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Documenting Changes in Migration Timing, Fisheries Catch, and Nonindigenous Perceptions of Eulachon (*Thaleichthys pacificus*): Analysis of Two Centuries of Historical Records

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Cover image: Recreational dip-net fishery for adult eulachon occurring on the Cowlitz River, Washington, on 14 February 2020. Photograph by R. Gustafson, NMFS/NWFSC.

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NOAA FISHERIES

Documenting Changes in Migration Timing, Fisheries Catch, and Nonindigenous Perceptions of Eulachon (*Thaleichthys pacificus*): Analysis of Two Centuries of Historical Records

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Plain Language Summary

Background

Eulachon are a type of small, schooling, silver-colored fish unique to the Pacific Northwest in the United States and Canada. Like salmon, eulachon migrate in large numbers from the ocean to reproduce in freshwater rivers. In addition to having ecologically important interactions with many other animals, eulachon migrations used to be so spectacular they were of significant cultural and economic importance to indigenous and nonindigenous people. Unfortunately, during the mid-1990s, eulachon began to experience declines in California, Oregon, Washington, and much of British Columbia, threatening these populations with extinction. Very few scientific or biological records exist prior to the declines, yet in order to plan and implement species recovery, scientists and resource managers must have information on historical migrations and human use before the declines. Therefore, it is necessary to search for and critically examine nonscientific historical documents such as newspapers or other periodicals, fishing records, personal journals, and eyewitness accounts to reconstruct the needed information.

This document compiles and analyzes newly uncovered and existing historical records to reconstruct historical migration timing for nine rivers in the Pacific Northwest where present-day populations are threatened with extinction. Records from as far back as 1806 provide over 200 years of information on how migration timing has changed in some rivers but not others. In addition, this updated set of historical records reveals changes in the commercial and societal value that nonindigenous people placed on eulachon.

Key Takeaways

- Because very few scientific or biological records for eulachon exist prior to population declines observed in the mid-1990s, scientists must search for and examine nonscientific historical records such as newspapers and other periodicals, fishing records, personal journals, and eyewitness accounts to understand eulachon migration and societal value prior to the decline.
- We uncovered new sources of nonindigenous historical information that expands existing documentation of eulachon migration timing to cover over two centuries (1806–present) and nine rivers in the Pacific Northwest.
- Historical records provide evidence that present-day migrations of eulachon into freshwater occur 15–32.8 days earlier in the Fraser, mainstem Columbia, Lewis, and Sandy Rivers compared to historical records. This change could be linked to changes in water temperature and river flow associated with climate warming.

- Historical records indicated no detectable changes to eulachon migration timing in the Grays, Cowlitz, Kalama, Umpqua, and Klamath Rivers.
- During periods of allowable commercial fishing (1896–1992), the highest prices of eulachon for sale commercially—standardized to the 2021 value of U.S. dollars—declined dramatically, from up to $31/lb ($62/kg) prior to 1915 to less than $3/lb ($7/kg) after 1975.
- How the majority of nonindigenous people perceive the societal value of eulachon has changed substantially—from a highly sought-after, valuable food fish supporting important indigenous and nonindigenous economies, to a nonfood fish suitable primarily for agricultural fertilizer or bait to catch more desirable fishes (e.g., sturgeon).
- In spite of changes in the economic value of and public perceptions about eulachon, continued strong interest in traditional indigenous harvest and nonindigenous recreational harvest of eulachon has potential to engage wider public interest in recovery efforts for threatened populations.

Links used in this section:

- Eulachon: https://www.fisheries.noaa.gov/species/eulachon
- Indigenous: http://traditionalanimalfoods.org/fish/searun-fish/page.aspx?id=6448
- Nonindigenous: https://www.nwcouncil.org/news/2021/04/12/little-fish-outsized-history/
- Species recovery: https://www.fisheries.noaa.gov/insight/recovery-endangered-and-threatened-species
- As far back as 1806: https://lewisandclarkjournals.unl.edu/item/lc.jrn.1806-02-24

Abstract

Eulachon (*Thaleichthys pacificus*) is an anadromous osmerid smelt that spends greater than 95% of its life at sea and spawns in the lower portions of rivers draining into the northeastern Pacific Ocean, ranging from northern California to the Bering Sea coast of southeastern Alaska. The Southern Distinct Population Segment (DPS) of eulachon is listed as threatened under the Endangered Species Act (USOFR 2010), and consists of numerous local spawning aggregations that occur from the Mad River in northern California to the Skeena River in British Columbia.

We examined over two centuries of historical records, including writings of early travelers, local newspaper accounts, fisheries periodicals, and archival records for information on adult migration timing, commercial fisheries catch, monetary market valuation, and sociocultural perceptions of the importance of eulachon in the Pacific Northwest. Using newspaper and other historical resources, we recorded initial migration timing of eulachon for the Fraser (1828–2005), Columbia (1806–1997), Grays (1928–2002), Cowlitz (1872–1997), Kalama (1915–95), Lewis (1882–2003), Sandy (1881–2015), Umpqua (1936–82), and Klamath (1895–2014) Rivers. Over these time periods, we detected statistically significant temporal trends toward earlier return timing of adult eulachon in the Fraser, mainstem Columbia, Lewis, and Sandy Rivers. However, migration timing was statistically unchanged in the Grays, Cowlitz, Kalama, Umpqua, and Klamath Rivers, based on the available data. These data established new dates for when commercial fisheries began in the Columbia (1866) and Fraser (1868) Rivers, and added seven and 37 years to the history of documented eulachon runs in the Sandy and Klamath Rivers, respectively.

Previous reports (Craig and Hacker 1940, Cleaver 1951, Smith and Saalfeld 1955) mentioned numerous gaps in eulachon harvest records from the Columbia River prior to 1894 and between 1901 and 1923. However, we uncovered additional published Columbia River commercial fishery landings data in annual reports of state and federal fisheries agencies and newspaper records that fill in most of these gaps in the catch record. These newspaper records also indicate that in some years—particularly in 1905, 1906, 1910, 1911, and 1917—substantially more eulachon tonnage was likely landed than was reported in federal or state fishery agency publications.

