermen. Later, however, the run decreased, and there is some doubt whether or not this is the main run. The fish have been late in coming up the river this year, although there have been small runs in the Cowlitz several times during the winter.

Morning Oregonian (Portland), Saturday, 25 February 1922, p. 12, col. 1

Columbia Smelt Price Is Reduced, Fresh Seafood Sells Three Pounds for 25 Cents
Large Supply on Hand, Smelt Prices Cut

The price of a popular seafood that is recognized in Portland as a real delicacy was cut almost in two when dealers reduced prices of Columbia River smelt. These tasty, silvery fish are now available at three pounds for 25 cents. The price a week ago was 15 cents a pound. Dealers report a good supply on hand to supply a brisk popular demand. The smelt are fresh from the Columbia River.

Morning Oregonian (Portland), Saturday, 4 March 1922, p. 15, col. 1

Smelt Also Take Fall

Another popular product that has dropped in price is Columbia River smelt. These tasty little fish may be had at two pounds for 15 cents or four pounds for a quarter. In some stores the price is three pounds for 15 cents. These prices are the lowest of the season so far and caused a heavy demand.

Morning Oregonian (Portland), Wednesday, 12 April 1922, p. 13, col. 3

Smelt Reported Running in Sandy
Fish Keeping to Middle of Stream, It Is Said
Licenses Not Needed

Nets, sieves, baskets and dippers of various kinds will be at a premium for a few days, and many thousand gallons will be consumed along the Columbia River highway route between Portland and the Sandy River, for the smelt are running again.

A silvery phalanx 15 feet wide and six inches deep is flowing upstream in the Sandy for the first time in two years, the dainty little fish completely ignoring the stream last year. By the millions, the tiny smelt are seeking the headwaters, a phenomenon which will attract thousands to the river banks and flood Portland homes with the toothsome little delicacy for many days.

For the true fisherman there is no sport in catching smelt during a run, for it requires no more effort than the dipping of a net into the water and removing it filled to the brim with flopping, silver fish, but the run has a great attraction for the fireside fisherman who desires great results from a minimum of effort.

Length of Run Uncertain [subhead]

How long will the run last? This is a question which cannot be answered with any degree of certainty. Runs have been known to last from two days to 24 days. A good deal depends on the weather. Should conditions moderate and a heavy, warm rain develop, high water in the Sandy will prove too great an obstacle for the small fish to negotiate. They have traveled a long distance by the time they arrive in the Sandy and are tired.

On the other hand, should the weather continue cool, with little rain, a long run can be anticipated. Indications are that there still will be a considerable run next Sunday to accommodate the holiday flow of autoists.

Though the smelt have been known to ignore the Sandy for as high as eight consecutive years, of late the runs have been quite constant, the failure of the fish to appear last year being quite out of the ordinary. A late spring usually presages a heavy smelt run, according to Lou Karlow, deputy county clerk, whose home is on the banks of the river and whose wife telephoned to Portland the first news of the run yesterday morning.

Run Appears Big [subhead]

The run looks like a big one, similar to that of two years ago, according to Carl Shoemaker, master fish warden, although he said yesterday the fish were keeping to the middle of the stream. However, he expected the run would reach such proportions, probably by today, that the merest tyro fisherman can stand on the bank of the stream and dip up all he wants.

No fishing license will be required, said Mr. Shoemaker, for persons who desire only to take smelt for their own use. Those who operate commercially, however, and sell their catch, must provide themselves with a dip net or dragnet license. No waste will be tolerated, said Mr. Shoemaker.

Morning Oregonian (Portland), Thursday, 13 April 1922, p. 8, col. 2

Smelt Thick in Sandy
Autoists Congest Highway in Rush for Fish
Calls for Assistance Cause Sheriff to Dispatch Entire Motorcycle Squad to District

Smelt scouts up the Sandy River evidently reported favorably concerning that stream as a spawning ground, for millions of the silvery little fish reached from bank to bank yesterday by the time autoists in any number began to gather in the vicinity of Troutdale.

More than 2,000 automobiles congested the Columbia River highway near the Sandy before noon and calls for assistance caused Sheriff Hurlburt to dispatch his entire motorcycle squad of six men and machines to the district to direct traffic and break the jam which had ensued.

Birdcages, lace curtains and many other substitutes for fish nets made their appearance and only a few minutes in the stream sufficed to supply any family with enough smelt for a reunion. All indications are that the run will last for a week or more and it is expected that the traffic will attain proportions by next Sunday which may make it necessary to employ traffic officers in addition to the sheriff's complement.

It is not necessary to have a fishing license if the smelt are dipped out of the river for the use of oneself and family.

Morning Oregonian (Portland), Thursday, 13 April 1922, p. 10, col. 7

Those Who Come and Go
Tales of Folks at the Hotels

Smelt in the Sandy River, out near Troutdale, are as interesting to tourists at the hotels as they are to the householders of Portland. News of the annual run of smelt in the Sandy was received at the hotels yesterday and many persons chartered automobiles to go out and see this famous run. To the easterner who is not familiar with a run of fish and particularly to people who live in the interior, the smelt are a wonderful attraction. The march of millions of these silver fish swarming up the confines of the glacial waters of the Sandy River toward their spawning grounds never fails to evoke exclamations of astonishment. Hotel clerks have learned that they can recommend a real attraction to visitors by sending them out the highway to see the run of smelt. Tourists yesterday were so notified and they were also advised to equip themselves with nets or buckets or something with which to scoop up the fish, for no one can stand on the bank of the stream and see the myriad of fish passing them without a wild desire to go fishing on the spot. The trouble with catching smelt is that the fisher gets more than he needs or can use, so he brings back a gunnysack or two with the fish and inflicts them on everyone who can be induced to accept them. Smelt are as fine eating fish as can be found when scooped from the Sandy waters, but a person cannot eat more than several dozen.

Sunday Oregonian (Portland), 16 April 1922, p. 3, col. 2

Smelt Season Ends at Kelso

Kelso, Wash., April 15—(Special)—Final shipment of smelt was made by Kelso fishermen this week, and they will be busy the rest of this month getting their salmon fishing equipment ready for the spring season and moving their outfits to drifts along the Columbia River. This has been a very good smelt season, the prolonged cold weather being a benefit to the industry.

Morning Oregonian (Portland), Tuesday, 18 April 1922, p. 1, col. 2

Locks Block Smelt Run
Millions of Tiny Fish Caught at Cascades of Columbia

Hood River, Ore., April 17—(Special)—The run of smelt has reached the Cascades of the Columbia, where they are blocked. Millions of the fish are trying to get to the headwaters by way of the government locks. Deputy Sheriff Meyers today telephoned to Sheriff Johnson that residents of Cascade Locks, utilizing as various an assortment of improvised nets as one sees at the Sandy, are taking fish by the boxfuls at the lower end of the locks.

Schools of smelt appeared at Eagle Creek Saturday.

Morning Oregonian (Portland), Monday, 1 May 1922, p. 4, col. 2

Pantries Stocked with Smelt

Hood River, Ore., April 30—(Special)—Residents of Cascade Locks and Stevenson, Wash., made the most of the recent smelt run up the Columbia to the foot of the rapids below the Cascades, and many pantries have been stocked with dried and salted fish. A. J. Pratt, a Stevenson, Wash. man, who captured 1,600 pounds of smelt, salted and smoked them. His shrinkage, he reports was 66 percent, as he now has left 575 pounds of kippered smelt.

Morning Oregonian (Portland), Monday, 1 May 1922, p. 8, col. 3

Marvel of the Smelt

The Eugene Register has printed what we think is a timely warning concerning smelt. It predicts that unless there is some curb on the taking of this variety of fish, smelt will go the way of the passenger pigeon and the buffalo.

Probably the fact made impressive by these early tragedies that wild life cannot long maintain itself against man's unrestrained rapacity, will cause us to take heed before the smelt have disappeared. But why not for once depart from the usual custom of delaying regulation until scarcity is upon us?

Smelt fishing in the Sandy River is an asset to Portland whose importance is hardly realized. The incidents of the spring run have no counterpart anywhere. The Sandy is not the only stream in which smelt appear in vast numbers, but it is the one stream in which they swarm that is readily accessible from a populous community.

Sandy River is a stream worth visiting for its scenic beauty alone. The point where the Columbia highway crosses it is within less than an hour's automobile ride from Portland over a paved road. It happens that the reaches of the stream directly above and below the highway bridge are the smelt fishing grounds.

There, in beautiful surroundings and without license, hindrance, or limit, the Portland citizen, one hour's journey from home, may with the crudest of home-made appliance dip out and take away as many delectable food fishes as the novelty of the occasion impels him to take. It is as the Eugene paper remarks—the rule is to take more than one can possibly use or give away. Smelt taking in the Sandy, in which thousands of persons—rich and poor—participate annually, is one of the spectacles, one of the marvels, of the northwest and of the Columbia highway.

The habits of the smelt, or candlefish as it is properly called, are little understood. Presumably they return to the stream in which they were spawned. If that be true, whatever protection given them elsewhere will not restock Sandy River if it is once fished out. As an important contribution to the food supply and as an advertisement for this community, smelt runs are worthy of scientific study and of protection, if need be, from greed and waste.

Morning Oregonian (Portland), Tuesday, 9 May 1922, p. 10, col. 8

How Indians Once Took Smelt
Nails in Canoe Paddles Impaled Fish, Recalls Captain Gray

Pasco, Wash., May 7—(To the Editor)—The Oregonian's editorial "Marvel of the Smelt" reminds me of the first runs of smelt in the Cowlitz River. The Indians drove sharp pointed nails through thin paddles, and as they forced their canoes upstream through the school, or rather stream of smelt, would soon fill their canoes by shaking the smelt from the nails in their paddles.

I have not been on the Cowlitz for many years, but understand that the smelt runs on that river do not compare with the runs of the '60s, when steamboats did not run above Monticello or Freeport—they now run to Kelso. Did steamboats on the Columbia or log booms at its mouth check its smelt run? If so your Sandy River runs are safe, as steamboats cannot disturb them.

We used to know when the smelt were in the Columbia by the number of seagulls that followed the schools.

Another thought: Is there not a danger of "overpopulation" of smelt if their taking is restricted? Hundreds of millions of eggs are deposited every year. Will the few thousands of fish captured relieve a congestion that would drive the smelt to some other stream? You are in error in saying the smelt is properly called a candle fish. The candle fish is only taken in salt waters like Puget Sound, and takes its name from the fact that when it is dried its mouth opens wide and makes a base to support the greasy bones that stand upright. A lighted match touched to the tail of the dried fish makes a perfect candle. The flesh of the candle fish is far inferior to the smelt.

The Columbia seems to be the only river that has the two distinct varieties of the best of fish, salmon and smelt.

The Yukon River salmon is larger and compares in flavor with our Columbia River variety, but there are no smelt to compare with the genuine Columbia River variety, which seek the Cowlitz, Kalama, Sandy and other small streams every spring to spawn. —W. P. Gray

Morning Oregonian (Portland), Friday, 29 December 1922, p. 12, col. 5

New Today in the Markets

A few smelt made their appearance on the Portland market yesterday, bringing the price, which was formerly about 35 cents, down to 30 cents. Marketmen state that fishermen have discovered a school of the fish making their way up the Columbia River.

Oregon (Umpqua River)

Eugene Register-Guard, Friday, 21 February 1969, p. C1

Streams Back in Shape, Fishing Slow, by Pete Cornacchia

Smelt dippers at Scottsburg Park, downstream from the highway bridge across the Umpqua, hadn't netted much since early in the week, reported Hugh Smith at the Tackle Box in Reedsport. But, judging from past years, the migration up to spawning grounds somewhere above Elkton is expected to continue at least another two weeks and a new batch of smelt could show at any time.

Lots of 25-pound limits were collected among the mob of dippers at the park last weekend, he said. Nearly all of the silvery fish were males, which usually are the first to show. Dipping was best along the bank and at night on the ebb tide. [Online at http://news.google.com/newspapers?id=SGkRAAAAIBAJ&sjid=B-gDAAAAIBAJ&pg=3321,4455711&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 28 February 1969, p. 5B

Long-handle Nets Ambush Smelt Migrating Close to Banks of Umpqua River [lead-in head], Action Slow on Steelhead, Smelt Run, by Pete Cornacchia

> The lower Umpqua has produced a few sturgeon recently in the Gardiner area but has been offering only a trickle of smelt to dippers up at Scottsburg Park. Regardless of reports in the Portland papers, Umpqua smelt dippers aren't getting their 25-pound limits.
>
> Smelt traffic has been light ever since the opening surge two weeks ago and hopes of another buildup in the run are dwindling. Oldtimers point out that swarms of gulls always follow the smelt up the river but there is no great number of birds on the river now. [Online at http://news.google.com/newspapers?id=T2kRAAAAIBAJ&sjid=B-gDAAAAIBAJ&pg=5316,6039358&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Sunday, 22 March 1970, p. 2C

It's Striper Time, by Pete Cornacchia

> … About a month ago several Mapleton fishermen started catching big stripers which apparently had followed a previously unheard-of smelt run into upper tidewater on the Siuslaw. [Online at http://news.google.com/newspapers?id=IcIUAAAAIBAJ&sjid=8eADAAAAIBAJ&pg=5240,5619960&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 5 February 1971, p. 3C

Umpqua Yielding Variety: Steelhead, Smelt, Sturgeon, by Pete Cornacchia

> And if you've had enough steelhead and/or hang-ups for one winter, Umpqua tidewater offers a good but sporadic run of smelt for dippers in the Scottsburg vicinity and increasing white sturgeon activity down in the bay. …
>
> The Umpqua appears to have a good smelt run, though they're coming through in spurts. Success for dippers on the banks at the state park below Scottsburg has varied from day to day. [Online at http://news.google.com/newspapers?id=9gwRAAAAIBAJ&sjid=EeEDAAAAIBAJ&pg=3712,778489&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 26 February 1971, p. 2B

Outlook Poor for Anglers, Good for Dippers, Diggers, by Pete Cornacchia

> Get that dip net out again, for those sneaky smelt are back again. Bigger than ever.
>
> But if you're less than thrilled with the chase and taste of the eulachon … tides are good … for dredging bay clams. …

After most of the smelting fraternity on the lower Umpqua had put their nets away for the year, these unpredictable fish suddenly showed again last weekend. Dippers at Scottsburg State Park have done quite well every night this week, reported Jim DiBala at Echo Resort. More smelt than before and they're larger than usual. [Online at http://news.google.com/newspapers?id=Cw0RAAAAIBAJ&sjid=EeEDAAAAIBAJ&pg=4477,5470935&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Tuesday, 8 February 1972, p. 3B

On the Outside [column head], Passing the Word, by Pete Cornacchia

When the smelt come up the Umpqua to spawn, usually about this time of year, I forget the steelhead and head for tidewater. Not to dip for smelt with all the others at Scottsburg State Park below the Highway 38 bridge, but to prey on the great white sturgeon and the striped bass which prey on the smelt as they move up the river.

Sure enough, smelt are beginning to show in the lower Umpqua. Just a trickle as yet, however. Several persons have told recently of seeing stripers feeding on smelt at the surface, but dippers at the park haven't been collecting much in their long-handled nets.

"Commercial netters have been getting a few from time to time," said Jim DiBala at Echo Resort. "But dipping has hardly been worth the effort. I fished about an hour yesterday and got three smelt, which is about how it's been.

"They should be here any time now, though. Could be on the next tide."

As in other streams, the smelt run in the Umpqua is a very unpredictable thing which has been quite strong in some years and very weak in others. Sometimes the fish go through when the river is too high and muddy to get at them.

Water conditions have been good for the past week, but the Umpqua was rising again Monday and probably will continue to climb if the thaw continues in the upper reaches. [Online at http://news.google.com/newspapers?id=Q8kTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=3531,1895262&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 25 February 1972, p. 1B

Smelt Run Picking Up in Umpqua, by Pete Cornacchia

The smelt run in the Umpqua, which for several weeks had been a slow walk rather than a run, came on strong Wednesday afternoon to spur hopes of both dippers and striped bass fishermen.

"Dipnetters took several limits last night and were still taking smelt this morning," Mrs. Jim DiBala reported Thursday from Echo Resort. She was referring to the dippers at the state park below the Highway 38 bridge at Scottsburg. For personal use, daily limit on smelt is 25 pounds.

How long the run would remain strong was anybody's guess. [Online at http://news.google.com/newspapers?id=UskTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=3871,6403187&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Sunday, 27 February 1972, p. 3D

Smelt Run Draws Many to Umpqua, by Pete Cornacchia

It had started raining again and the cold wind which had been whipping up whitecaps on the flats along the lower Umpqua had an awfully mean bite for a southwester.

But the men, women, kids and dogs strung along the silty beach above and below the boat ramp at Scottsburg State Park didn't seem to mind. In shiny wet rain gear or soggy wool jackets, some huddled by the spitting and sputtering fires while others knee-deep at the edge of the high and muddy river swung long-handle nets out into the chocolate flow.

When they lifted the nets from the water after a long sweep downstream, usually a handful of silvery fish flashed in the bottom of the cords. The fish were dumped into a bucket or plastic container, then the dipper waded back into the water to make another sweep.

The smelt were running strong at last and some of the dippers were getting their 25-pound limits, as had others the previous afternoon and night. The run had been light up to this last week of February, as it had been on other streams in Oregon and Washington.

But now lots of the little fish were moving upstream to spawn and the dippers were there to get their share, no matter how raw the weather or how muddy the river. The strong run might continue for several more days, or it could be back to a sporadic trickle by tomorrow.

Like the swarms of gulls which follow the smelt up the river and tell of their presence, the dippers can't count on tomorrows.

For a host of anglers, the arrival of smelt raises hope not so much for a tasty meal as for the oncoming of voracious striped bass which also prey on the little fish as they travel upstream. [Online at http://news.google.com/newspapers?id=VMkTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=4273,6843290&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 3 March 1972, p. 5B

High, Muddy Streams Ruin Angling Hopes.

Lower Umpqua: … Smelt still in river; few limits. [Online at http://news.google.com/newspapers?id=4mkRAAAAIBAJ&sjid=DuEDAAAAIBAJ&pg=6514,720966&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 21 April 1972, p. 3B

Fish Prospects Better as Streams Improve, by Pete Cornacchia

> … Discovery of the very late smelt run brought the dipnetters back to Scottsburg Park, where several quick 25-pound limits were collected early in the week. [Online at http://news.google.com/newspapers?id=6cQUAAAAIBAJ&sjid=SOEDAAAAIBAJ&pg=6493,5070734&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Tuesday, 25 April 1972, p. 3B

On the Outside [column head], High Lakes, by Pete Cornacchia

> … weather was great but catches fell off sharply.
>
> So did smelt dipping on the Umpqua. …
>
> The Chinook in the Umpqua apparently haven't done much reading and aren't aware that salmon don't eat much after moving into freshwater on their spawning runs, [the Game Commission's Dave Anderson] noted. Many of the fish which he has checked recently were packed with smelt, just like the stripers.
>
> Dipnetters weren't doing quite that well on smelt, though Dave did check a 25-pound limit for one patient and persistent soul near Scottsburg Park. The man got his quota with about one smelt on each dip. At a few ounces per fish, that took a few dips. [Online at http://news.google.com/newspapers?id=7cQUAAAAIBAJ&sjid=SOEDAAAAIBAJ&pg=6535,6170162&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Sunday, 4 February 1973, p. B1

Arrival of Smelt Draws Gulls, Stripers, Sturgeon, Anglers to Lower Umpqua [lead-in head], Smelt: Tiny, Tasty, Unpredictable, by Pete Cornacchia

> "They were getting quite a few smelt here last weekend," remarked a man standing beside a fire. "Some came close to getting their 25 pounds, too.
>
> "Not much since then, though. We had a big crowd here last night, but nobody did much."
>
> But the unpredictable smelt might suddenly start showing again any time, he said.
>
> "Last year, the run faded out for several weeks and we figured that was it," he went on. "Then a lot of smelt came through in the middle of April. Wife and I caught two Chinook and a 30-pound striper that were stuffed with them. …"
>
> For many anglers, the arrival of smelt in the Umpqua raises hope not so much for a tasty meal of them as for the oncoming of sturgeon and striped bass. Like the gulls and the dippers, sturgeon and stripers also come running when the smelt

are running. [Online at http://news.google.com/newspapers?id=o2oRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4621,691873&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 9 February 1973, p. 3D

Lower Umpqua Promising; Angling Slow on Steelhead, by Pete Cornacchia

Smelt keep coming up Umpqua tidewater in spurts ….

The Umpqua has lost its winter tan and in turning green has cleared enough that most of the smelt are traveling well out in the middle of the river. At Scottsburg State Park, dippers in boats have been doing better than those on the banks. [Online at http://news.google.com/newspapers?id=qGoRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4830,2011247&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Friday, 16 February 1973, p. 3D

From Smelt to Sturgeon, Prospects Best on Umpqua, by Pete Cornacchia

Smelt are still running in the lower Umpqua but they're staying well out in the middle of the relatively clear flow and dipnetters on the bank at Scottsburg State Park haven't been doing much. [Online at http://news.google.com/newspapers?id=r2oRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4286,3686790&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Tuesday, 20 February 1973, p. 3B

On the Outside [column head], Wary Bass, by Pete Cornacchia

In checking angling pressure and catch on the lower Umpqua from February into fall last year, Game Commission biologist Dave Anderson also did a lot of stomach content analysis on stripers.

… In the spring, from the middle of March through the middle of May, 46.7 percent of the stomachs examined in the river above Reedsport had nothing in them.

In that stretch and during that period, smelt were found in 50.7 percent of the stomachs and made up 91 percent of the springtime diet. …

In mid-April, when anglers in the Scottsburg area were catching both spring Chinook and stripers, a late and large run of smelt suddenly showed up. Salmon or striper, most of the fish caught in the next couple weeks were stuffed with smelt. [Online at http://news.google.com/newspapers?id=smoRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=5421,4513119&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 31 January 1974, p. 3B

Outlook for Outside [lead-in head], Rivers Rising; Smelt Arrive, by Pete Cornacchia

> Arrival of smelt in the lower Umpqua has made dippers happy, but there's little good news to precede the bad for steelhead anglers.
>
> Swarming gulls pointed to the first waves of the Umpqua's smelt run the latter part of last week and dipnetters have been taking fish each day since then, according to Dave Anderson, State Wildlife Commission fisheries biologist at Reedsport.
>
> He said dippers along the banks at Scottsburg State Park below the highway 38 bridge have had varying success from day to day, with some 25-pound limits for the harder workers. The Umpqua like most coast streams remains muddy and rather high. [Online at http://news.google.com/newspapers?id =jLoUAAAAIBAJ&sjid=P-ADAAAAIBAJ&pg=6688,6779760&dq=site:news .google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 7 February 1974, p. 3B

Outlook for Outside [lead-in head], Hopes Better for Anglers, by Pete Cornacchia

> Dipnetters are still taking smelt from the Umpqua below Scottsburg, with success varying from day to day. Best hauls have come at low tide. [Online at http://news.google.com/newspapers?id=tQUTAAAAIBAJ&sjid =A9gDAAAAIBAJ&pg=6348,1409295&dq=site:news.google.com+Umpqua +smelt&hl=en]

Eugene Register-Guard, Sunday, 17 February 1974, p. 5B

Monsters lurk in Umpqua, by Pete Cornacchia

> … we had seen no sign of the big white sturgeon which usually follow close behind the smelt at this time of year. The smelt had been running for nearly three weeks and the dippers were still taking a few up at Scottsburg. [Online at http:// news.google.com/newspapers?id=vgUTAAAAIBAJ&sjid=A9gDAAAAIBAJ &pg=4770,3459056&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Tuesday, 26 March 1974, p. B1

On the Outside [column head], Sun Out, Fish In, by Pete Cornacchia

> The poor water conditions and long spell of foul weather didn't keep dipnetters from converging on a strong smelt run at Scottsburg. [Online at http://news.google.com/newspapers?id=ABMRAAAAIBAJ&sjid =NOADAAAAIBAJ&pg=6255,5535261&dq=site:news.google.com+Umpqua +smelt&hl=en]

Eugene Register-Guard, Thursday, 29 January 1976, p. 2D

On the Outside [column head], Sturgeon Following Smelt into Umpqua Fishing Holes, by Pete Cornacchia

> [White sturgeon are] gathering in the murky depths near Gardiner and above Reedsport to feed on spawned-out smelt. …
>
> As for the smelt, the run has shriveled to a trickle and dipnetters at Scottsburg have had to work hard for the few fish they've panned this week. [Online at http://news.google.com/newspapers?id=knkRAAAAIBAJ&sjid=PeADAAAAIBAJ&pg=6627,7406766&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Sunday, 8 February 1976, p. 3B

Like the Gulls, the Great White Sturgeon Comes Running when Smelt Are Running [lead-in head], Waiting for the Big Ones, by Pete Cornacchia

> Like the gulls that were cruising back and forth, the several people who were standing knee-deep near the bank weren't finding much in the green waters of the lower Umpqua.
>
> Like the white and grey birds winging along or resting in the eddies, they had gathered where the river rolls past Scottsburg State Park in hopes of scooping up smelt. But not since the arrival of a good run three weeks ago had there been much sign of the silvery little fish.
>
> Time after time, the men dipped their long-handled nets into the water, lifted, and dipped again. Neither was there much reward for the efforts of the two men who were dipping from a boat anchored in the middle of the river.
>
> Still, the dippers knew, the smelt could suddenly show again at any time.
>
> For many anglers, however, the arrival of smelt in the Umpqua raises hope not so much for a tasty fried meal as the oncoming of the great white sturgeon. Like the gulls and the people, these huge fish come running when the smelt are running. [Online at http://news.google.com/newspapers?id=CxMRAAAAIBAJ&sjid=K-ADAAAAIBAJ&pg=2919,1791554&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 26 February 1976, p. 2B

On the Outside [column head], Conditions Remain Lousy for Anglers, by Pete Cornacchia

> Smelt are running again in the lower Umpqua. …
>
> Smelt were back in the Umpqua at Scottsburg early in the week but they were running deep and in the middle of the river. Dippers in boats took some 25-pound limits on the evening low tides. [Online at http://news.google.com/newspapers

?id=HRMRAAAAIBAJ&sjid=K-ADAAAAIBAJ&pg=6253,6671366&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Tuesday, 25 January 1977, p. B1

Steelies in Mind, Smelt in Net, by Pete Cornacchia

> And that's where we finally came upon a gathering of fish [on the Siuslaw River].
>
> Scattered over the sand and gravel along the shallow edges, like purplish noodles, were rafts of smelt.
>
> O'Neal grabbed the big landing net and went splashing and slashing through the shallows like an Alaskan brown bear ankle-deep in sockeyes. But the mesh, of course, was too wide for dipping fish six to seven inches long. So he folded the cords over in a wad and tied them so that the net looked more like King Kong's fly swatter.
>
> Then he stood in one spot while I circled around and drove the scurrying groups of smelt past him, where he flipped them onto the bank in quick scoops. Before the little devils finally tired of all this nonsense and departed, we managed to gather enough for a meal or two. …
>
> For either steelhead or smelt, however, the much larger Umpqua should offer better prospects than the Siuslaw in the next month. While the unpredictable smelt usually are beginning to arrive in both streams about this time, the Umpqua normally draws a much greater run over a longer period. [Online at http://news.google.com/newspapers?id=KYoQAAAAIBAJ&sjid=KuADAAAAIBAJ&pg=3816,6033795&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 3 February 1977, p. 2B

Outlook for Outside [lead-in head], Prospects Remain Poor for Anglers, by Pete Cornacchia

> No smelt are evident yet in the Scottsburg vicinity on the Umpqua, reports Ben Carlson at Greenacres. [Online at http://news.google.com/newspapers?id=UXwRAAAAIBAJ&sjid=mtkDAAAAIBAJ&pg=4244,542469&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 24 March 1977, p. 3B

Outlook for Outside [lead-in head], Chinook Caught in Lower Rivers, by Pete Cornacchia

> Still no sign of smelt in the Scottsburg area. …
>
> At midweek, state police reported that the heavy smelt run in the Sandy [River] was on the decline but dippers were still doing fairly well at Troutdale. The fish have been staying in the deepest water during the day and running close to the banks only at night. [Online at http://news.google.com/newspapers?id

=2XkRAAAAIBAJ&sjid=JOADAAAAIBAJ&pg=4351,5873279&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 2 February 1978, p. 2B

Outlook for Outside [lead-in head], Lower Umpqua Good for Smelt, Sturgeon, by Pete Cornacchia

> Smelt dippers are still doing well around Scottsburg State Park, according to Ben Carlson in Ben's Bait and Tackle Shop at Green Acres. He reported that 25-pound limits have been rare but dippers have been taking fish consistently at night and at low tide. Daytime dipping has been better from boats in midstream than from the bank. [Online at http://news.google.com/newspapers?id=cHARAAAAIBAJ&sjid=7uEDAAAAIBAJ&pg=6680,369906&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 23 February 1978, p. 6B

Outlook for Outside [lead-in head], Bay Catches Better, But Streams Stingy, by Pete Cornacchia

> … The Umpqua … has been slow … for smelt at Scottsburg. [Online at http://news.google.com/newspapers?id=hXARAAAAIBAJ&sjid=7uEDAAAAIBAJ&pg=6645,6113567&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, Feb 15, 1979, p. 2C

Outlook for Outside [lead-in head], Smelt Make their Move, But Not the Steelhead, by Pete Cornacchia

> The slowly receding waters have brought a new batch of smelt to the lower Umpqua but no great upswing in catches for steelhead anglers on most other streams.
>
> The Umpqua was high and muddy Wednesday after rising five feet from the previous day, but smelt dippers on the bank and in boats were doing well at Scottsburg Park, reported John Johnson, state fisheries biologist at Reedsport. [Online at http://news.google.com/newspapers?id=724RAAAAIBAJ&sjid=_uEDAAAAIBAJ&pg=6561,4446377&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 7 February 1980, p. 2D

On the Outside [lead-in head], Siuslaw Good Steelhead Bet, by Pete Cornacchia

> … Increasing sturgeon activity at Gardiner on the lower Umpqua points to the arrival of smelt, though dippers have not found much sign of the latter up at Scottsburg. …