We compiled the yearly high and low monetary valuation of eulachon in price per pound (converted to 2021 U.S. dollar values) in the Portland, Oregon, fish markets as stated in over 740 newspaper accounts or advertisements from 1896–1992. Eulachon were more highly valued prior to about 1915, when the price per pound for the first eulachon of the season commonly ranged from about $10 to over $31 per pound ($22–$61/kg). In more recent years (e.g., 1966–78), even the first eulachon of the season were rarely valued at over $2 to $3 per pound ($4–$7/kg). The dramatic decline in the relative monetary value of eulachon from the 1890s to the 1970s was likely influenced by a combination of eulachon abundance, catchability, economic conditions, and consumer preference.

Historical sources in the lower Columbia River basin also documented dramatic shifts in local societal/sociocultural perceptions of eulachon, as well as large declines in the monetary economic value of eulachon since the 1890s. Contemporary first-person

narratives of early nonindigenous visitors to the Pacific Northwest and anecdotal descriptions in over 15 decades of local newspaper records document a dramatic shift in nonindigenous sociocultural perceptions of eulachon over the past two centuries, particularly in the lower Columbia River basin. We found over 1,700 newspaper articles from sources in the lower Columbia River basin that mentioned eulachon: 1) as vital to the nutrition and cultures of indigenous peoples, 2) as a gourmet food fish for nonindigenous peoples, 3) as the basis of a large economically important commercial fishery, 4) as fertilizer for farmers, or 5) as a baitfish for other fisheries, such as sturgeon. This degradation of the original positive societal view of eulachon—from savior fish and gourmet food fish to baitfish—parallels the declining trend in the monetary value of eulachon.

Although some perceptions of eulachon as a commercial commodity have changed over time in the Columbia River basin, there has always remained a strong interest in eulachon by tribal fishers for subsistence and ceremonial purposes, and by recreational dip-net fishers as a food fish. Currently, eulachon are sometimes described as having little commercial importance (Armstrong and Hermans 2007, Benson et al. 2019); however, they and other forage fish are increasingly being recognized as playing a crucial role as prey for many species in marine food webs (Marston et al. 2002, Sigler et al. 2004, Womble et al. 2005, Armstrong and Hermans 2007).

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Introduction

Eulachon (*Thaleichthys pacificus*, Osmeridae) is an anadromous smelt that spends 95% of its life in the ocean and spawns in the lower portions of rivers that have prominent spring peak-flow events, from northern California to the southeastern Bering Sea coast of Alaska (Hay and McCarter 2000, Willson et al. 2006, Moody and Pitcher 2010). Eulachon have great nutritional, medicinal, economic, and ceremonial importance for local indigenous peoples (Mitchell and Donald 2001, see references in Gustafson et al. 2010). The historically high abundance of eulachon, their early spring return timing when other resources were scarce, and the value of their rendered oil as a trade item in areas to the north of the Fraser River meant that eulachon were second only to salmon in importance as a natural resource to many local indigenous peoples (Mitchell and Donald 2001). The high lipid content of eulachon (18.8% in the Gulf of Alaska; Payne et al. 1999) also makes them a significant prey item for many marine mammals, birds, and marine and freshwater fishes.

Despite their ecological and human resource importance, eulachon were a poorly monitored species prior to abrupt declines in recreational and commercial fishery catches that occurred in the early to mid-1990s (Hay and McCarter 2000, Gustafson et al. 2012). The perceived decline in abundance in the southern portion of its range (followed by continued low returns), in addition to other risk factors, led to a listing of the Southern Distinct Population Segment (DPS) of eulachon as a threatened species in Washington, Oregon, and California under the Endangered Species Act (ESA; Gustafson et al. 2010, 2012). Subsequently, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed two designatable units (DU) of eulachon in British Columbia as endangered, the Fraser River DU and the Central Pacific Coast DU (COSEWIC 2011, 2013). The relative scarcity of studies on eulachon biology prior to the 1990s—some notable exceptions are Hart and McHugh (1944), Smith and Saalfeld (1955), Barraclough (1964), and Parente and Snyder (1970)—coupled with its importance as a natural resource that was often written about in nonscientific sources, make eulachon a prime candidate for historical ecological research.

Although fisheries catch data may be available for some economically valuable marine species beginning in the early 1900s, fisheries-independent data and life-history diversity are rarely known from this era (Eero and MacKenzie 2011). Even for species of high economic value, modern stock assessments that provide a time series of stock abundance may extend only as far back as the early 1970s (Cardinale et al. 2009, Eero and MacKenzie 2011). In many cases, demographic responses of marine fish species to both past climatic variation and early anthropogenic impacts, which pre-date modern systematic data collection, are unavailable through traditional sources. In recent decades, marine conservation biologists and fisheries scientists have begun to use nontraditional historical sources to fill some of these data gaps and help establish natural baseline conditions in regards to spatial distribution, abundance, demographic structure, and life-history characteristics in marine fishes (Holm et al. 2010, McClenachan et al. 2012, 2015b, Thurstan et al. 2015). These baselines have been used as historical reference points to better assess the conservation status of marine fish populations (Thurstan et al. 2015), as well as in recovery of at-risk species and ecosystems (Williams et al. 2010). In the absence of an historical perspective, shifts in these baseline conditions may go unrecognized by modern fisheries scientists (i.e., "shifting baseline syndrome;" Pauly 1995, Pinnegar and Engelhard 2007).

Nontraditional sources of historical ecology can include written sources, oral history (e.g., traditional ecological knowledge and fishers' knowledge), archival DNA analyses, and zoo-archaeological and paleo-oceanographic studies (Pitcher 2001, Szabó 2010, 2015, McClenachan et al. 2012, Thurstan et al. 2015). More specifically, non-traditional written data sources include ship logbooks (Alexander et al. 2009), eyewitness accounts of early observers (Sáenz-Arroyo et al. 2005, 2006), newspaper articles (Thurstan et al. 2016, Buckley et al. 2017), photographs (McClenachan 2009), and even cookbooks (Levin and Dufault 2010) and restaurant menus (Van Houtan et al. 2013).

In the case of eulachon, previous contributions have explored written historical sources of information in regards to geographical distribution (Moody and Pitcher 2010, Gustafson et al. 2010), fisheries (Stacey 1995, Martin 2006, Moody and Pitcher 2010), and regional fluctuations in perceived abundance (Hinrichsen 1998, Moody and Pitcher 2010, Martin 2014, Morin et al. 2023). In addition, Reynolds and Romano (2013) and Lower Fraser Fisheries Alliance (LFFA 2015) have pioneered efforts to gather traditional ecological knowledge in the Columbia and Fraser Rivers, respectively; and Butler (2004) and Rosenberg (2015) have examined zoo-archeological evidence related to historical utilization, abundance, and ecology of eulachon in the lower Columbia River. Similarly, Patton et al. (2019) examined zoo-archeological, ethnographic, and oral historical evidence for pre-contact eulachon fisheries on the northern coast of British Columbia, Canada. Recently, Morin et al. (2023, p. 303) compiled archaeological, ethnohistoric, and scientific/regulatory records of indigenous and commercial fisheries' harvest of eulachon (and other forage fishes) that detail "significant reductions in the major forage fish fisheries around Vancouver [British Columbia] within decades of the initial Euro-Canadian settlement."