Lower Umpqua and Smith rivers: … Some smelt are showing. The run is not large enough to dip. [Online at http://news.google.com/newspapers?id=uBoRAAAAIBAJ&sjid=1OEDAAAAIBAJ&pg=6685,1874436&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 28 February 1980, p. 4B

On the Outside [lead-in head], Streams Are High, Fish Are Dark, by Pete Cornacchia

The lower Umpqua remains slow … and smelt dippers at Scottsburg no longer have much hope of getting a run this winter. [Online at http://news.google.com/newspapers?id=xRoRAAAAIBAJ&sjid=1OEDAAAAIBAJ&pg=4258,7969800&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 19 February 1981, p. 2B

Brood Rainbows Planted in Ponds, by Pete Cornacchia

… smelt could be pleasing dippers near the head of tidewater at Scottsburg before long. A big rise often will bring a rush of these unpredictable fish, which may arrive any time from January into spring and sometimes never show. Dippers on the bank usually will do better when the river is up and colored, rather than low and clear, for the smelt frequently will be running along the edge of the water instead of deep in midstream. [Online at http://news.google.com/newspapers?id=EHERAAAAIBAJ&sjid=S-IDAAAAIBAJ&pg=6662,5105936&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 5 March 1981, p. 7B

Cold Water Hasn't Helped Fishing Prospects, by Pete Cornacchia

Lower Umpqua: … No smelt showing. [Online at http://news.google.com/newspapers?id=_EkVAAAAIBAJ&sjid=SuIDAAAAIBAJ&pg=6624,1285997&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 11 February 1982, p. 2C

Outlook for Outside [lead-in head], It Depends on the Weather, by Pete Cornacchia

… Smelt dippers are still waiting for another batch to show near the head of tidewater at Scottsburg [on the Umpqua River], where a small run faded soon after appearing about two weeks ago. [Online at http://news.google.com/newspapers?id=wnERAAAAIBAJ&sjid=XOIDAAAAIBAJ&pg=3596,2269070&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 17 February 1983, p. 2C

Outlook for Outside [lead-in head], Steelhead There, But Fishing Isn't, by Pete Cornacchia

> … Little sign of smelt has been reported in the Scottsburg area. [Online at http://news.google.com/newspapers?id=k3ERAAAAIBAJ&sjid=WeIDAAAAIBAJ&pg=6567,3925333&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Tuesday, 15 March 1983, p. D1

Spring Fever, by Pete Cornacchia

> The only smelt seen in the Umpqua this winter have come from the market, which may be the chief reason for the generally poor response from sturgeon. [Online at http://news.google.com/newspapers?id=0soTAAAAIBAJ&sjid=QOIDAAAAIBAJ&pg=6221,3529041&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 23 February 1984, p. 6C

Outlook for Outside [lead-in head], Lake Creek Fishing Good, by Pete Cornacchia

> The high water has brought no sign of smelt in the lower Umpqua or in the Sandy on the Columbia. [Online at http://news.google.com/newspapers?id=uGoVAAAAIBAJ&sjid=juEDAAAAIBAJ&pg=6505,5503108&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 14 February 1985, p. 2C

The Coastal Streams Too Full to Fish, by Pete Cornacchia

> Very little sign of smelt in the Columbia, Sandy and Umpqua. [Online at http://news.google.com/newspapers?id=McUUAAAAIBAJ&sjid=i-EDAAAAIBAJ&pg=6681,3015823&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 7 March 1985, p. 2B

Outlook for Outside [lead-in head], State's Angling Action is Better on the Coast, by Pete Cornacchia

> Despite a lack of smelt as attractive forage, the lower Umpqua has been yielding a fair number of sturgeon … . [Online at http://news.google.com/newspapers?id=j2oVAAAAIBAJ&sjid=iOEDAAAAIBAJ&pg=6658,1567378&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 14 March 1985, p. 2B

Outlook for Outside [lead-in head], Trout Plants Spice Action, by Pete Cornacchia

> Apparently this will be another year in which smelt dippers will not be taking very many fish from the Sandy or Umpqua. Smelt entered the Sandy last week but have remained below the Interstate 84 bridge, where state police report dipping has not been worth the effort. [Online at http://news.google.com/newspapers?id=lWoVAAAAIBAJ&sjid=iOEDAAAAIBAJ&pg=6742,3370082&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 30 January 1986, p. 3C

Outlook for Outside [lead-in head], Steelheading Good on Upper Siuslaw, by Pete Cornacchia

> … No smelt have been reported [on the Umpqua River]. [Online at http://news.google.com/newspapers?id=12AVAAAAIBAJ&sjid=BeEDAAAAIBAJ&pg=4531,6382367&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 27 February 1986, p. 2B

Outlook for Outside, Fishing

> Lower Umpqua: … No smelt reported. [Online at http://news.google.com/newspapers?id=JsUUAAAAIBAJ&sjid=kOEDAAAAIBAJ&pg=3330,6304140&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 19 February 1987, p. 2B

Outlook for Outside [lead-in head], Coast Rivers Improve But Not Fishing, by Pete Cornacchia

> Lower Umpqua: … No smelt have shown so far. [Online at http://news.google.com/newspapers?id=Z2kVAAAAIBAJ&sjid=fOEDAAAAIBAJ&pg=5540,4244267&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 21 January 1988, p. 2D

Outlook for Outside [lead-in head], Conditions Improve for Steelhead Anglers, by Pete Cornacchia

> Lower Umpqua [under subhead Angling]: … No smelt have shown. [Online at http://news.google.com/newspapers?id=5msVAAAAIBAJ&sjid=n-EDAAAAIBAJ&pg=2617,4250273&dq=site:news.google.com+Umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday 11 February 1988, p. 1D-2D

Cowlitz Smelt a Quick Catch for Dipnetters, by Pete Cornacchia

> Smelt also used to make frequent January-April appearances in Oregon's Umpqua but have forsaken this river in recent years. [Online at http://news.google.com/newspapers?id=FmwVAAAAIBAJ&sjid=p-EDAAAAIBAJ&pg=5029,2166079&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 2 March 1989, p. 2D

Outlook for Outside, Angling

> Lower Umpqua: … No smelt have shown yet. [Online at http://news.google.com/newspapers?id=0W0VAAAAIBAJ&sjid=seEDAAAAIBAJ&pg=4949,391197&dq=site:news.google.com+umpqua+smelt&hl=en]

Eugene Register-Guard, Thursday, 23 March 1989, p. 2D

Outlook for Outside, Angling

> Lower Umpqua: … no harvestable numbers of smelt. [Online at http://news.google.com/newspapers?id=420VAAAAIBAJ&sjid=seEDAAAAIBAJ&pg=2299,6102792&dq=site:news.google.com+umpqua+smelt&hl=en]

Washington

Vancouver Register (Washington Territory), Wednesday, 6 April 1867, p. 3, col. 1

> Smelt—This delicate fish, which has never before been known to come up higher than Lewis River, has made its appearance off this city in large numbers. They can be caught by hand—evening, just after dark is the best time.

Kalama Beacon (Washington Territory), Friday, 1 March 1872, p. 1, col. 1

> A Piscatorial Exploit—A few days ago, at Camp Enterprise on the Cowlitz, Johnny McGrath, who "runs" things there, performed a feat at smelt catching that places him in the van of fishers. With a little dip net of only 16 inches diameter across the open end, he stood on the river bank and caught by scooping two barrels of fish within half an hour! In the lower Columbia River tributaries this species of herring are now running in schools of myriads, and literally fill the Cowlitz in shoals that occupy the entire space of the stream; and what is singular, although apparently moving forward up the river, there is at present no diminution of their volume.

Kalama Beacon, (Washington Territory), Friday, 22 March 1872, p. 1, col. 1

The Smelts—These piscatory phenomenon seemed to pass the rear of their column up the Cowlitz and tributaries last week. There seems to be no return of any portion of them downstream; and whither they are tending, and where can such myriads find room at the head of the Cowlitz, is something that would not be an inappropriate study for an Agassiz, or some other piscatorial student.

Kalama Beacon, (Washington Territory), Saturday, 8 February 1873, p. 1, col. 2

A Piscatory Advent—The annual return to the Cowlitz River of that delicious little fish called the smelt commenced a couple of weeks ago, and the river is literally alive with them. With a scoop net of about 15 to 20 inches in diameter, it is practicable to stand anywhere on the bank and scoop a barrel full in 10 or 15 minutes. The run will last about a month longer, but toward the latter end of the season they are pronounced inferior and the catch is abandoned. A few days ago, the steamer Rescue transported seven tons of these fish at once to fill orders from Portland.

Kalama Beacon, (Washington Territory), Tuesday, 10 February 1874, p. 1, col. 1

The Smelt Run—That delicious little fish is playing truant this season, so far. According to the period of their annual visits heretofore, they have been due in the Cowlitz for two or three weeks past; but they have not yet put in an appearance, and may fail altogether, as they do sometimes in streams frequented by them.

Daily Olympian, Monday, 16 March 1896, p. 3, col. 4

Fresh Supply of Fish

The Columbia Market today received a fresh supply of … Columbia River smelt … All fresh and nice. Columbia foot of Sixth.

Daily Olympian, Wednesday, 2 February 1898, p. 3, col. 1

Brevities of the Day

M. Giles of the Main Street Market has just received an invoice of fine Columbia River smelt.

Centralia Daily Chronicle, Wednesday, 3 February 1909, p. 3, col. 1

Fresh Columbia River Smelts, 5 c per Pound at Kent's Fish Market, Tower Avenue Phone 613 and Your Order Will Be Promptly Delivered

Centralia Daily Chronicle, Tuesday, 16 March 1909, p. 3, col. 2

The Last Run of Fresh Smelts Is On and Will Last Only a Few Days Longer
A Good Supply at Kent's Fish Market on Tower Avenue, 5 Cents per Pound, Phone 613

Centralia Daily Chronicle, Tuesday, 8 February 1910, p. 3, col. 2

The Columbia River Smelt Are Now In. Get Them at the Main Street Fish Market

Centralia Daily Chronicle, Thursday, 23 February 1911, p. 3, col. 1

Columbia River Smelt Can Be Had at the Main St. Fish Market and the Centralia Fish Market on North Tower Ave, 5 Cents per Pound

Centralia Daily Chronicle, Thursday, 1 February 1912, p. 3, col. 5

Centralia Fish Market
Columbia River Smelts, Per lb 5c

Centralia Daily Chronicle-Examiner, Thursday, 16 January 1913, p. 6, col. 6

Columbia River Smelts, 5c per Pound, City Fish Market, Carsten Building

Centralia Daily Chronicle-Examiner, Friday, 17 January 1913, p. 6, col. 2

Smelt Run Is On in Earnest

> Kelso, Jan. 17—Columbia River smelt, or Cowlitz River smelt, as they should be called, have come into the Cowlitz in ever increasing numbers since the fag end of last week, and fishermen now report that the run is a satisfactory one, although not extremely large. Monday saw the first large catch, more than one thousand boxes of 50 pounds each, or 50,000 pounds, being caught and shipped from Kelso. The gill nets have been discarded for the nets of the dip variety, and a force of a score or more of boats has been busy in midstream.

Centralia Daily Chronicle, Friday, 31 January 1913, p. 3, col. 6

We are Now Well Supplied with Choice Columbia River Smelt, Shipments Daily, 5 Cents a Pound, City Fish Market, Carstens Building

Centralia Daily Chronicle-Examiner, Monday, 10 February 1913, p. 6, col. 6

> 1,200,000 smelt were caught in the Cowlitz River last Sunday.

Olympia Daily Recorder, Wednesday, 14 January 1914, p. 2, col. 7

Run of Smelt Largest Ever in the Columbia

Portland, Ore., Jan. 14—The greatest run of smelt ever in the Columbia River is now being harvested. Fresh offerings of Columbia River smelt were quoted at 5 cents a pound today by the wholesale fish trade and there were indications that even this low price would be cut. The market is glutted.

Such heavy catches by gillnetters of the lower Columbia River were never before seen in this market. As a rule the gillnetters catch only limited supplies before the fish enter the Cowlitz, when they are caught in abundance with dip nets.

Centralia Daily Chronicle-Examiner, Tuesday, 23 February 1915, p. 3, col. 3

Heavy Smelt Run in Lewis

Kelso, Feb. 23—That the heavy run of smelt have passed up the Cowlitz River for this season seems certain from the enormous numbers of the tiny fish which have poured up the Lewis River during the past few days. Not satisfied with the Kalama River, which they first entered, the main run of the fish went into the Lewis River, and at the present time that stream looks like the Cowlitz at this season of other years. Smelt everywhere in the waters, filling it from bank to bank and all the way from the mouth far above Woodland.

Centralia Daily Chronicle, Wednesday, 17 March 1915, p. 3, col. 4

Big Smelt Run

Woodland, Wash., March 17—The great run of smelt in the Lewis River during the past month and which seemed to be decreasing last week has been increased by another run which started yesterday, and the fish coming now are of as good quality as have ever been caught here, but the price has ruled so low that there are not many fishermen taking them. Seagulls and other fish-eating birds are doing their best to clean them up. The gulls are on the river by the hundreds of thousands, their flight being almost solid at times, and the sand bars when covered by them look like a snow bank. Immense numbers of the little fish are lying dead in the river and a good rain, with a rise in the river, would be a great help, as it would wash the dead fish out. This is the first season in seven years the fish have come in here.

Centralia Daily Chronicle-Examiner, Wednesday, 31 March 1915, p. 1, col. 3

Smelt Come Too Late

Kelso, March 31—Too late to do the fishermen of the Cowlitz River any good, because the market is already loaded up and the price down, large numbers of smelt came into the river some time last week. For some unknown reason the smelt this year wandered everywhere except into the Cowlitz, which in seasons past has been their regular abode. This is the first run of smelt of any size in the Cowlitz this year.

Centralia Daily Chronicle-Examiner, Friday, 17 December 1915, p. 2, col. 2

Smelt Coming In

Kelso, Dec. 17—Smelt are coming into the Cowlitz River in increasing numbers, as shown by growing catches of the gillnetters. Gillnetting for smelt at this season of the year is profitable, as the fish bring 20 cents a pound. Later on the fishermen will be lucky to get that much a box.

Centralia Daily Chronicle-Examiner, Friday, 31 December 1915, p. 7, col. 5

Many Smelt Caught

Kelso, Dec. 31—Since the drop in the Cowlitz River smelt have been plentiful in the stream and gillnetting for them has been going on merrily. Many boxes of fish are being caught daily in this manner and the fishermen are getting good prices for them.

Centralia Daily Chronicle, Wednesday, 12 February 1920, p. 8, col. 4

Wait for Smelt

Kelso, Feb. 12—A few smelt have been caught in the Cowlitz River the past two years and fishermen are hopeful that a heavy run of the fish will soon appear in the stream. Smelt in large numbers were reported to be nearing the mouth of the Cowlitz just before the recent cold weather and fishermen think that they may soon be in the stream now that the ice is gone. Last year was the only one in the last three years that the smelt came into the Cowlitz, the main run going up the Lewis River in 1927 and 1928.

Centralia Daily Chronicle, Friday, 25 January 1929, p. 2, col. 5-6

Smelt Running

Longview, Jan. 25—The annual horde of smelt is coming up the Columbia River. The run is at present in the vicinity of Cathlamet, about 40 miles west of here, according to local fishermen. There is considerable conjecture here as to whether the shining silvery millions of little fish will journey up the Cowlitz or the Lewis rivers. The Cowlitz was the usual habitat until two years ago when they selected the Lewis, 30 miles further up stream. It was thought to be an "off year," which occurred once in about seven years previous. But last season the smelt passed by the Cowlitz and went up the Lewis again. Fishermen are scratching their heads and wondering which stream will be selected this year.

Centralia Daily Chronicle, Saturday, 23 February 1929, p. 4, col. 4

Smelt Overdue

Kelso, Feb. 23—The main run of Columbia River smelt into the Cowlitz or Lewis rivers is considerably past due and fishermen are waiting for the run to enter one of the streams. The run has gone up the Lewis River for the past two years. The fish have been caught by gillnetters in large quantities in the Columbia River near Rainier, Ore., recently. It is believed the cold spell and the low stage of water in the streams has held up the migration.

Centralia Daily Chronicle, Tuesday, 5 March 1929, p. 8, col. 5

Smelt Shipped

Kelso, March 5—Shipments of Columbia River smelt from Kelso have averaged 150 boxes a day during the past week, according to express company representatives. The fish are taken by gillnetters operating in the Columbia River, the run not having entered either the Cowlitz or Lewis rivers to date this year. Ordinarily the run enters one of the streams late in January or early in February and it has never been known to be as late as it has been this year.

Centralia Daily Chronicle, Saturday, 8 March 1930, p. 4, col. 1

Smelt Are Running—Stories of "smelt catches" are running rampant about town this week. The silvery fish entered the Cowlitz several days ago and are now reported to be working their way upstream between Ostrander and Castle Rock. A net on the end of a long pole, a little deftness in its use and one's smelt order is soon filled.

Chehalis Bee Nugget, Friday, 21 March 1930, p. 5, col. 2

Smelt at Toledo

For the past week the Cowlitz River bank has been crowded with people who are busy dipping smelt from the river.

Centralia Daily Chronicle, Wednesday, 31 December 1930, p. 8, col. 3

Smelt Are Running

Kelso, Dec. 31—A few Columbia River smelt, are being dipped from the Cowlitz River each night, but the run of fish this winter is lighter than the usual small midwinter run and the fish will be gone within a few days. The main run of smelt does not come into the Cowlitz until late in February ordinarily. Smelt are now selling at about 15 cents a pound.

Centralia Daily Chronicle, Thursday, 29 January 1931, p. 4, col. 4

Smelt Run Begins

Longview, Jan. 29—(AP)—The smelt run is on! Innumerable thousands of the little fish are wriggling their way up the Cowlitz River today after meandering for several weeks in the Columbia below here. Several score boxes were packed from last night's dipping by eager commercial fishermen and heavy shipments to outside points have begun. The fish sell locally at four pounds for 25 cents.

Centralia Daily Chronicle, Saturday, 21 February 1931, p. 5, col. 3

Smelt Still Run

Kelso, Feb. 21—Heavy rains the past few days, which brought the Cowlitz River up several feet, have not interfered with the run of smelt that came into the river early this month, and heavy catches of fish were made the past two days. A new run of fish came into the Cowlitz this week. The demand for the fish is holding firm and heavy shipments are going out by rail, truck and boat daily.

Centralia Daily Chronicle, Thursday, 12 March 1931, p. 2, col. 2

Smelt Still Run

Kelso, Mar. 12—Another heavy run of smelt came in the Cowlitz River Sunday. They are of fine quality and fishermen are catching great quantities of them. The markets are holding up well this year and heavy shipments continue by rail, mail and truck. Distribution of smelt by truck has been developing on a large scale, and trucks now carry the smelt to points as far distant as Idaho and northern California.

Centralia Daily Chronicle, Tuesday, 22 December 1931, p. 3, col. 5

First Smelt of Season Show Up

Kelso, Dec. 22—(AP)—Mother Nature presented Cowlitz County a Christmas present today when the first smelt of the season appeared in the Cowlitz River. Johnny Wannassay, veteran Indian smelt fisherman, dipped the first catch. It ran about 200 pounds. For several years Wannassay has beaten other fishermen to this honor.

This first run [of] smelt is small. In fishing parlance it is called the scout run and precedes a major or larger run. The smelt come into the Cowlitz in large schools between December and May. When smelt fishing is at its height approximately 200 men find employment in dipping, packing and processing the fish, which are shipped to all parts of the world in one form or another.

Centralia Daily Chronicle, Wednesday, 6 January 1932, p. 8, col. 6

Quality of Smelt Unusually Good

Portland, Jan. 6—(AP)—"The smelt are running." This was the call today from many Columbia River and Cowlitz River points as hordes of the small fish piled up stream in silvery waves. Reports from the two streams said the run is one of the earliest large invasions on record, and it was taken by many to presage an early spring.

Dealers here report the quality of the fish this year is unusually good. The present showing is regarded as rather spectacular and wholly unexpected. Many unemployed persons are working with dip nets on the two rivers. Fancy smelt are selling in Portland markets as low as three pounds for 25 cents.

Centralia Daily Chronicle, Monday, 1 February 1932, p. 2, col. 8

May Plant Smelt

Kelso, Feb. 1—Another attempt will probably be made this year by the state fisheries department to transplant Columbia River smelt to streams flowing into Puget Sound. Attempts have been made in the past and a large number of smelt were planted in the Nisqually River several years ago. Floyd [Lloyd] Royal of the state biological department is making a study of the matter here, and it is probable that smelt spawn will be hatched in the state hatchery on the Kalama River and the young smelt planted in both the Snohomish and Skagit rivers if the attempt to hatch them proves successful. The smelt are believed to have a four-year cycle, returning to their native stream after four years, to spawn.

Centralia Daily Chronicle, Monday, 4 April 1932, p. 4, col. 7

Smelt Run Ends

Kelso, April 4—(AP)—The annual smelt run in the Cowlitz River appears to be over and from other points comes word that catches in the Lewis River and in the Sandy River near Portland are also practically nil. Shipments from Kelso last Friday, when catches made before the closed period beginning Friday morning were sent to market, were very light and yesterday several fishing boats that went as far upstream as the regulations permit, found no smelt worth dipping in the Cowlitz River.

Centralia Daily Chronicle, Wednesday, 4 January 1933, p. 6, col. 5

Smelt Running

Longview, Jan. 4—(AP)—The annual winter run of smelt, forerunner of a spring run to come a month or two later, is hovering in the mouth of the Cowlitz River this week. The run has been proceeding slowly up the Columbia River for the past several weeks. Gillnetters in the Columbia are making most of the catches while a few commercial fishermen with dip nets are operating in the Cowlitz.

Centralia Daily Chronicle, Monday, 7 April 1933, p. 3, col. 2

Fish Notes—Smelt fishing in the Cowlitz River ended several days ago, but the seagulls remained to do their own fishing. Now, according to fishermen returning from the river, each day sees fewer gulls hovering over the water. This is taken as a sure indication that the smelt run is just about over.

Centralia Daily Chronicle, Wednesday, 28 February 1934, p. 6, col. 2

Smelt Season—Smelt are in the Cowlitz River but in "straggly" quantities, according to fishermen who have been after them with nets. Welfare people here received smelt yesterday that were collected at Castle Rock by fish inspectors, who took them from persons having in their possession more than the legal limit of 20 pounds. The Cowlitz is closed from 8 a. m. Friday to 8 p. m. Saturday to both individual and commercial fishermen.

Centralia Daily Chronicle, Friday, 1 February 1935, p. 8, col. 2

Shipping Smelt

Kelso, Feb. 1—The largest shipments of Columbia River smelt of the year have been made from here the past few days. Approximately 400 boxes, or more than 10 tons of the fish have been shipped daily by express to the more distant points and by truck to Portland and Puget Sound.

The heaviest shippers are the Columbia River Smelt Company and the Central Smelt Company. The latter is an organization of gill-net operators.

Centralia Daily Chronicle, Thursday, 5 December 1935, p. 14, col. 3

Smelt Running

Longview, Dec. 5—(AP)—The first smelt run of the 1935–36 season was reported off Clatskanie, in the lower Columbia River, today. A small shipment was made from that point to Portland markets yesterday, and two boxes were shipped from Kelso.

Smelt takes so far are males, indicating them to be the advance, or scout run. The female schools are due later.

California

Daily Evening Bulletin (San Francisco), Friday, 5 December 1879, p. 1, col. 1

> Candle Fish of the Klamath—A very odd fish is found in large numbers in the Klamath, near its mouth. They are called candle fish. When grown, they are only six or eight inches long. They are very full of oil, which seems to be distributed all through their bodies. Dry them thoroughly and light either end and they will burn with as bright a light as a candle, and for about as long a time. Hence their name. They can be caught abundantly with seines. In their dry state they are quite pleasant to eat, the oil in them not having an odor or disagreeable flavor.

San Francisco Call, Saturday, 2 May 1908, p. 12, col. 5

> Redwood City, May 1—The local Izaak Waltons, who have been pressed for time, have been enjoying good fishing within the city limits. Redwood Creek, especially, near the works of the Alaska Codfish Company, is teeming with smelt, some of those recently caught running over a foot in length.

San Jose Mercury Herald, Saturday, 15 February 1919, p. 5, col. 4

Candle Fish Run Opens in the North

> Eureka, Cal., Feb. 14—The yearly run of candle fish has begun in the Klamath River and fishermen state that it exceeds in volume anything heretofore recorded. It is said that if any means could be found of canning this fish a new product of high food value could find its way to the market. The candle fish is particularly rich in valuable oils.

Humboldt Standard (Eureka), Thursday, 21 February 1952, p. 9, col. 7–8

Around Our Town, by Scoop Bean

> Scattered Notes—Candle fish are running in the Klamath River—they are caught at night with dip nets—the fish are said to have received their present name from early white settlers who sometimes inserted a wick in the smoked fish for a source of candlelight.

Humboldt Standard (Eureka), Friday, 1 April 1955, p. 10, col. 3–5

How're They Biting? by Chet Schwarzkopf

> … Jack Morris, maestro at Blue Creek Lodge on the Klamath, … says … "I guess you know we also have a big run of candlefish each spring that affords the people here lots of fun as well as good eating."

Humboldt Standard (Eureka), Wednesday, 10 April 1963, p. 10, col. 3

Heavy Candlefish Run in Klamath

Klamath—Meat market sales showed a sharp decline around Klamath over the weekend and Monday. Almost everyone was eating crisp-fried candlefish. Awaited by the old-timers, as a heavy run of candlefish seems to herald a good salmon and steelhead fishing season to come, word spread fast, when the "run" started, a little late this year. Most popular "dipping" area was near the public boat ramp in the Klamath Glen area, perhaps due to easy accessibility.

Owners of the large nets needed to dip for these small fish reported a "turn-over" practically every hour, as each one borrowing it returned the net within a very short time. A few dips netted each one their limit in pounds, and more than enough to feed their families.

Humboldt Standard (Eureka), Monday, 15 April 1963, p. 13

Thousands of Candlefish in Heavy Redwood Creek Run

[Photo caption 1:] Joe January of Sacramento dips up a net load of candlefish at the mouth of Redwood Creek near Orick. Thousands of the silvery fish, called Columbia River smelt in most waters, are running in the creek and the Klamath River, heading upstream to spawn. According to local Fish and Game authorities, this is the first time candlefish have run up Redwood Creek in large numbers. Normally the fish are found only in the Klamath River and a few other northern rivers.

[Photo caption 2:] Commercial fishermen net candlefish in the ocean at the mouth of Redwood Creek. Left to right are Fred Shipman, Stanley Dombek and Lawrence Lazio. Commercial catches must be made in salt water.

[Photo caption 3:] A herd of sea lions enjoys a feast of candlefish as the silvery smelt run by the thousands at Redwood Creek. Fish derive their local name from the fact Indians dried them and used them for candles.

[Photo caption 4:] Silvery candlefish measure five to six inches in length, with a few up to nine inches. Thousands of the small smelt are running up Redwood Creek and the Klamath River to spawn.

[Photo caption 5:] Lawrence Lazio of Eureka demonstrates the density of the current candlefish runs by catching them with his hands. Many people lacking nets did just that and caught enough fish for a large fish fry.

[Photo caption 6:] Fred Shipman, left, and Stanley Dombeck deliver a large commercial catch of candlefish to a local fish company. The smelt will be sent to the Bay Area and Los Angeles.

Humboldt Standard (Eureka), Tuesday, 16 April 1963, p. 7

Candlefish Running in Mad River

> [Photo captions:] Local fishermen use nets for an unusual run of silvery candlefish in the Mad River. In top photo, two unidentified men watch as Bill Damgaard, left, and Bob Hoffman, both of McKinleyville, wade into the water to net the fish. Mrs. Sarah Gillman, below, of McKinleyville, empties her net laden with candlefish into a bucket. Heavy runs of the fish, also known as Columbia River smelt, also are reported in Redwood Creek and the Klamath River.

Humboldt Standard (Eureka), Tuesday, 23 April 1963, p. 20

Surf Netters Catch Candlefish near Redwood Creek

> [Photo caption:] Countless candlefish are still running at Redwood Creek, this time in the Pacific surf. Scores of fishermen took advantage of Sunday's spring weather to enjoy the sport and prepare for a fish fry. The silvery fish, commonly called Columbia River smelt, derived their local name from the fact Indians used them as candles. The fish normally run only in the Klamath River and other northern streams but recently heavy runs have been reported in Redwood Creek and Mad River and now in the surf.

Humboldt Standard (Eureka), Friday, 9April 1965, p. 13, col. 1

Sideline Slants[column head], Candlefish Run Top Weekend Prospect, by Don Terbush

> The annual spawning run of candlefish is on in the Klamath River and the oily rascals are said to be numerous. Big runs are usually followed by large runs of salmon, according to veteran anglers along the river.
>
> Don't forget—a valid fishing license is required.

Times-Standard (Eureka), Thursday, 14 March 1968, p. 19, col. 1

Anglin' Around, by Ray Peart

> Candlefish at Klamath—It has started. The small fish called candlefish or eulachon are making their spawning run up the Klamath and should be found in Redwood Creek and Mad River soon.
>
> Eulachon normally die after spawning, but Marine Resources biologists tell me they have recovered a few spawned-out fish in the ocean while conducting shrimp sampling cruises.
>
> The eulachon (Thaleichthys pacificus) was first recorded from British Columbia waters in 1866 by A. Gunther on the basis of four specimens eight to nine inches in length, collected near Vancouver Island by C. B. Wood, surgeon on HMS Plumper, and presented to the British Museum. The fish is common along the whole coast of British Columbia, and enters large rivers during March, April

and May to spawn. It matures at two to three years of age and usually dies after spawning. The average female spawns 25,000 eggs which hatch in two to three weeks. The young are then carried by the current to the sea where they mature.

In the old days, eulachon were used extensively by Indians for food and production of oil for cooking. Previous to the advent of manufactured candles and other lighting devices, these fish were dried, fitted with wicks and used as candles, hence the frequently used name, candlefish.

Most people now smoke the fish, and some of the oil is worked out this way. They are very rich. Others pickle them. A gourmet treat is the roe from females mixed with salami and eggs, made into patties and fried.

Last year there was a huge run of candlefish in Redwood Creek. For eight days, these small dry-feeling fish swam up past Orick in a continuous school from bank to bank. That was around the first week in April.