In this contribution, we expand on these previous studies of written accounts through analysis of qualitative and quantitative writings of early explorers, fur trappers, settlers, missionaries, etc.; local newspaper articles and advertisements; fisheries periodicals; and archival records of fisheries management agencies that provide evidence about past life history, commercial catch, monetary value, and changing sociocultural perceptions of eulachon in the Pacific Northwest. A key life-history trait for anadromous fishes is adult migration timing, which affects individual reproductive success, and thereby genetic fitness, and is likely influenced by local environmental conditions, particularly water flow and temperature (Jonsson 1991). We examined our historical sources for temporal trends in migration timing of adult eulachon spawning runs in the Fraser River, the Columbia River and its lower tributaries, and the Umpqua and Klamath Rivers. Based on studies showing adult run timing in some Pacific salmon occurring earlier now than historically (Quinn and Adams 1996, Cooke et al. 2004, Taylor 2008, Kovach et al. 2013, 2015), we postulated that eulachon in these environments might have also shifted to an earlier return timing in response to warming seasonal water temperatures or changes in water flow. We also attempted to reconstruct aspects of historical fisheries catch of eulachon in the Pacific Northwest using our historical sources. In particular, we examined available data on commercial and recreational eulachon catch from the Fraser River, coastal British Columbia, and the Columbia River basin. These additional historical newspaper sources also document shifts in the monetary value and nonindigenous sociocultural perceptions of the importance of eulachon over the past two centuries.

We are cognizant of the observation, sampling effort, preservation, and recording biases inherent in historical written sources (McClenachan et al. 2015a). Although these nontraditional sources may fill critical gaps in our knowledge, it is important to recognize the difficulties inherent in applying scientific analyses to these accounts. We have not attempted to estimate historical abundance with these records, since catch records for eulachon were often driven by market forces, weather conditions, fishing effort, and many additional factors other than actual fish abundance.

Materials and Methods

Study Area

For the purposes of this study, we define the Pacific Northwest as a combination of the states of Washington, Oregon, and northern California, and the Province of British Columbia, Canada. We have specifically limited our historical analyses to the coastal regions of the Pacific Northwest, with an emphasis on the U.S. portion of the DPS and to areas south of Knight Inlet on the coast of British Columbia, where written sources are more common. This area includes both the Coastal Range Ecoregion in the United States (Omernik 1987) and the Pacific Maritime Ecozone in Canada (Ecological Stratification Working Group 1995), and is roughly equivalent to the geographic boundary of the Southern DPS of eulachon (Gustafson et al. 2012; Figure 1). This area also incorporates the entirety of the Fraser River DU and a portion of the Central Pacific Coast DU in British Columbia (COSEWIC 2011).

Data Sources

Our sources of historical information on adult migration timing, commercial fisheries catch, monetary market valuation, and sociocultural perceptions of eulachon include first person narratives and eyewitness descriptions of early explorers, surveyors, fur trappers, missionaries, and settlers; logbooks of fur company posts; field notes recorded by local fisheries biologists; reports of various fisheries agencies; and articles in newspapers and early fisheries periodicals. A list of primary source collections examined for historical written documents is available as supporting information (Table S1). A list of digitized and microfilmed newspapers examined, keywords searched, and time span searched is available as supporting information (Table S2). Transcribed qualitative data from all historical written sources and newspapers are presented chronologically in four separate databases arranged geographically and available as supporting information: British Columbia (Table S3), the Columbia River (Table S4), the Umpqua River on the Oregon Coast (Table S5), and the Klamath River in northern California (Table S6).

Narratives

Many of the first-person journals, diaries, logbooks, and eyewitness descriptions cited in Tables S3–S6 were accessed from online websites such as the digital collection of The Champlain Society,[1] digital collections of the Washington State Library,[2] the Library of Western Fur Trade Historical Source Documents,[3] etc. (Table S1). We accessed additional first-person sources in hard copy and through interlibrary loan from local libraries and historical societies such as King County Library System's Northwest Collection (King County, Washington), Humboldt Room Special Collections at California State Polytechnic University, Humboldt (Arcata, California), and Clark County Historical Museum (Vancouver, Washington).

[1] https://champlainsociety.utpjournals.press/
[2] https://www.sos.wa.gov/library/digcolls.aspx
[3] https://user.xmission.com/~drudy/mtman/