It's fun to net these fish. Take the family for a day at the beach. The limit is 25 pounds and you do need a license. Check the 1968 Sport Fishing Regulations for new rules concerning netting candlefish in Redwood Creek and Mad River.

Times-Standard (Eureka), Wednesday, 16 April 1969, p. 21, col. 5

Candlefish Run Again in Klamath

Klamath—Large catches of candlefish have been taken from the Klamath River this past week, and were still running heavily Sunday evening.

Quite a number of fish are brought up each dip of the large nets used. The heavy run is late this year, as usually the month of March is the time of most of the run. A number of the local people smoke large quantities of the fish, as well as those who enjoy them just fried very crisp.

Candlefish are similar to the Columbia River smelt. A heavy concentration of seagulls and large groups of sea lions accompany the run. Several days last week, the sand spit at the mouth of the river was covered with the sea lions, as they sunned themselves, after dining on the fish, no doubt.

Times-Standard (Eureka), Friday, 19 March 1971, p. 11, col. 1

Sideline Slants [column head], Candlefish Running, by Steve Terbush

"Candlefish are running at the mouth of the Klamath River," was Bill Dimmick's comment from Orick. "I've seen a lot of nets heading that way."

Times-Standard (Eureka), Friday, 5 May 1972, p. 19, col. 1

Sideline Slants, by Steve Terbush

Mrs. Paul observes from Klamath that "this has been a wonderful candlefish year and that usually means a good salmon year on the Klamath River."

Times-Standard (Eureka), Friday, 16 April 1976, p. 13, col. 1

Sideline Slants, by Steve Terbush

> Humboldt County Fish hatchery chief Steve Sanders … noted that "they are still picking up candlefish at Redwood Creek. The catches are light although some limits are being taken."

Times-Standard (Eureka), Friday, 23 April 1976, p. 9, col. 1

Sideline Slants, by Steve Terbush

> Candlefish in the Klamath, Redwood Creek and Mad River … are the major items of interest to North coast sports anglers this weekend.
>
> "There are lots of candlefish in the Mad River," reports hatchery superintendent Bob Will. "Last weekend it was hot. They are higher up than I've ever seen them—clear up to Blue Lake which is unusual. Of course, the fishing area is only open to the railroad bridge at Essex.
>
> "About every third year there are always a few," Bob added. "This year it seems there is an extraordinary amount."
>
> "They are still picking up candlefish in Redwood Creek, said Humboldt County Fish Hatchery chief Steve Sanders. "And I would recommend Stone Lagoon for fishing. There's not much pressure and I'm sure there are fish in there. If they (anglers) have a boat all the better."

Appendix C: Selected Accounts of Eulachon in Early Historical References

[Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting minor misspellings without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncrasies of spelling and phrasing in these older works are generally preserved.]

Klamath River

Autobiography of Clarence E. Pearsall (Pearsall 1928, p. 1614)

Early 1890s

> At other times, with a single haul of their dip nets they [the Yurok fishers] caught fifteen or twenty pounds of quah-rah [candlefish], a small fish that when thoroughly dried burns like a candle.

Columbia River

Journal of Patrick Gass [Sergeant on the Lewis and Clark Expedition] (Gass 1807, p. 194–197 in Moulton's 1996 reprint edition)

25 February 1806 (Fort Clatsop)

> Tuesday 25. The rain continued and the weather was stormy. About 10 o'clock the Natives went away, though it continued to rain very fast. They brought us yesterday a number of small fish [eulachon], of a very excellent kind, resembling a herring, and about half the size.

26 February 1806 (Fort Clatsop)

> Wednesday 26. We had a fair morning; some of the hunters went out, as our store of provisions was getting small, and three men went in search of these small fish, which we had found very good eating.

2 March 1806 (Fort Clatsop)

> Sunday 2. This day was also wet. The fishing party returned at night, and brought with them some thousands of the same kind of small fish, we got from the Natives a few days ago, and also some sturgeons.

6 March 1806 (Fort Clatsop)

> Thursday 6. Our stock of provisions being nearly exhausted, six men were sent out in different directions to hunt, and three more were sent to endeavor to procure some fish, as the Natives take a great number of the small fish about 20 miles distant from the fort by water.

9 March 1806 (Fort Clatsop)

> In the afternoon some of the Natives came to visit us, and brought some of the small fish, which they call ulken.

11 March 1806 (Fort Clatsop)

At noon our fishermen returned with some ulken and sturgeon.

The Definitive Journals of Lewis and Clark, Down the Columbia to Fort Clatsop (Moulton 1990)

24 February 1806 (p. 342–344)

> This evening we were visited by Comowooll the Clatsop Chief and 12 men women & children of his nation. … The chief and his party had brought for sail … a species of small fish which now begin to run, and are taken in great quantities in the Columbia R. about 40 miles above us by means of skiming or scooping nets. On this page I have drawn the likeness of them as large as life; it is as perfect as I can make it with my pen and will serve to give a general idea of the fish. The rays of the fins are boney but not sharp tho' somewhat pointed. The small fin on the back next to the tail has no rays of bone being a thin membranous pellicle. The fins next to the gills have eleven rays each. Those of the abdomen have eight each, those of the pinna-ani [anal fin] are 20 and 2 half formed in front. That of the back has eleven rays. All the fins are of a white colour. The back is of a bluish duskey colour and that of the lower part of the sides and belley is of a silvery white. No spots on any part. The first bone of the gills next behind the eye is of a bluis cast, and the second of a light goald colour nearly white. The puple of the eye is black and the iris of a silver white. The underjaw exceeds the upper; and the mouth opens to great extent, folding like that of the herring. It has no teeth. The abdomen is obtuse and smooth; in this differing from the herring, shad anchovey &c of the Malacopterygious Order & Class Clupea, to which however I think it more nearly allyed than to any other, altho' it has not their accute and serrate abdomen and the underjaw exceeding the upper. The scales of this little fish are so small and thin that without minute inspection you would suppose they had none. They are filled with roes of a pure white colour and have scarcely any perceptable alimentary duct. I find them best when cooked in Indian stile, which is by roasting a number of them together on a wooden spit without any previous preparation whatever. They are so fat they require no additional sauce, and I think them superior to any fish I ever tasted, even more delicate and lussious than the white fish of the lakes which have heretofore formed my standart of excellence among the fishes. I have heard the fresh anchovey much extolled but I hope I shall be pardoned for believing this quite as good. The bones are so soft and fine that they form no obstruction in eating this fish. We purchased all the articles which these people brought us …. The sturgeon which they brought us was also good of it's kind. We determine to send a party up the river to procure some of those fish.

2 March 1806 (p. 368)

> … late this evening Drewyer arrived with a most acceptable supply of fat sturgeon, fresh anchovies [eulachon] and a bag containing about a bushel of wappetoe. We feasted on anchovies and wappetoe.

4 March 1806 (p. 378)

> The anchovey [eulachon] is so delicate that they soon become tainted unless pickled or smoked. The Natives run a small stick through their gills and hang them in the smoke of their lodges, or kindle a small fire under them for the purpose of drying them. They need no previous preparation of guting &c and will cure in 24 hours.

The Definitive Journals of Lewis and Clark, From the Pacific to the Rockies (Moulton 1991)

16 [March 1806] (p. 44)

> The anchovey [eulachon] had ceased to run; the white salmon trout [steelhead] have succeeded them.

25 March 1806 (p. 12)

> ... at noon we halted and dined. Here some Clatsops came to us in a canoe loaded with dryed anchovies [eulachon], which they call olthen [Chinookan ú-lxan, meaning dried eulachon], wappetoe and sturgeon.

29 March 1806 (Sauvies Island) (p. 27)

> They had large quantities of dryed anchovies [eulachon] strung on small sticks by the gills and others which had been first dryed in this manner were now arranged in large sheets with strings of bark and hung suspended by poles in the roofs of their houses.

The Journals of John Ordway [Member of the Lewis and Clark Expedition] May 14, 1804–September 23, 1906, (Moulton 1995, p. 275–278)

2 March 1806 (Fort Clatsop)

> … in the evening the three men returned from the village with a considerable quantity of the little fish [eulachon] resembling herren [sic] only a size smaller—and some sturgeon and a few wapatoes, which they purchased from them. The Natives catch a vast quantity of fish.

9 March 1806 (Fort Clatsop)

> Several of the Clatsop Indians came to the fort with some small fish [eulachon] … to trade to us.

11 March 1806 (Fort Clatsop)

> Sergt. Pryor returned with a considerable quantity of small fish and sturgeon.

21 March 1806 (Fort Clatsop)

> … a number of Natives visited us with some dryed small fish to trade which they call in their language oll-can [dried eulachon].

The Journals of Joseph Whitehouse [Sergeant on the Lewis and Clark Expedition], May 14, 1804–April 2, 1806 (Moulton 1997, p. 423–430)

26 February 1806 (Fort Clatsop)

> … 2 of our men went in a canoe in order to go to the Clatsop & Cathlameht Village in order to purchase some fish from the Natives. We found the fish that we had purchased from them 2 days past, to be well tasted & fat, especially the small fish [eulachon], which had the resemblance of a herring but much better tasted.

2 March 1806 (Fort Clatsop)

> In the evening, three of our men returned who had been trading at the Clatsop Village. They brought with them a considerable quantity of those small kind of fish, which we purchased from the Natives some days past; these fish were a size smaller than the herring. … The Natives gave them some fish without any recompence being made to them. These Indians catch great quantities of different kinds of fish in a creek lying a small distance above their village.

5 March 1806 (Fort Clatsop)

> … a number of the Natives came in canoes to the fort. They brought with them some sturgeon & some small fish [eulachon] to trade with us. Our officers purchased the whole of them.

17 March 1806 (Fort Clatsop)

> … purchased from the Natives … a few small fish [eulachon], the small fish not unlike a herring getting scarce among the Natives.

21 March 1806 (Fort Clatsop)

> The Natives came to the fort & brought some dried fish, which the Indians called all-can [dried eulachon], we purchased some of these fish from them.

The Discovery of the Oregon Trail: Robert Stuart's Narratives of his Overland Trip Eastward from Astoria in 1812–13 (Rollins 1995)

1812 (p. 8)

> … the dreary months of January and February, after which sturgeon and uth-le-chan [eulachon] may be taken in great numbers, the former sometimes by the spear, but more generally by the hook and line; and the latter by the scoop net. The uthlechan is about six inches long and somewhat similar to our smelt, is a very delicious little fish, and so fat as to burn like a candle, and are often used for that purpose by the Natives.

1 July 1812 (p. 30)

> Here are the best and almost only fisheries of uthulhuns [eulachon] and sturgeon—the former they take in immense numbers by the operation of the scoop net from the middle of March till the middle of April, and the latter [principally] by the hook and line during the spring and fall seasons—the uthulhuns are a kind of smelt, and when dried for preservation, are much similar to smoked herrings.

Wilson Price Hunt's Diary of his Overland Trip Westward to Astoria in 1811–12 (Rollins 1995, p. 308)

15 February 1812

> On the 15th, we passed several large islands. The land on the left bank was covered with oaks and ash trees, but all was inundated. I stopped at some Indian huts where I found four of our fellow countrymen who were bartering for sturgeon and were fishing for excellent small fish, which were about six inches long. The Indians call them othlecan [eulachon], and catch many of them in the springtime.

A Voyage to the Northwest Coast of America (Franchère 1968, p. 180)

> February brings a small fish about the size of a sardine. It has an exquisite flavor and is taken in immense quantities by means of a scoop net which the Indians, seated in canoes, plunge into the schools: but the season is short, not even lasting two weeks.

Adventure at Astoria, 1810–1814 (Franchère 1967, p. 108)

> February brings a little fish, somewhat longer and broader than the sardine, that we took at first to be a smelt [eulachon]. It has a delicate flavor and is abundant, but the season for catching it lasts only a short time.

The Journal of Gabriel Franchère, 1811–1814 (Franchère 1969, p. 110–111)

> At the beginning of February [1812] the Indians brought us large quantities of a small fish [eulachon] six or seven inches long, which we found excellent. …
>
> The Natives continued to supply us with small fish until the 20th, when the season was over. This fish, which is very abundant, is caught by means of a scoop or rake, which is simply a long pole to one end of which they have fastened sharply pointed pegs; by pulling it back and forth through the water they catch the fish on the pegs and soon have a canoe full. The women dry these fish, which furnish their principal food supply during the months of April, May, and June, threading them when dry in a double row on cords which are six feet long. They even trade in them with the Natives of the upper river, for these fish are not caught further up than the territory of the Chreluits [Chinook Indians], about 15 leagues from the mouth of the Columbia.

The Journal of Alexander Henry the Younger 1799–1814 (Gough 1992)

6 January 1814 (p. 635)

> This evening a canoe arrived from above which brought us four large sturgeon and a few smelt [eulachon]. These are the first of these small fish we have seen here this season. They generally make their appearance here in February, but the gentlemen who arrived today from above tell us the Indians take them at present in great abundance about the entrance of the Willamette River.

7 January 1814 (p. 637)

> The great smoke which now rises from the three Chinook villages denotes the return of these people to their winter quarters, which is usually at this period. They will contrive to augment in numbers daily, as the smelt [eulachon] fishing is approaching fast and then the sturgeon fishing follows, and, as the spring draws near, the salmon fishing approaches, the Natives from the northward will also bend their course here also.

11 January 1814 (p. 642)

> Passed Mount Coffin on the north side. … We saw … many of the Natives fishing smelt [eulachon] with a scoop net along the shores.

27 January 1814 (p. 665)

> The insides of these Indians houses are crowded with smelt [eulachon] drying, suspended by the heads to poles, the roofs are lined everywhere excepting the fire place is full, all hanging tail downwards. Several canoes were also full laying off at anchor. ... We passed several fishing parties, tented on the beach, who had … canoes loaded with smelt. …. At 9 o'clock we passed Mount Coffin, and at 11 o'clock we passed Oak Point. We saw several sea lions. … The number of gulls

and other birds that feed on fish are surprisingly numerous here at present, much more so than last fall. The cause I presume is they are attracted by the numerous shoals of smelt which are going up the river at this season of the year. Seals are very numerous also.

8 February 1814 (between Mount Coffin and Oak Point on the Columbia River, p. 676)

We observed on the beach and floating on the surface of the water great numbers of smelt [eulachon] dead and dying, the same fate which attends the salmon, and seems to attack the small fish in the river. They all die apparently for want of food, there being not the least particle of any substance in their gut, which consists of only one very small green filament. Gulls, shell drakes, and other waterfowl that feed on fish are uncommonly numerous, also eagles both baldhead and grey. Herons are very common along the shore and perched on the trees.

26 February 1814 (Fort George, aka FortAstoria, p. 683)

Two Indian canoes came over, on their way up to catch sturgeon and smelt [eulachon]. I saw a kind of pole about 10 feet long and 2 inches broad, one side was fixed a range of small bones, about a ¼ of an inch asunder, and about one inch in length, and very sharp; the range of teeth extending about six feet up the blade, this I understand is used in the smelt fisheries.

6 March 1814 (Fort George, aka Fort Astoria, p. 695)

Several canoes deeply loaded with smelt [eulachon] and sturgeon arrived from above and proceeded to the Calpoh's Village, having sold some of the smelt to us and passed on.