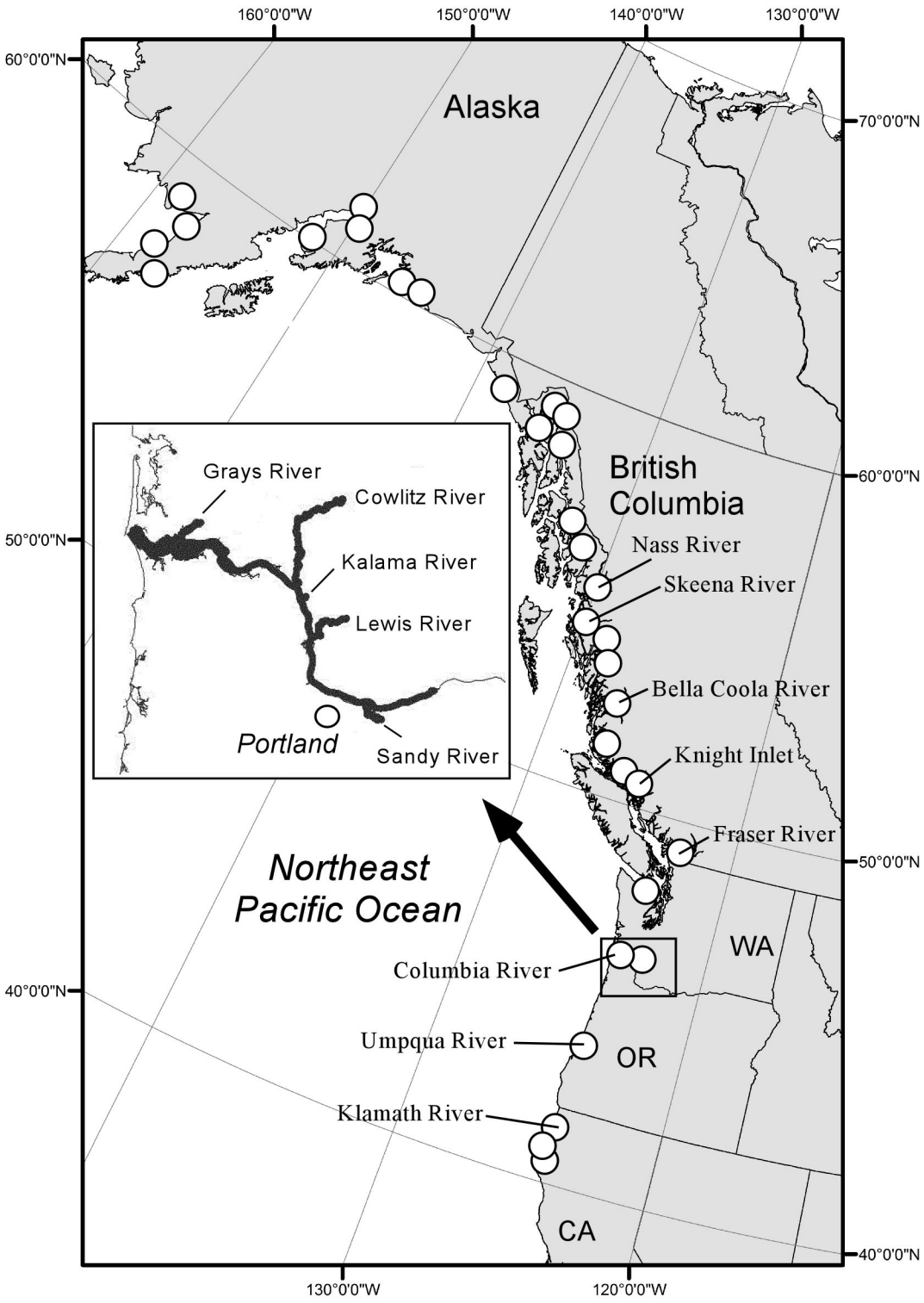

Figure 1. Schematic diagram showing eulachon spawning rivers (open circles) and specific rivers mentioned in the text. Inset depicts the lower Columbia River basin.

Newspapers

We examined historical accounts of eulachon from nearly 70 newspapers that began publication as early as the 1850s in the Pacific Northwest for reference to eulachon. Newspapers were available in online digital or library microfilm format (Table S2). Keyword searches were conducted in online digital newspaper archives using local common names such as *eulachon*, *oolichan*, *oolachan*, *oulachon*, *ooligan*, *ulahans*, *smelt*, *Columbia River smelt*, and *candlefish*. Early Pacific Northwest newspapers available only in microfilm format were manually scanned for eulachon information in four main libraries: 1) the Microforms and Newspapers Collection in the University of Washington's Suzzallo Library (Seattle, Washington), 2) the newspaper collection in the California State Polytechnic University, Humboldt Library (Arcata), 3) the Washington State Library (Olympia, Washington, microfilm on loan), and 4) the California State Library (Sacramento, California, microfilm on loan; see Table S2). Since eulachon return to spawn during the months of December to April in northern California, November to April in the Columbia River basin, and March to May in the Fraser River, only these months of the year in newspapers from these locales were searched manually for reference to eulachon occurrence.

Fisheries periodicals and archived government agency records

The *Pacific Fisherman* was a fishing industry magazine published from 1903–66. Digitized copies of this periodical from 1903–11 were examined in the online digital collections of the University of Washington library.[4] Additional issues of *Pacific Fisherman* were manually searched for eulachon information at the Northwest Fisheries Science Center Library (Seattle) and the University of Washington's Suzzallo and Allen Library (Seattle).

Information on eulachon ecology and fisheries landings was also extracted from archived state and federal government fishery agency documents accessed in the University of Washington's Suzzallo and Allen Library (Seattle). Documents included annual reports and bulletins of the Washington State Fish Commissioner (1890–1921), the Washington State Supervisor of Fisheries (1921–25), the Washington State Department of Fisheries and Game (WDFG, 1925–31), the Washington Department of Fisheries (WDF, 1931–93), the Washington Department of Fish and Wildlife (WDFW, 1994–2008), and the annual or biennial reports of the Oregon State Board of Fish Commissioners (1889) and Oregon State Department of Fisheries (1900–13). Similarly, a manual search was performed for eulachon information in the Annual Reports on the Fisheries of British Columbia (1873–1917, published as part of the Sessional Papers of the Parliament of Canada) and the Fisheries Statistics tables published by the Canada Dominion Bureau of Statistics (1917–28) and the Canada Department of Trade and Commerce (1929–49). These latter documents were accessed in the Government Publications depository of the University of Washington's Suzzallo Library (Seattle). We also extracted eulachon information from the Annual Reports of the Department of Indian Affairs of the Dominion of Canada (1882–1916), which were accessed online at the Library and Archives Canada website.[5]

[4] http://content.lib.washington.edu/pacfishweb/index.html
[5] https://recherche-collection-search.bac-lac.gc.ca/eng/Home/Search?q=Indian+Affairs+Annual+Reports&DataSource=Library%7cIndAffAnnRep&num=25&start=0

We reviewed and extracted data related to eulachon migration timing and commercial fisheries catch from field notes (WDFG 1929, 1931) taken by WDFG biologists during the Columbia River eulachon run in 1928–31 and archived at the Washington State Archives (Olympia). We also examined eulachon landings records from WDF (1949–93) and WDFW (1994–2008) records to extract approximate eulachon arrival dates in the Columbia River and the Grays, Cowlitz, Kalama, and Lewis Rivers based on dates of initial commercial landings and first day of delivery of over 1,000 pounds (454 kg) of eulachon, which we hereafter refer to as the "first large catch" (Table S7). Commencing in 1998, commercial fishing in the Columbia River basin was restricted to between one and four days per week in January–March, and therefore, post-1997 landings data cannot be used as an accurate indicator of the date of initial appearance of eulachon in the Columbia or Cowlitz Rivers.

Temporal Trends in Adult Eulachon Migration Timing

A combination of newspaper records and information in early narratives and initial commercial fishery landings (Tables S3–S7) was used to reconstruct the approximate date of initial river entry of adult eulachon. In some cases, earliest appearance of eulachon in local fish markets as reported in newspaper records was used as a proxy for initial river entry. We realize that time to market and time to publication varied with differing modes of transportation and communication. If news articles mentioned specific first river-entry dates, then these dates were not adjusted. In all other cases, we adjusted dates of actual first river entry or first catch based on river-specific criteria that depended on modes and speeds of transportation of eulachon to market or on varying modes of communication available at the time.

To account for delays in transportation and publication, dates of newspaper records mentioning or advertising that Fraser River eulachon were on the market were adjusted to one day earlier if the source was a New Westminster, BC, newspaper on the Fraser River. Prior to 1910, date of arrival was adjusted to two days earlier than the newspaper date if the source was a Vancouver, BC, newspaper. After 1910, newspaper dates from Vancouver newspapers were adjusted to one day earlier, assuming more rapid transportation and communication. Additional information for the date of initial river entry into the Fraser River below Mission Bridge was available in Fishery Officers narratives from Ladner, BC (1948–79). These data were transcribed and edited by D. E. Hay and published in LFFA (2015, pp. 81–83). A further seven years of initial entry dates (1995–2002) were derived from first recorded catch in the Fraser River test fishery (the fishery did not operate in 1999; Hay et al. 2003, their Table 6). The initial date of entry in the test fishery and most of our newspaper records are based on observations of eulachon in the Fraser River near New Westminster, whereas eulachon entry dates from LFFA (2015) are based on dates of river entry at Ladner, approximately 18 km downstream of New Westminster. To account for this difference, four days were added to the entry dates at Ladner, based on the average difference in first date of observation of eulachon at New Westminster and Ladner across seven years of overlapping data. Calendar dates were converted to day-of-the-year (DOY) for the Fraser River.

We also adjusted our newspaper-derived proxy dates of first arrival of eulachon in the Columbia River basin. Typically, the first Columbia River eulachon of the season were caught in a commercial gill-net fishery operated between Cathlamet, Washington—at river kilometer (RKM) 62—to Oak Point, Washington (RKM 85), to the mouth of the Cowlitz River at Longview, Washington (RKM 108). These fish were then transported upriver to the distribution centers of Kelso, Washington (near the mouth of the Cowlitz River) or Rainier, Oregon (across the Columbia River from the Cowlitz River). The main market being Portland, Oregon (a distance of 93 km from Kelso), eulachon would travel by steamboat, arriving in Portland the day after they were caught and thus were in market within two days. Paddlewheel steamboats began operating on the Columbia River in 1861, and the steamer *Joseph Kellogg* usually made the trip between Kelso and Portland in about 5.5 hr, with a record of 3 hr 5 min. After 1908, many eulachon were transported by rail across the new Willamette and Columbia River bridges to Portland. Unless the precise day of capture was mentioned, we adjusted proxy dates for eulachon arrival in the mainstem Columbia River to two days earlier than the publication date of their appearance in Portland fish markets, to account for transportation and publication delays.

Cowlitz River eulachon were typically caught at night by commercial dip-net fishers working out of Kelso, placed on fast steamboats or trains, and arrived in Portland fish markets one day after they were caught. Similarly, eulachon were commercially caught in the Kalama and Lewis Rivers by dip-net fishers from Kelso and arrived in Portland the day after they were caught. Unless the precise day of capture was mentioned, we adjusted proxy dates of first occurrence in Portland markets for eulachon caught in the Cowlitz, Kalama, or Lewis Rivers to one day earlier than the newspaper date, based on transportation and publication delays. The dates of first commercial fishery delivery as reported in WDF/WDFW landings records from the Columbia River mainstem—and the tributary Grays, Cowlitz, Kalama, and Lewis Rivers (1949–97, Table S7)—were also used as a proxy for yearly date of initial river entry of adult eulachon.

In most cases, we know the exact date of first yearly entry of eulachon into the Sandy River, since eulachon were easily observed in the river's clear waters, and the presence of numerous local observers led to rapid communication of the presence of eulachon to local newspaper outlets. Similarly, the clear water of the Umpqua River, on the Oregon Coast, resulted in many precise dates of first arrival of eulachon, as recorded by recreational dip netters. However, as the Umpqua River at Scottsburg, Oregon, is relatively remote, we adjusted proxy dates of first occurrence to two days earlier than newspaper dates, due to delays in communication and publication.

The mouth of the Klamath River is remote from the nearest towns that had a significant history of newspaper publications: Crescent City, California (31.5 km), and Eureka, California (107 km). A through-road opened from Crescent City to Eureka in 1894, with a ferry crossing at the Klamath River until 1926 when a bridge was completed (Bearss 1981). Requa, California, at the mouth of the Klamath River, did not receive telephone service until after 1909; however, a stage line connected Requa with Crescent City and Eureka prior to 1909, providing service three days per week, both to and from Requa (Scotton 1909). Therefore, unless an exact date of eulachon occurrence was mentioned in newspaper accounts, we subtracted two days before 1910, and one day after 1909, from dates of publication of Klamath River eulachon (i.e., candlefish) occurrence, as published in Crescent City and Eureka papers.

Because eulachon migration timing in the Columbia River and its tributaries can be as early as November and as late as late April, spanning two calendar years, all dates of initial river entry or fishery delivery in this study—with the exception of the Fraser River—have been converted, for graphical purposes, to the day-of-the-run-year (DORY), beginning on 1 November. As the vast majority of eulachon in these rivers enter after 1 January, the run year is designated by the calendar, beginning in January. For comparative purposes, migration dates for the Umpqua and Klamath Rivers were also converted to DORY. We used linear regression to estimate trends in the initial date of adult migration timing and to evaluate how migration has changed over time.

Historical Fisheries Catch

From the historical data sources listed above, we compiled statements on the historical distribution and fisheries catch of eulachon in British Columbia (Tables S9 and S10) and the Columbia River (Table S11). We also compiled eulachon fisheries landings from archived state and federal government fishery agency documents. These sources were the only available relative proxy for historical abundance of eulachon, besides the traditional ecological knowledge of local indigenous peoples.