19 March 1814 (Fort George, aka Fort Astoria, p. 701)

The sturgeon continue to be plenty, and the smelt [eulachon] few; they do not all die as soon as I had imagined when I was last above in the beginning of February, as Mr McKay tells me they are now in the same state as they were then, a few found dead along the beach, and others dead and dying in the water.

3 April 1814 (p. 708)

We now have sufficient of their dried smelt [eulachon] which has been purchased mostly from the Chinooks and Clatsop, who buy the fish above themselves, and before it is brought down and strung up to dry it is spoiled. The dried smelt from above is much better by being dried on the spot. I now desired them to be traded at 1 fathom of small blue Canton beads for 5 fathoms of smelt. Yesterday we had traded at 4 fathoms.

Adventures of the First Settlers on the Oregon or Columbia River &c (Ross 1849, p. 94–95)

> There is a small fish resembling the smelt or herring, known by the name of ulichan, which enters the [Columbia] river in immense shoals, in the spring of the year. The ulichans are generally an article of trade with the distant tribes, as they are caught only at the entrance of large rivers. To prepare them for a distant market, they are laid side to side, head and tail alternately, and then a thread run through both extremities links them together, in which state they are dried, smoked, and sold by the fathom, hence they have obtained the name of fathom-fish.

Trading Beyond the Mountains: The British Fur Trade on the Pacific, 1793–1843 (Mackie 1997, p. 30)

> In April 1821, James Keith of Fort George [at Astoria, Oregon] wrote to his supplier, Perkins and Company, about the difficulties of obtaining a provision supply in this extremely remote region. Keith was dependent on the Chinook people of the lower Columbia for salmon, sturgeon, and wildfowl. "The winter has been unusually severe both as to the degree of cold & quality & duration of the snow," he wrote. "The fishery of the smelt [eulachon] being lately over, the Natives begin to bring us a chance sturgeon & wild fowl, which when more abundant will be gratifying to people from a long sea voyage…."

***Salmo* (*Mallotus*?) *pacificus* (Richardson) North-west Capelin (Richardson 1836, p. 226–227)**

> The Indian name of this fish is oulachan. It comes annually in immense shoals into the Columbia about the 23rd of February, but ascends no higher than the Katpootl [Lewis River], a tributary which joins it about 60 miles from its mouth. It keeps close to the bottom of the stream in the day, and is caught only in the night. The instrument used in its capture by the Natives is a long stick armed with sharp points, which is plunged into the midst of the shoal, and several are generally transfixed by each stroke. It is the favourite food of the sturgeon, which enters the river at the same time, and never has a better flavour than when it preys on this fish. The oulachan spawns in the different small streams which fall into the lower part of the Columbia. It is much prized as an article of food by the Natives and arrives opportunely in the interval between the expenditure of their winter stock of dry salmon and the first appearance of the quinnat [Chinook salmon] in May.

Report on the Fishes Collected on the Survey (Suckley 1860, p. 348–349)

> They [eulachon] formerly entered the Columbia River in great numbers, and were equally abundant in Puget Sound. At present, although sparingly found in the waters named, they cannot be considered as occurring in large numbers south or east of the southern end of Vancouver's Island. In the latter locality they are very abundant in certain seasons, but nearly always a season of abundance is followed

by three or four years of scarcity. Further northward they are constantly abundant. The Haida, Stickene, and Chumtseyan Indians, living along the coasts of British and Russian America, bring vast quantities of these fish with them when visiting the white settlements on Puget Sound. The fish thus brought are for the consumption of the strangers during their stay, and have been simply dried, without salt, and for convenience in drying or transportation have been strung on sharp, pliable sticks which are passed through the heads.

In July 1856, Dr. William Fraser Tolmie, chief factor of the Hon. Hudson Bay Company, a gentleman well known to naturalists for his interest in science, presented me with a bunch of dried eulachon, which he had obtained from some of the "Northern" Indians. Dr. Tolmie also gave me the following memoranda: "These fish were caught at the mouth of Nass River, which empties into salt water near latitude 54°40′ north. The Indian name of the species is almost unspellable. Formerly they were quite abundant between the 46th and 49th parallels of north latitude. They are now but seldom caught south of latitude 50° north in any great number. North of that point they are still taken by the savages in vast quantities, and are smoked and dried for trade and home consumption. When eaten after being thus prepared they should be either steamed or broiled."

The Naturalist in Vancouver Island and British Columbia, Vol. 1 (Lord 1866, p. 96)

Some 50 years ago, vast shoals of eulachon used regularly to enter the Columbia; but the silent stroke of the Indian paddle has now given place to the splashing wheels of great steamers, and the Indian and the candle-fish have vanished together. From the same causes the eulachon has also disappeared from Puget's Sound, and is now seldom caught south of latitude 50°N.

The Dominion at the West: A Brief Description of the Province of British Columbia, its Climate and Resources (Anderson 1872, p. 30–32)

A very valuable fish entering Fraser River to spawn in early spring, is the *Thaleichthys* (or preferably *Osmerus*) *Richardsonii*—locally known as the oolâhan.* It appears in immense shoals, and is caught either with the scoop net, or, like the herring on the seaboard, with the rake. This simple device is merely a long light pole, flattened in one direction so as to pass readily through the water, and with the edge set towards the lower extremity with a row of sharply pointed teeth. The fisherman, entering the shoal, passes the implement repeatedly through the water, with a rapid stroke, each time transfixing several fish. Thus a copious supply is soon secured. The oolâhan is, in the estimation of most people, one of the most delicious products of the sea. Smaller than the herring, it is of a far more delicate flavor; and so rich that, when dried, it is inflammable.† This fish is not confined to Fraser River, but frequents likewise the Nass, a large stream issuing on the frontier between British Columbia and Alaska; another stream debouching into Gardner's Canal; and probably other rivers along the coast. Those caught at the mouth of the Nass are of a qua1ity even richer than those of Fraser River. The Natives, who assemble there in great numbers in spring to prosecute the fishery, besides drying them in large quantities, extract from the surplus a fine oil, which is highly prized by them as a luxury, and forms a staple article of barter with the interior tribes.

* I was long under the impression that this fish was a variety of Pilchard (*Clupanodon thrissa*) peculiar to the Pacific; and am indebted to Dr. Robert Brown, of Edinburgh, formerly in command of the Vancouver Island Exploring Expedition, for the correction adopted above.

† So much so, indeed, that, in Alaska, where it is likewise found, it is I believe called the "candle-fish." It is mentioned by Franchère, in his account of the Columbia River, under the name of outhelekane, from which its present designation is modified; and, from the circumstance of its being strung on cords by the Natives to dry, was called by the voyageurs poisson à la brasse, or fathom-fish. They were formerly very abundant in spring on the lower Columbia; but suddenly, about the year 1835, they ceased to appear, and thence forward up at least to 1858, none frequented the river. I have been informed, however, that they have since reappeared, and that there is now a regular supply as formerly.

Reminiscences of Cowlitz County (Huntington 1963, p. 5)

Not within the memory of the oldest white inhabitant had there been any smelt in the Cowlitz River until some time in the early sixties. I am not certain what year I first saw them, but there was a heavy run and nobody paid much attention to them—not even the Indians. The Indians and white people at times caught a few with a stick with a sharp nail in it. After the second or third year of their return, people began to sit up and take notice. In 1865, a young lady school teacher, Miss Baker (afterward my wife), having learned how to make hair nets, conceived the idea of making dip nets in which to catch them and soon everybody had nets and were catching them by the ton and shipping them to Portland. The Indians had a tradition that there had been smelt here many many years before, but to punish them for some offense the Sahely Tyee had taken them away and it must have been a good many years as the oldest of them did not seem to know much about tradition.

Narrative of the Overland Journey to Oregon (Crawford 1878, unpublished manuscript, p. 369)

Events of 1865
Appearance of Smelts on Cowlitz

In Feby and March 1865, there appeared a strange little fish unknown to the early settlers of Cowlitz or lower Columbia River. Although the Indians declared that those little finny swarming beings of the deep had frequented the waters of the Cowlitz River before but had absented themselves for 17 years, during which period no Indian had seen a school. They always go along in close trains from one foot wide to two or three feet wide, falling in close concert. The early settlers on the lower Cowlitz remember having a few such little fellows in small numbers.

Report of the Inspector of Fisheries for British Columbia for the Year of 1876 (Anderson 1877, p. 345)

> The oolá-han, called also in Alaska, the candle-fish, (*Thale-chthys* or *Osmerus Richardson*) although it may occur low down in the list of marine and anadromous fishes which I undertake at present only partially to furnish, is not therefore to be regarded as in my estimation the least important. I again venture to refer to certain notes which I have already made public; and I now repeat my increased conviction that the value of this fish for diverse economical purposes has not yet been fully understood. Formerly resorting in enormous shoals to the estuary of the Columbia River, it disappeared suddenly about the year 1837, and continued to absent itself for many years, until recently, when it suddenly reappeared in shoals as numerous as of yore. In Fraser River these fish are found, and resort thither regularly in heavy shoals; but little advantage is taken of their advent, beyond what are caught and consumed as a luxurious adjunct to the table while fresh, and a few casks hastily salted for sale and consumption at home, chiefly in fulfilment of private orders. At the Squawmish River, discharging at the head of Howe Sound, I found, on enquiry, that these fish enter the river, as elsewhere, early in the spring, and ascend as high as the head or the Island of Stââ-mis, forming the delta; thence, after spawning, returning to the sea. Several other rivers along the coast are known to be frequented by these fish; and there are doubtless others of which we are not, so far, cognizant. The Nass River, however, discharging into Observatory Inlet, close to the Alaskan boundary, stands preeminent as an oolá-han fishery, as well for the enormous supply it yields, as for the superior quality of its fish.

Astoria, or, Anecdotes of an Enterprise beyond the Rocky Mountains (Irving 1868, p. 404)

> About the beginning of February, a small kind of fish, about six inches long, called by the Natives the uthlecan, and resembling the smelt, made its appearance at the mouth of the river. It is said to be of delicious flavor, and so fat as to burn like a candle, for which it is often used by the Natives. It enters the river in immense shoals, like solid columns, often extending to the depth of five or more feet, and is scooped up by the Natives with small nets at the end of poles. In this way they will soon fill a canoe, or form a great heap upon the riverbanks. These fish constitute a principal article of their food; the women drying them and stringing them on cords. As the uthlecan is only found in the lower part of the river, the arrival of it soon brought back the Natives to the coast; who again resorted to the factory to trade, and from that time furnished plentiful supplies of fish.

The Eulachon or Candle-fish of the Northwest Coast (Swan 1881, p. 258)

> The eulachon are found in limited numbers at certain seasons in the Columbia River, Shoalwater Bay [Willapa Bay], Gray's Harbor, and at the mouth of the various small streams of the coast, and also in the waters of Puget Sound, where they are taken in seines and nets with smelt and other varieties of small fish, but

they are thin and poor, and not to be compared to the same varieties further north. Even those taken in Fraser's River near the boundary line between Washington Territory and British Columbia are superior to those taken further south, and are sold in the Victoria market, where their excellence is highly prized. The few secured on Puget Sound are sold by the fishermen as smelts. The best kinds are caught further north, and great quantities are salted by the Hudson's Bay Company, at their trading post at Fort Simpson, British Columbia, and either sold in the Victoria market or shipped direct to London in tierces, barrels, and kits.

As an article of food and for the grease or fat contained in them, the eulachon are highly prized by the Indians of northern British Columbia and southern Alaska, where they abound; particularly at the Nass River, British Columbia, where they are annually taken in enormous quantities, and where they seem to attain their very finest condition.

Fraser River, British Columbia

The Fort Langley [a Hudson's Bay Company post on the lower Fraser] Journals, 1827–1830 (MacLachlan 1998)

28 April 1828 (p. 60)

> The little fishes which the Chinooks call ullachun [eulachon] begin to make their appearance here, and are joyfully hailed by the Indians of the river.

29 April 1828 (p. 60)

> We made a trial to take some of the little fish Chinook fashion [with the rake], and proved very successful as enough were taken to give a prog [?] to all hands.

14 April 1829 (p. 109)

> The small fish in the Columbia called ulluchans [eulachons] is also within the river, but not yet this high.

4 May 1830 (p. 147)

> The small fish called ulachans [eulachons] are arrived.

Other British Columbia Waters

The Economic Fishes of British Columbia (Green 1891, p. 30)

> The oolachan (*Thaleichthys pacificus*), an anadromous fish of about 9 inches in length, makes its appearance in the tidal waters of the Fraser about the middle of April, and in the Nass about the 23rd of March. When fresh is a delicious little fish, but it deteriorates with carriage, and is never seen to perfection in the

Victoria market. Numbers of oolachans are put up in pickle in small kits, and some are cured and smoked like bloaters.

Oolachan grease is an article much used and appreciated by the Indians. A large trade is done in this commodity between the Indians of the Nass River and those of the interior, in exchange for furs. In appearance and consistency it resembles lard, and is used on dried salmon or halibut, much in the same manner as we use butter on bread. A short account of its manufacture on the northern rivers may be of interest to you. As I before stated the oolachans arrive in March when the ice is still on the river. All the Indians who have any right to fish in the river, and this priviledge is jealously guarded, come from far and near to the fishery, and erect temporary dwellings along the banks or on the ice. The firewood for drying out the oil has to be brought from a distance, all that in the immediate vicinity of the fishery having been used long ago. The fish are taken under the ice with purse nets, and are left in heaps until they are, to say the least of it, high; partial decomposition assisting the extraction of the oil. They are then boiled in troughs which are about 5 feet long by 2 feet wide, and the fat is skimmed off, and put into square cedar boxes about the size and shape of a coal oil tin. Originally the grease was extracted by filling a wooden trough with water, and heating it with red-hot stones; this mode is now obsolete, the troughs having a sheet iron bottom built over a long and narrow furnace.

The oolachan has more than its fair share of enemies; sturgeon, salmon and porpoises follow it into the rivers, while bears and the settler's pigs gorge themselves with the exhausted shotten [sic] fish. At Port Hammond I once saw two pigs standing up to their backs in the water, and diving for oolachans; they seldom failed to bring one up.

Vancouver Island and British Columbia: Their History, Resources, and Prospects (MacFie 1865, p. 163–165)

Hoolakans ascend the streams in April in dense shoals. Their approach is indicated by the presence of seagulls swooping down to devour them, and causing the banks of the river to echo with their screeching. This species are about the size of a small herring, and are so fat as to baffle ordinary methods of cooking to prepare them for the table. Oil is pressed from them by the Indians on the coast, and disposed of to tribes in the interior. …

When dried, the hoolakan is often used by the Natives as a torch, and, when lighted, it emits a brilliant light. The Indians catch this species of fish by impaling them on rows of nails at the end of a stick, about four feet long, and so thickly do they swarm, that every time this rude implement is waved in the water, two or three of them adhere to it.

The Coast Indians of Southern Alaska and Northern British Columbia (Niblack 1890, p. 276 and p. 299)

Eulachon (*Thaleichthys pacificus*), the so-called "candle-fish," a kind of smelt, run in March and April at the mouth of the Skeena, Nass, and Stikeen rivers.