Temporal Trends in Monetary Market Value of Eulachon

We analyzed newspaper records from 1866–1992 that reported an advertised price per pound for Columbia River eulachon. All historical price per pound values were adjusted, for comparative purposes, to 2021 U.S. dollar values (the most recent year available) using a Purchasing Power Calculator based on the Consumer Price Index, available online at MeasuringWorth.com[6] (Williamson 2023). This calculator uses the price of a set of consumer purchases to compute the relative value of an historical U.S. dollar amount to 2021 dollar values (Williamson 2023). Sufficient data exist to infer changes in the seasonal range of monetary valuation for eulachon in most years from 1889 to 1992. We also compared the yearly high and low price per pound for eulachon for each year.

Sociocultural Perceptions of Eulachon Importance

We compiled first-person narratives of early nonindigenous visitors to the Pacific Northwest and anecdotal descriptions in over 15 decades of local newspaper records that document how eulachon were perceived by nonindigenous society in the Pacific Northwest, and particularly in the Columbia River basin, at various times during the past two centuries. We compiled and enumerated the number of records that referred to eulachon as: 1) a vital source of food for indigenous peoples, 2) a gourmet food fish in nonindigenous society, 3) the basis of a large, economically important commercial food fishery, 4) a source of farm fertilizer, 5) a source of food for zoo animals or domestic species, and 6) a baitfish.

[6] https://www.measuringworth.com/calculators/uscompare/index.php#cpi

Investigating Potential Data Source Bias

As the majority of historical information on migration timing and fisheries catch used in this study came from newspaper accounts or early narratives, it is important to recognize the difficulties inherent in applying scientific analyses to such accounts. They include the likelihood that eulachon were more apt to appear in newspaper accounts when they were unusually scarce or abundant, or unusually early or late in returning. In addition, newspaper accounts can arise from second- or third-hand information. The level of perceived local reader interest can also influence whether reports of a natural event, like the return of eulachon, will make it into the papers. Nevertheless, newspaper accounts have been used to study the historical range and abundance of the passenger pigeon (*Ectopistes migratorius*, Schorger 1955); the ecological history of koala (*Phascolarctos cinereus*) habitat in Australia (Knott et al. 1998); historical perspectives on urban biodiversity in Finland (Vuorisalo et al. 2001); and original distribution and relative abundance of lake sturgeon (*Acipenser fulvescens*) in Lake Michigan tributaries (Cochran and Elliott 2012). In the marine realm, newspapers have been used to study historical nesting locations, densities, and exploitation of green sea turtles (*Chelonia mydas*, Kittinger et al. 2013); historical catch rates of Australian snapper (*Pagrus auratus*, Thurstan et al. 2016); and historical declines in catch rates and loss of spawning aggregations in Spanish mackerel (*Scomberomorous commerson*, Buckley et al. 2017).

To minimize the risk of misidentification of other smelt species (e.g., surf smelt, *Hypomesus pretiosus*, from Puget Sound), only accounts that refer explicitly to eulachon caught in the Columbia River basin (i.e., Columbia River smelt), the Fraser River (i.e., oolichan, oolachan, oulachon, ooligan, and ulahans), or the Klamath River (i.e., candlefish) were used as source information in their respective river basins. Due to their earlier migration timing, eulachon caught in the Columbia River can appear for sale in British Columbia long before the return of Fraser River eulachon (Table S3). Therefore, British Columbia newspaper records that did not explicitly refer to Fraser River eulachon, or one of its many other local names, were removed from these analyses.

Results and Discussion

Use of Historical Newspaper Sources

Smith et al. (1953), Hinrichsen (1998), and Martin (2014) used a small subset of historical newspaper articles to inform past occurrence of eulachon in the Cowlitz or Columbia Rivers. After the failure of eulachon to enter the Cowlitz River in 1949–51, Smith et al. (1953) examined two local newspapers (*The Kelsonian*, Kelso, 1889–1920, and the *Longview Daily News*, Longview, 1923–35) to determine "whether the Cowlitz had experienced other seasons without smelt." Although Smith et al. (1953) used these newspaper articles to conclude that eulachon had not entered the Cowlitz River in at least four years over this time period (1915, 1918, 1927, and 1928), they did not attempt to analyze past migration timing of eulachon. Our records (Table S3) confirm the absence of eulachon in the Cowlitz River in 1927–28, but indicate eulachon did make an appearance in this river in 1915 and 1918. Hinrichsen (1998) extracted limited information from several local newspapers for his review of the history of eulachon harvests in the Cowlitz River, but did not attempt to analyze past migration timing or ecology. In addition, Martin (2014, p. 34) cited several newspaper articles as evidence of the "fish's apparently random behavior" in an historical summary of eulachon population fluctuations. The above examples, together with the eulachon status review (Gustafson et al. 2010), are the only known previous studies to use newspaper articles as source documents for historical information on eulachon. Unconventional data sources such as newspapers are particularly useful for species, like eulachon, that lack agency records.

Temporal Trends in Adult Eulachon Migration Timing

We present the results of our migration-timing analyses by river basin from north to south in the order of Fraser, Columbia, Umpqua, and Klamath Rivers, and, for Columbia River tributaries, from nearest to the ocean to furthest inland: Grays, Cowlitz, Kalama, Lewis, and Sandy Rivers (Figure 1). Table 1 provides the sample size (number of years with information) for each river population; the earliest, latest, and mean date of first entry; and regression statistics for the relationships between migration timing and year. In large rivers such as the Fraser and Columbia, eulachon may enter the lower river reaches and remain for days, or even weeks, awaiting favorable spawning temperatures prior to proceeding upriver or into tributaries to spawn. However, eulachon entering tributaries such as the Cowlitz River are likely actively spawning, or soon will be.

About 67% of our initial eulachon arrival dates in the mainstem Columbia River from 1866 to 1997 were sourced from newspaper reports, 31% from WDF/WDFW initial commercial landings data, and 2% from early narratives. Newspaper reports also accounted for about 57, 57, and 77% of our initial river-entry dates in the Fraser, Cowlitz, and Sandy Rivers, respectively, and nearly 100% in the Umpqua and Klamath Rivers. Newspaper data sources for migration timing consisted of more than 180 entries for the Fraser River from 1867–1995; over 2,300 entries for the Columbia River basin, including the Grays, Cowlitz, Lewis, Kalama, and Sandy Rivers, from 1866–2008; over 70 entries for the Umpqua River in Oregon from 1936–82; and over 85 entries for the Klamath River in California from 1895–1978 (Figure 1, Tables S3–S6).

Table 1. Summary of adult eulachon migration timing for each river population, and linear regression statistics for initial river entry dates versus year. Bold and underlined values indicate significance at $P < 0.05$ and $P < 0.001$, respectively.

River	Range of years	Earliest first entry date	Latest first entry date	Mean first entry day	Regression equation	*n*	*P* value	r^2	Change in first entry day/yr
Fraser River	1828–2005	14 Mar 1997	28 Apr 1925	8 Apr	DOY = 274.44 – (0.09 × year)	92	**<u>0.001</u>**	0.212	0.09 d earlier
Columbia River	1806–1997	10 Nov 1895	4 April 1867	30 Dec	DORY = 317.64 – (0.13 × year)	134	**0.013**	0.046	0.13 d earlier
Columbia River (large catch)	1867–1997	12 Dec 1939	8 April 1868	25 Jan	DORY = 442.52 – (0.18 × year)	119	**0.001**	0.085	0.18 d earlier
Grays River	1928–2002	10 Dec 1941	20 Feb 1949	23 Jan	DORY = –496.80 + (0.30× year)	23	0.218	0.071	n/a
Cowlitz River	1872–1997	25 Nov 1905	6 Mar 1966	14 Jan	DORY = –86.31 + (0.08× year)	103	0.229	0.014	n/a
Cowlitz River (large catch)	1889–1997	18 Dec 1978	7 Apr 1959	28 Jan	DORY = 50.90 – (0.02 × year)	92	0.793	0.001	n/a
Kalama River	1915–1995	14 Jan 1954	1 Apr 1951 1 Apr 1957	2 Mar	DORY = 238.62 – (0.06 × year)	25	0.746	0.005	n/a
Lewis River	1882–2003	5 Jan 1980	14 Apr 1988	6 Mar	DORY = 563.13 – (0.22 × year)	45	**0.021**	0.118	0.22 d earlier
Sandy River	1881–2015	23 Jan 2003	28 Apr 1924	25 Mar	DORY = 622.41 – (0.25 × year)	57	**<u>0.001</u>**	0.255	0.25 d earlier
Umpqua River	1936–1982	10 Jan 1972	9 Mar 1977	5 Feb	DORY 393.00 – (0.15 × year)	15	0.710	0.011	n/a
Klamath River	1895–2014	20 Jan 1932	23 Apr 1915	8 Mar	DORY = –34.26 + (0.08 × year)	48	0.524	0.009	n/a

Fraser River

Journals kept by James McMillan and Archibald McDonald at the Hudson Bay Company's Fort Langley on the Fraser River show that eulachon were first seen on 28 April, 14 April, and 4 May in 1828, 1829, and 1830, respectively (MacLachlan 1998; Table S3). We found additional newspaper accounts (Table S3) for 52 years from 1867–1988, fishery officer reports (LFFA 2015) for 27 years from 1949–79, and test fishery records[7] for 10 years from 1995–2005, that reported on the first yearly appearance of eulachon in the Fraser River. Overall, we found usable records on the initial date of appearance of eulachon in the Fraser River for 92 years between 1867 and 2005, in addition to the three-year period from 1828–30. The fitted regression line for the relationship between first day of entry of eulachon to the Fraser River and year is statistically significant (Table 1, Figure 2), with eulachon returning about 0.09 days earlier per year (Table 1), and about 15 days earlier in the year over the full period of the data, from 1828–2005 (Figure 2).

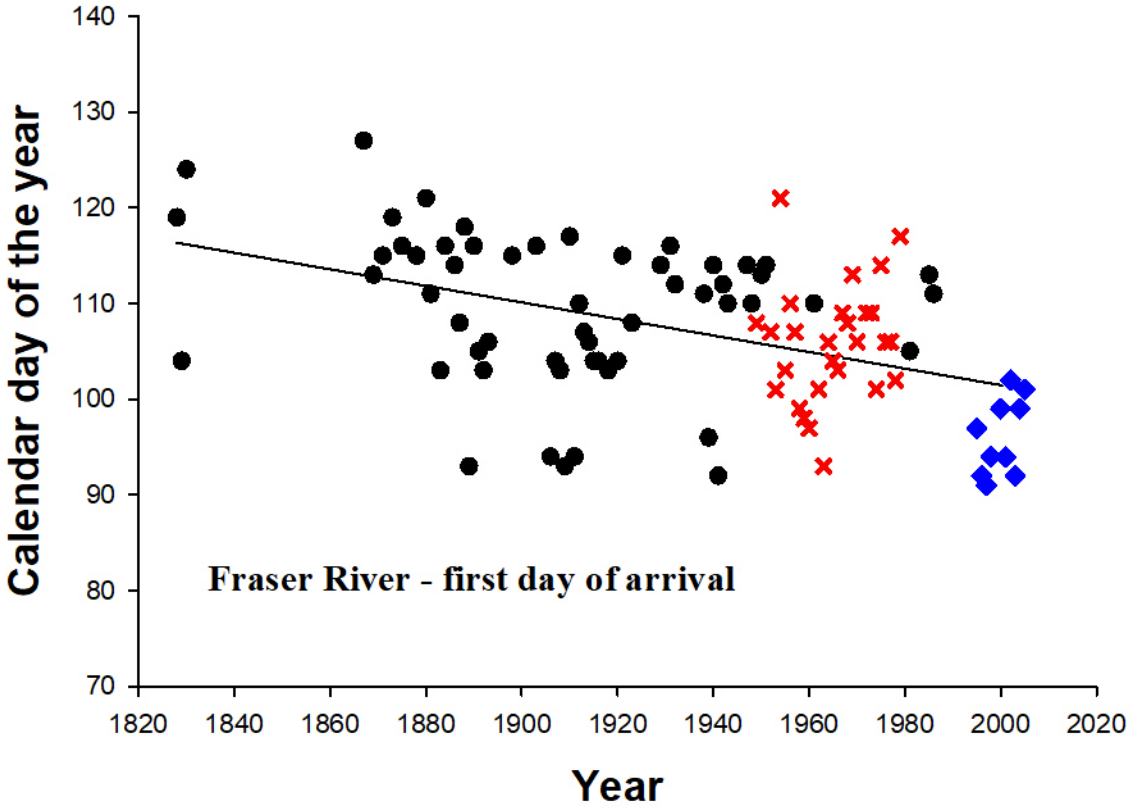

Figure 2. Initial calendar day of yearly river entry of eulachon in the Fraser River, based on historical written sources, newspaper records, and dates of first appearance in a test fishery. Black circles represent data from newspaper records and Fort Langley journals (Table S2). Red x symbols indicate earliest yearly start of the Fraser River eulachon migration at Ladner, British Columbia (1948–80), as described in Fishery Officer narratives (LFFA 2015, pp. 81–83). Dates of first appearance at Ladner have been advanced by 4 days to account for migration delay between Ladner and New Westminster, British Columbia. Blue diamonds indicate dates of first occurrence in the Fraser River test fishery from 1995–2005. Linear regression line is significant ($P < 0.001$) and plotted using all data points.