These have the greatest proportion of fatty matter known in any fish. In frying they melt almost completely into oil, and need only the insertion of some kind of a wick to serve as a candle. …

Eulachon or "candle-fish" run only in the mouths of rivers, particularly the Skeena, Nass, and Stikine in this region. They are considered great delicacies, and are dried and traded up and down the coast by the Indians who are fortunate enough to control the season's catch.

Appendix D: Selected Accounts of Eulachon in an Early Periodical

[Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting minor misspellings without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncrasies of spelling are generally preserved.]

Pacific Fisherman, March 1905, vol. 3(3), p. 19

Big Catch of Smelt

C. R. Gatchet, a Portland fish dealer, reports that 150 tons of smelt were taken from the Cowlitz River between February 1 and 7. All were caught between Kelso and the mouth of the river. Mr. Gatchet kept a close account of the output. Allowing five smelt to the pound, the catch represents 1,500,000 fish. At the market price of five cents a pound they are worth $15,000.

Pacific Fisherman, April 1905, vol. 3(4), p. 11

Kelso Smelt Industry

Kelso, in Cowlitz County, Washington, with 1,200 population, is the center of the smelt industry. No other point visited by the myriad schools of fish can rival it. The season lasts several months, that just closed having commenced November 19, and ended March 15. During this period Kelso records show that 400 tons of smelt were sent from there to the world. This tonnage represents 16,000 boxes of smelt, each box weighing 50 pounds.

The fact that you can dip smelt from the Cowlitz River with a pitch fork, drive a wagon into the stream and load the bed in a short time, or annually ship to the hungry world 400 tons of this diminutive fish is a matter of pride at Kelso, for this community takes first honors in the smelt industry.

Catching smelt on the Cowlitz is an interesting process. The fleet of small boats stand out in the stream, one man to each craft, armed with dip net having a 15-foot handle. The ring at the end of the pole has a spread of 18 inches, while the net behind it is of sufficient capacity to carry many pounds of fish. The schools of fish, which surge up the river, are soon located, when the fishermen commence dipping down stream. Each stroke is richly rewarded, for, after a school is located, there are few water hauls. Lee Galloway, one of the best fishermen of the stream, has last season's record, catching 96 boxes in one night, each box weighing 50 pounds. This record means that with one of these poles he lifted from the stream 4,800 pounds of fish, or about two and a half tons.
—Charles R. Gatchet

Pacific Fisherman, April 1906, vol. 4(4), p. 16

Smelt Cease Running—The run of smelt on the Cowlitz River has ceased after a very successful season. The season's catch was the largest ever taken from the Cowlitz River. Over 700 tons were shipped, the amount being double that handled last year.

Pacific Fisherman, April 1907, vol. 5(4), p. 8

Kelso's Important Smelt Fishing Industry, by G. E. Kellogg

There are places, hundreds of them, which are noted for the production of some staple or marketable article, and of all the thus noted towns in Western Washington, Kelso has the distinction of being the best known on account of the smelt industry.

The little fish which tickles the palates of thousands of people each winter are the mainstay of the fishing people of this vicinity and not only put thousands of dollars in their pockets each year, but they add a great deal to the prosperity of Kelso and vicinity.

The smelt are a peculiar fish. Hatched in the headwaters of the Cowlitz or Sandy they return to the open sea in the spring. Returning in the fall and winter they unfailingly enter the Cowlitz, seeking the old spawning grounds beyond the reach of fishermen's nets. They travel in schools, or rather strings, the first run arriving at or near Kelso about the Holidays. The run of fish is most uncertain. Sometimes they last until the middle of March and sometimes they stop short in January.

So far this season there have been upwards of 3,000 boxes shipped from Kelso, a total of 37,350 pounds, going by express in the month of January alone. Carload shipments have been made in years when smelt were plentiful and cheap, but lately the demand has kept up so steadily that the fish are shipped almost as fast as they can be taken from the water.

Smelt have always been so plentiful that they never needed protection by law other than licensing fishermen, and there has never been any thought or fear of their extinction entertained by anyone who knew their habits.

Thus we have an industry which might be called perpetual, as there is no doubt of its continuance for many years to come.

We are enabled to produce the accompanying engravings showing smelt fishing scenes in the vicinity of Kelso by the courtesy of the Kelso Journal.

Pacific Fisherman, April 1907, vol. 5(4)

Smelt in the upper Columbia River—For the first time in many years smelt are running up the Columbia River above Kalama. Large schools have been passing Vancouver, Wash., and fishermen have reaped a rich harvest. The few smelt which have hitherto gone further up the river have been of poor quality, but these have been of the best. Just what turned the smelt aside from their favorite haunts up past Kelso has not yet been determined.

Pacific Fisherman, January 1910, vol. 8(1), p. 19

Columbia River

> … Smelt have arrived in the river for the first time this winter and are being caught in the vicinity of Kathlamet. They are a luxury on the breakfast table as the fishermen are wholesaling them at 25 cents per pound, but at the same time their flesh is so firm and high flavored that they are well worth the price for an epicure.

Pacific Fisherman, March 1910, vol. 8(3), p. 14

Columbia River

> The largest run of smelt for years in the Cowlitz River is now in progress. The river has never been known to contain so many smelt in the memory of the oldest fishermen. This may bode good for the coming fishing season in the Columbia, as it is said that a good run of smelt has always been followed by a good run of salmon. The increased run found the trade unprepared to handle it successfully and this accounts for the breaking of values to 10c and even lower. … Although the smelt, now so generously in the Portland markets, bear the name "Columbia River," the great preponderance of them is taken in the vicinity of Kelso from the Cowlitz River. Kelso this season has shipped out approximately 15,000 boxes. Each box contains 50 pounds and the fish average eight to the pound. The catch, so far, therefore represents approximately 6,000,000 fish.

Pacific Fisherman, April 1913, vol. 11(4)

Donate Carload of Smelt to Sufferers

> The citizens of Kelso, Wash., donated a carload of Columbia River or Cowlitz River smelt, 20,000 pounds in all, to the Ohio flood sufferers. The Kelso fishermen donated 400 boxes of fish, the businessmen paid for the boxes and labor and an express company and the railroad furnished the transportation free.

Pacific Fisherman, February 1914, vol. 12(2), p. 20

Heavy Run of Smelts in Columbia River Valley

> An unusually heavy run of smelts appeared in the Columbia River in January and large catches are now being made in that river and its numerous tributaries, more particularly in the Cowlitz River, where the annual run of this delicious species forms the basis of a considerable commercial industry. This year, in addition to being shipped fresh on ice, large numbers are being dried at the Kelso plant of the Northwestern DeAquating Company, thus making it possible to almost indefinitely extend the market for Cowlitz smelts.

Pacific Fisherman, February 1915, vol. 13(2), p. 29

Smelt in the Kalama River

> Early in February smelt entered the Kalama River in large numbers and the fishermen reaped a harvest for a time. It is a rare thing for the smelt to enter this river in any numbers. In the Cowlitz River, where the smelt usually run in immense numbers, few have been seen this season. Considerable catches have been made in the Columbia River proper.

Pacific Fisherman, March 1918, vol. 16(3), p. 51

Eulachon Run Late

> Great preparations were made this year for handling large shipments of eulachon from the Columbia River, as the fish has become well established in several Eastern markets and interest has been greatly stimulated by the Bureau of Fisheries exploitation work. The run, however, has so far been very disappointing. Up to the first of March the usual run in the Cowlitz River has not appeared, and a fair run that started in the Kalama River was of short duration.
>
> During the second week of March the eulachon appeared in large numbers in the Lewis River, and large catches have been made, with the fish in unusually good condition. The handling of the catch is somewhat more difficult than if the fish had run in the usual direction, but a heavy shipping movement to the East has been started, and it is expected that the shipments in that direction will reach important figures before the run is over. There was a fairly large movement last year, and the fish were well liked wherever they appeared, a large quantity having been placed on the New York market at a time of acute food shortage.

Pacific Fisherman, May 1920, vol. 18(5), p. 48

Oregon Smelt Running

> The annual run of smelt in the Sandy River, an Oregon tributary of the Columbia, started April 24.

Pacific Fisherman, March 1924, vol. 23(3), p. 35

Shipping Smelt

> For several weeks during February, shipments of smelt from Kelso, Wash., amounted to about 2,000 fifty-pound boxes daily, according to W. A. Mabie, manager of the Columbia River Smelt Company. Most of the shipments went to Portland, Ore., for distribution to consuming markets.

Pacific Fisherman, February 1926, vol. 24(3), p. 30

Columbia River Activities

Up to the last of January, the run of smelt in the Columbia River, which usually starts about January 15, had not appeared. About the middle of the month there was a small run, but few went up as high as the Cowlitz River or any of the other small streams which empty into the Columbia, except for about one day Grays River on the Washington side opposite Astoria fishermen secured considerable poundage. The run is still looked for by experienced men.

Pacific Fisherman, March 1926, vol. 24(4), p. 44

Good Oulachan Pack

The Candle Fish Company, Kelso, Wash., engaged in dry salting oulachans, or Cowlitz River smelts, for the Chinese market, reports that owing to the unusually good run this year little difficulty is anticipated in filling their contracts. More than 80 tons of salted oulachans were in the company's vats on the Kelso dock Feb. 15. Profiting by this year's experience the company is planning on improvements that will more than double their production next year.

Most of the catches during February were made at Sandy Bend between Kelso and Castle Rock. Fishermen and individual shippers of fresh smelts have been reaping a harvest from their catches, the Columbia River Smelt Company shipping on an average of 500 boxes daily.

Pacific Fisherman, Annual Statistical Volume, January 1930, vol. 28(2), p. 189

The run of Columbia River smelt appeared in the Cowlitz River again in 1929 in volume reported to exceed that of any previous season. The two preceding years had been complete failures and had given rise to the fear that pollution had destroyed the Cowlitz smelt, a supposition adequately disproved by the experience in 1929.

Pacific Fisherman, Annual Statistical Volume, January 1933, vol. 31(2), p. 167

Cowlitz Smelt

At the opening of the year production of fresh fish in the Pacific Northwest centered to a large degree on the Columbia River, where the winter salmon season yielded in a normal way, while the smelt run supplied another item of fresh fish. Before the smelt entered the Cowlitz the fishermen were able to hold the price to them at 2c per lb or above by the simple expedient of suspending their operations whenever the price went below that figure.

When the smelt run struck the Cowlitz the price dropped off sharply, as has been mentioned. The Washington smelt catch was one of the largest on record, being 1,476,939 lbs, surpassed in the previous seven years only by 1931.

Appendix E: Substantive Scientific Comments from Peer Review

We received comments from five peer reviewers of the summary of the eulachon (*Thaleichthys pacificus*) status review completed in December 2008 (BRT 2008) and respond to them here. Reviewers were asked to assess the scientific validity of the status review, including any assumptions, methods, results, and conclusions. Reviewers were asked to focus on the quality of the data collected or used for the assessment, appropriateness of the analyses, validity of the results and conclusions, and appropriateness of the scope of the assessment (e.g., whether all relevant data and information were considered). We have summarized and organized the reviewers' comments into categories relevant to issues raised by the Eulachon Biological Review Team (BRT), composed of 10 federal scientists from 3 agencies: National Marine Fisheries Service, U.S. Fish and Wildlife Service, and U.S. Forest Service. The peer reviewers are identified by number in order to preserve their anonymity.

In general, four of the five reviewers supported the conclusions of the Eulachon BRT. One reviewer did not agree with the delineation of the southern DPS of eulachon and argued that genetic and demographic evidence supports a much finer distinct population segment (DPS) structure for eulachon in this region. This same reviewer also pointed out a lack of information on eulachon marine distributions off the U.S. West Coast.

Delineation of a Distinct Population Segment

Review

Reviewer 1 stated that the discreteness and significance decisions were "well considered and defensible" and agreed that "the proposed DPS is discrete and significant and that its northern boundary is most defensibly delineated by Nass River, British Columbia." Reviewer 2 commented extensively on the proposed DPS scenario, and a summary of this reviewer's comments and our responses are presented below. Reviewer 3 stated that "the possibility exists that the Klamath River population (and associated populations to the south) is or was distinct." Reviewer 4 stated that the "conclusion that multiple discrete populations of eulachon exist appears well supported by the available evidence" and that "designation of a DPS encompassing all areas south of the Nass River/Dixon Entrance … appears to be the most strongly supported by the weight of available evidence, although other configurations of DPS(s) cannot be ruled out." Reviewer 5 did not address the appropriateness of the proposed southern DPS of eulachon, but requested clarification on one item, which we respond to below.

Response

No response is required to comments by reviewers 1 and 4. With regard to the comment of Reviewer 3, the BRT was also cognizant of the possibility that the eulachon population in the Klamath River and in other steams of California may represent fish that have unique characteristics; however, the best available information is insufficient at present to identify what these characteristics are or were and whether they may have risen to the level of identifying eulachon in California as being “markedly separated” from populations to the north.

Reviewer 2, Item 1

Reviewer 2 felt that it was not clear “why there were only six [DPS] scenarios when many more might have been proposed” and found “it puzzling that the BRT did not consider the option that the Columbia River was a DPS.” Furthermore, Reviewer 2 suggested that “the scenario that each river system represents a DPS … would have an approximate conceptual model of a river-based or stream-based salmon (*Oncorhynchus* spp.) stock structure as a precedent.”

Response

As described in the “Evaluation of Discreteness and Significance for Eulachon” subsection of the BRT report, “other possible geographic configurations [of a DPS] that incorporated the petitioned unit were contemplated, but were not seriously considered by the BRT” (BRT 2008, p. 26) The BRT did discuss during its deliberations whether the Columbia River was a DPS, and after examining the available data and applying the discreteness and significance criteria for delineation of a DPS, no member of the BRT advocated for including this scenario in the final list that was voted on. The inclusion of scenario 6 (Multiple DPSs of eulachon in Washington, Oregon, and California) in the final voting process allowed BRT members to place some “likelihood points” in this scenario, which was representative of a scenario where every river is a DPS (including the Columbia River). Only 4% of all members’ likelihood points were cast for scenario 6.

We agree that, conceptually, it is reasonable to view stock structure of eulachon in a similar manner to Pacific salmon, and believe we have applied the DPS policies with regard to eulachon in a manner consistent with how previous BRTs have applied this policy to Pacific salmon. With regard to most Pacific salmon that have been examined under the U.S. Endangered Species Act, DPSs (which in the case of Chinook [*O. tshawytscha*], coho [*O. kisutch*], sockeye [*O. nerka*], chum [*O. keta*], and pink salmon [*O. gorbuscha*] are statutorily defined as Evolutionarily Significant Units [ESUs]) of these species consist of numerous demographically independent populations occupying a large number of individual drainages spread over large geographic areas. In only a few instances (e.g., some sockeye salmon ESUs) have Pacific salmon ESUs been designated on the basis of a single river basin. Pacific salmon DPS structure is thus conceptually consistent with the structure of the proposed southern DPS of eulachon, which may be composed of multiple subpopulations or stocks.

Reviewer 2, Item 2

Reviewer 2 stated that "it is difficult to reconcile the conclusion of the BRT that there is one major DPS with the assertion that the BRT also acknowledges that finer population structure may exist." Reviewer 2 felt that spawn timing and genetic differences represent compelling evidence "that finer structure does exist between the Fraser and Columbia rivers."

Response

The ESA requires the best available scientific and commercial information be used in determining the listing status of a species. However, the best available scientific information for eulachon is at present inadequate to define a particular DPS with 100% certainty, as reflected in the percentage distribution of likelihood points among four of six proposed DPS scenarios (see Table 1). Thus the BRT acknowledges that additional scientific research might result in evidence supporting either subdivision or expansion of the current DPS boundaries.

It is also important to acknowledge that the discreteness and significance criteria (USFWS-NMFS 1996) define a DPS, which is likely to be composed of many stocks or subpopulations. Previously designated DPSs of several marine fish include a number of identifiable subpopulations with numerous isolated spawning locations and a substantial level of life history, genetic, and ecological diversity (Gustafson et al. 2000, 2006, Stout et al. 2001a, Carls et al. 2008). Similarly, application of NMFS's ESU policy to Pacific salmon in the contiguous United States has resulted in designation of 52 ESUs, each of which is commonly composed of numerous populations that are often genetically and demographically differentiated one from another. In practical terms, if all genetically differentiated populations were to receive ESU status, there could conceivably be thousands of Pacific salmon ESUs.

The BRT did not believe that the available genetic or demographic data provide evidence that eulachon in the Fraser and Columbia rivers were "markedly separated" populations, as required by the DPS policy. With regard to the genetic microsatellite DNA study of Beacham et al. (2005), the BRT was concerned that this study compared samples between the Fraser and Columbia rivers taken in a single year, and thus the temporal stability of the genetic variation observed between these two rivers could not be adequately assessed. The BRT concerns with regard to temporal stability derive from the realization that reported year-to-year genetic variation within three British Columbia coastal river systems (Nass, Kemano, and Bella Coola rivers) in that study was as great as the variation among the rivers (Beacham et al. 2005). This temporal genetic variation indicates that additional research is needed to identify appropriate sampling and data collection strategies to fully characterize genetic relationships among eulachon populations.

Reviewer 2, Item 3

Reviewer 2 invoked "significant genetic differences" between the Columbia and Fraser rivers described in Beacham et al. (2005) as evidence supporting a finer DPS structure, but at the same time described the statistically "significant differences in genetic composition between a sample taken in the Cowlitz River and one taken in the main stem of the Columbia" as "puzzling" in light of the assumption that the "basis for a [eulachon] population would be an estuary, perhaps formed by the confluence of a number of rivers." Reviewer 2 felt that "clearly some additional genetic analyses focusing on examination of potential differences within the Columbia River system would be very revealing."

Response

Genetic samples described in Beacham et al. (2005) were taken in the Cowlitz and Columbia rivers in different years, which may partly explain the statistical differences in genetic composition between these two samples from the Columbia River drainage. Comparison of multiple year samples in the Kemano, Bella Coola (2 years of sampling each), and Nass (3 years of samples) rivers also showed statistically significant differences among samples from the same river across years. Beacham et al. (2005, p. 367) stated that "differentiation among sampling years within populations was similar to the level of differentiation among populations for these three putative populations." Thus it is uncertain whether some of the observed genetic differences described in Beacham et al. (2005) are temporally stable. We agree with the reviewer that further genetic studies of eulachon within the Columbia River and elsewhere are necessary to resolve these questions.

Reviewer 5, Item 1

In reference to the third item in our list of evidence supportive of DPS scenario 4 (one DPS from Fraser River to California), Reviewer 5 stated that:

> … you argue that the pattern [of increasing length and weight with an increase in latitude] is found in many other vertebrate poikilotherms, so you tended to discount this evidence. However, in other places in the document, you seem to use parallels found in other fishes to support your findings. I found this somewhat contradictory, so perhaps a little more explanation would be useful.

Response

Many quantifiable marine fish life history characters—such as body size-at-age, maximum age, and fecundity—increase with increasing latitude and the associated decline in rearing temperatures. Although some of these traits may have a broad genetic basis and may reflect local adaptations of evolutionary importance, they are usually strongly influenced by environmental factors over the lifetime of an individual or over a few generations. Differences can arise among populations in response to environmental variability among areas and they can sometimes be used to infer the degree of independence among populations. However, differences in phenotypic and life history traits among populations do not provide definitive information on reproductive isolation between populations, because the genetic basis of many phenotypic and life history traits is weak or unknown.

At decreasing rearing temperatures, which can be expected in the northern portion of a species range in the northern hemisphere, a near universal relationship ensues among poikilotherms (i.e., cold-blooded organisms) where rates of growth are slower and size at a given age is larger (Ray 1960, Atkinson 1994). As most vertebrate poikilotherms exhibit similar latitudinal clines in these life history characters, their presence in eulachon offers at best weak evidence that eulachon in the southern and northern portion of their range are "markedly separated" from one another.

In both DPS scenario 4 (one DPS from Fraser River and south) and DPS scenario 1 (no DPS structure), where latitudinal differences in quantifiable life history characters or lack of differences other than those associated with latitude were mentioned as a supportive factor, parallel patterns with other fish species were pointed out to illustrate the apparent weakness of this evidence. We considered these geographic patterns in life history characters similarly in considering both DPS scenarios. Latitudinal variation in life history characters offered little support for either scenario (although other evidence may be more supportive), a fact which is reflected in the BRT's assignment of likelihood points to these two DPS scenarios (about 27% to scenario 4 and about 12% to scenario 1).

Appropriateness of the Scope of the Assessment

Review

Reviewer 1 stated that "it is my opinion that the best available data on eulachon spawning from California north to Alaska have been detailed and analyzed as part of the review" and the BRT "has made appropriate and exhaustive use of the best available scientific data that bear upon the questions at hand." Reviewer 2 commented that "the thoroughness of the literature review is impressive and … all facets of life history, historical use, habitat, commercial fisheries and traditional uses are described." However, Reviewer 2 questioned whether the BRT examined all available databases relevant to marine distribution of eulachon in offshore waters of Washington, Oregon, and California. Reviewer 3 commented that the "Summary of the Scientific Conclusions" was an "excellent review of the literature." Reviewer 4 stated that the "status review is very thorough" and "it appears that the BRT has based its conclusions on the best available information." Reviewer 4 also stated that inclusion "of historical anecdotal records (e.g., old newspaper reports) and aboriginal traditional knowledge … were important in filling out the gaps in scientific data, and were influential in developing a qualitative 'weight of evidence' of eulachon status." Reviewer 5 stated that "it seems to me you have been very thorough."

Response

No response is required to comments by reviewers 1, 3, 4, and 5. Although known marine distribution and abundance of eulachon was thoroughly discussed during the BRT's deliberations, we agree that the summary of the status review (BRT 2008) failed to present or summarize all available information on marine distribution of eulachon off the U.S. West Coast and we attempt to rectify that oversight in this technical memorandum (see the Marine Distribution subsection in the Historical and Current Distribution subsection).

Status of the Southern DPS of Eulachon

Reviewers 2 and 4

Reviewer 2 did not address the appropriateness of the status assessment of the southern DPS of eulachon. Reviewer 4 stated that the BRT's conclusion that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range "appears to be strongly supported by the available information, which indicates severe declines in abundance and historically low population levels throughout most of the species range." Comments of the other reviewers are addressed below.

Reviewer 1

Reviewer 1 stated that the "BRT has appropriately weighed the various degrees to which age and size at maturity and fecundity can influence rate of population recovery." Furthermore Reviewer 1 felt that the BRT "note[d] correctly (in my opinion) the high probability that eulachon require comparatively high minimum viable population sizes to persist throughout the DPS." Reviewer 1 also believed that the BRT's application of the risk matrix approach "is not unreasonable when assessing extinction risk." However, in light of the demographic risks outlined by the BRT, Reviewer 1 "was somewhat surprised by the conclusion that the DPS is at moderate, rather than high, risk of extinction" and "might have expected a greater percentage of the available points to have been in the high risk category." In addition, although Reviewer 1 acknowledged that "the BRT has concluded that the DPS is at moderate risk of extinction throughout all of its range," the reviewer felt that "an explicit statement as to whether the BRT considers the southern eulachon DPS to be at high risk of extinction in a significant part of its range would be useful."

Response

The BRT also noted and discussed the apparent discrepancy between its high concern for individual demographic risks (abundance, productivity, spatial connectivity, and diversity) and the placement of the majority of likelihood points in the "moderate" rather than "high risk" category. It was apparent that some BRT members placed substantial emphasis on the innate productivity and demonstrated resilience of eulachon to ameliorate concerns they may have had in the categories of abundance, spatial connectivity, and diversity, and that factor weighed heavily on their overall consideration of the DPS's relative risk of extinction. This divergence of opinion on the productivity category is also reflected in the risk matrix scores for that demographic criterion compared to abundance, spatial connectivity, and diversity. For instance, BRT scores for abundance of the DPS ranged from 4 ("high risk") to 5 ("very high risk") with a modal score of 4, whereas BRT scores for growth rate and productivity of the DPS ranged from 2 ("low risk") to 5 ("very high risk") with a modal score of 2. This divergence of opinion on the ability of the species' innate productivity potential to buffer its extinction risk is also likely reflected in the final risk vote; although all BRT members put the preponderance of their points in the moderate or high risk category, only 3 of 10 members put the majority of their points in the high risk category.

In the memo from the NMFS Northwest Region Office to the Northwest Fisheries Science Center requesting the formation of a BRT to review the status of eulachon, the BRT was instructed as follows:

> If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range. In determining whether a portion of the species' or DPS' range is "significant," please follow the guidance articulated in Waples et al. 2007 (Waples, R. S., P. B. Adams, J. Bohnsack, and B. Taylor. 2007. A biological framework for evaluating whether a species is threatened or endangered in a significant portion of its range. Conserv. Biol. 21(4):964–974).

Once the BRT had concluded that the southern DPS of eulachon was at "moderate risk" of extinction throughout all of its range, the BRT did begin to discuss the implications of whether the DPS may be at "high risk" of extinction in a significant portion of its range, but determined that its instructions from the region did not require a formal analysis of this question. Thus the BRT believes that providing "an explicit statement as to whether the BRT considers the southern eulachon DPS to be at high risk of extinction in a significant part of its range" involves legal and policy issues that are currently beyond the scope of its mandate. The BRT was also cognizant of the fact that previous BRTs involved in ESA status reviews, which had resulted in equivalent conclusions of moderate risk ("likely to become at risk of extinction") throughout a species' range, had not felt compelled to formally pursue the question of whether the species was then at high risk ("at risk of extinction") in a significant portion of its range (Good et al. 2005, Hard et al. 2007).

Reviewer 3

Reviewer 3 agreed with the BRT's "conclusion that the southern DPS of eulachon, as defined in the report, is at moderate risk of extinction throughout its range." However, Reviewer 3 stated the evidence also "suggests that eulachon … are on the verge of extinction" in California.

Response

The BRT had similar concerns about eulachon in northern California. As presented in the summary of the status review (BRT 2008, p. 63), with the exception of abundance, the BRT had most concerns about demographic risks related to spatial structure and connectivity of the southern DPS of eulachon (see Table 13); and the BRT was particularly concerned about the potential for extirpation of the northern California subpopulation. Overall, the BRT scores for spatial structure and connectivity of the DPS ranged from 3 to 5 with a mean score of 3.7 and a modal score of 4, indicating that risks to the spatial structure of the southern DPS of eulachon were rated as high risk by the BRT (see Table 13).

Reviewer 5

In reference to Table 9 through Table 13 in the summary of the status review (BRT 2008, Table 15 through Table 19 in the present document), which summarized the results of the BRT's attempt to qualitatively rank the severity of threats to eulachon, Reviewer 5 was "troubled by the statement that an opinion of not applicable for a particular threat criterion was rated the same as unknown (i.e., equivalent to not voting on that criterion)" and the reviewer stated that, "If a factor is not applicable to a given river system, then it seems to me that this would mean a rating of 1; (low threat)—or even better a zero (if that were possible). I have to wonder if this would change the rankings of factors in these lists."

Response

In practical terms, 2 members of the BRT voted a total of 5 times that a threat was "not applicable" out a total of 600 individual votes on the various threat categories and subareas of the DPS. Nearly all members voted "unknown" at least once, for a total of 100 times. If these 5 "not applicable" votes are scored as 1 or very low threat, the rankings of threats in the Klamath and Columbia River subpopulations are unaffected. "Dams/water diversions" in the Fraser River subpopulation drops from 8th place to 11th place and "dams/water diversions" in the mainland British Columbia subpopulation drops from 11th place to 12th place, based on rankings of the mean scores. Modal scores are unaffected. These readjustments would have no impact on the BRT's identification of the severity of the top four identified threats in each subarea of the DPS.

Use of Political Boundaries for Defining a DPS

Review

Reviewer 2 commented extensively on the petitioner's argument (see Cowlitz Indian Tribe 2007) that, under the DPS policy, eulachon populations in Washington, Oregon, and California are collectively "discrete" from more northerly populations because they are delimited by an international governmental boundary (i.e., the U.S.-Canada border between Washington and British Columbia) across which there is a significant difference in exploitation control, habitat management, or conservation status. After providing comments on differences in management of eulachon between the U.S. and Canada, Reviewer 2 stated that "the delineation of DPSs on the basis of political boundaries is probably mistaken, both on biological and operational grounds."

Response

We agree. Although the joint USFWS-NMFS policy (USFWS-NMFS 1996) states that international boundaries within the geographical range of the species may be used to delimit a DPS in the United States, in past assessments of DPSs of marine fish and ESUs of Pacific salmon, NMFS has placed the emphasis on biological information in defining DPSs and ESUs and has considered political boundaries only at the implementation of ESA listings. Therefore, the BRT focused only on biological and ecological information in identifying whether DPSs of eulachon could be delineated.

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103 **Dufault, A.M., K. Marshall, and I.C. Kaplan. 2009.** A synthesis of diets and trophic overlap of marine species in the California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-103, 81 p. NTIS number pending.

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101 **Sands, N.J., K. Rawson, K.P. Currens, W.H. Graeber, M.H. Ruckelshaus, R.R. Fuerstenberg, and J.B. Scott. 2009.** Determination of independent populations and viability criteria for the Hood Canal summer chum salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-101, 58 p. NTIS number pending.

100 **Linbo, T.L. 2009.** Zebrafish *(Danio rerio)* husbandry and colony maintenance at the Northwest Fisheries Science Center. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-100, 62 p. NTIS number PB2009-113299.

99 **Rawson, K., N.J. Sands, K.P. Currens, W.H. Graeber, M.H. Ruckelshaus, R.R. Fuerstenberg, and J.B. Scott. 2009.** Viability criteria for the Lake Ozette sockeye salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-99, 38 p. NTIS number PB2009-113298.

98 **Johnson, L.L., G.M. Ylitalo, M.S. Myers, B.F. Anulacion, J. Buzitis, W.L. Reichert, and T.K. Collier. 2009.** Polycyclic aromatic hydrocarbons and fish health indicators in the marine ecosystem in Kitimat, British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-98, 123 p. NTIS number PB2009-110295.

97 **Roegner, G.C., H.L. Diefenderfer, A.B. Borde, R.M. Thom, E.M. Dawley, A.H. Whiting, S.A. Zimmerman, and G.E. Johnson. 2009.** Protocols for monitoring habitat restoration projects in the lower Columbia River and estuary. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-97, 63 p. NTIS number PB2009-113671.

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