[7] https://www.pac.dfo-mpo.gc.ca/fm-gp/fraser/docs/archiv-reports-rapports/commercial/eulachonreport.htm

Based on when the historical fishery operated, entry and spawn timing of eulachon in the Fraser River occurs from early April until late May (McHugh 1939) or mid-March to mid-May (Ricker et al. 1954). However, local indigenous knowledge suggests there may be as many as three separate runs of eulachon in the Fraser River. LFFA (2015, p. 11) stated that there is "an early run near the end of February–beginning of March with smaller fish, followed by a second run in the first week of April with medium sized fish, and lastly a third run at the end of April until about the second week of May with the biggest fish." Our data indicated a mean date of initial appearance of eulachon in the Fraser River of 8 April, which is more than four months later in the run year than the average date of first occurrence of eulachon in the Columbia River (30 December). Eulachon populations in northern British Columbia spawn in February to early March, whereas more southern populations including the Fraser River typically spawn in April (Moody and Pitcher 2010). Other eulachon populations in British Columbia typically spawn in February to early March, which suggests that Fraser River eulachon have the latest average spawn timing of any population south of Alaska.

Columbia River basin

The time of first entry into the Columbia River basin typically occurs in February and March, although adults can enter the system from November to April (see references in Gustafson et al. 2010). An early winter run of eulachon enters the Columbia River, and eventually the tributary Cowlitz River, often in late November, December, or early January. This early winter run has been given the popular labels of *scout*, *widow*, or *pilot* run, as these fish enter these rivers several days to weeks prior to the main eulachon run and are often composed mainly of male fish (Stockley and Ellis 1970, JCRMS 2004, 2012, Reynolds and Romano 2013). We found 43 newspaper articles for the Cowlitz River and ten for the mainstem Columbia River referring to an early winter run, pilot run, or scout run of eulachon (Table S4). The presence of early winter runs in the Columbia and Cowlitz Rivers complicates analysis of eulachon migration timing. In addition, it was customary from the 1880s through the 1930s for fishers to search extensively for the first eulachon of the season, due to the high monetary value of the first Columbia River smelt in the market.

During the 1870s to about 1910, local "fish dealers" in Portland vied with each other for the coveted bragging rights of having the "First Columbia River Smelt of the Season" for sale. Dealers such as Quinn's (Union Market, Washington Street), Charles A. Malarkey (northwest corner of Fourth and Morrison Streets), Dougherty & Browne's Washington Market (corner of Fourth and Washington Streets), and Wm. McGuire & Co. (Third and Morrison Streets) advertised in local newspapers as having the first smelt for sale in various years. Some dealers, such as Charles A. Malarkey, hired fleets of fishers to search out the first smelt in the lower river, and bragged in 1886 of having received the first lot of smelt that came to market during each of the past 13 years. The *Morning Oregonian* (Portland) for 31 January 1886 (Table S4) stated that:

> 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.

This competition meant that "men are out with seines, prospecting for the first school of smelt, as the first bring 50 cents and even 75 cents per pound" (*Oregonian*, Portland, 24 March 1902, p. 5; Table S4). As a result, the first smelt of the season were reported in Portland markets earlier and earlier. They were first reported on 17 December in 1889 (*Morning Oregonian*, 18 December 1889), 26 November in 1892 (*Morning Oregonian*, 28 November 1892), and "in time to be served for breakfast on Thanksgiving morning" in 1903 (*Oregonian*, 28 November 1903, p. 9; Table S4).

Because of these efforts, eulachon were caught earlier and earlier in the season during this period of intense interest in securing the "First Columbia River Smelt of the Season." An undue focus on early winter runs of eulachon, and historical efforts to search out the first eulachon of the season, might bias a portion of migration timing data for eulachon in the Columbia and Cowlitz Rivers. Therefore, we chose to separately analyze the DORY when the first large catch of eulachon (>454 kg) occurred, as reported in newspaper accounts (Table S4) or in WDF/WDFW commercial fishery landings in the Columbia and Cowlitz Rivers (Table S7). We consider that the date of the first large catch of eulachon would be more representative of the first entry date of the main run of eulachon in these two rivers.

Columbia River mainstem

In 1806, members of the Lewis and Clark Expedition reported that they first encountered eulachon, on 24 February (Moulton 1990; Table S4). The eulachon were captured by the local indigenous peoples and used as barter for trading with the expedition. Subsequent observers reported on the initial appearance of eulachon in the Columbia River around 2 February 1812, 13 February 1813 (Pacific Fur Company log; Jones 1999), and 6 January 1814 (Alexander Henry the Younger; Gough 1992; Table S4). In addition, we found newspaper accounts, beginning as early as 1866, reporting on the first yearly appearance of eulachon in the Columbia River or on first appearance of eulachon in the fish markets of Portland (Table S4, Figure 3A). Using a combination of these historical records (Table S4) and first deliveries in the commercial fishery (Table S7), we found initial dates of appearance of eulachon in the Columbia River for 130 of the 132 years from 1866–1997, in addition to the four years between 1806 and 1814 discussed above (Table 1, Figure 3A). The fitted regression line for this full relationship is significant, and these data suggest that eulachon are returning to the Columbia River about 0.13 days earlier each year and a full 25.6 days earlier in the year over the full period of the data from 1806–1997 (Table 1, Figure 3A).

Changes in the yearly date of the first large catch of eulachon in Columbia River commercial fisheries as mentioned in newspaper accounts from 1867–1948 (Table S4) and in WDF/WDFW landings from 1949–97 (Table S7) show a temporal trend toward earlier delivery of the first large catch in recent decades (Figure 3B). The fitted regression line for this relationship is highly significant, and these data suggest that the date of the first large catch in the Columbia River is occurring 0.18 days earlier each year, and 24 days earlier over the time period of our data from 1867–1997 (Table 1, Figure 3B).

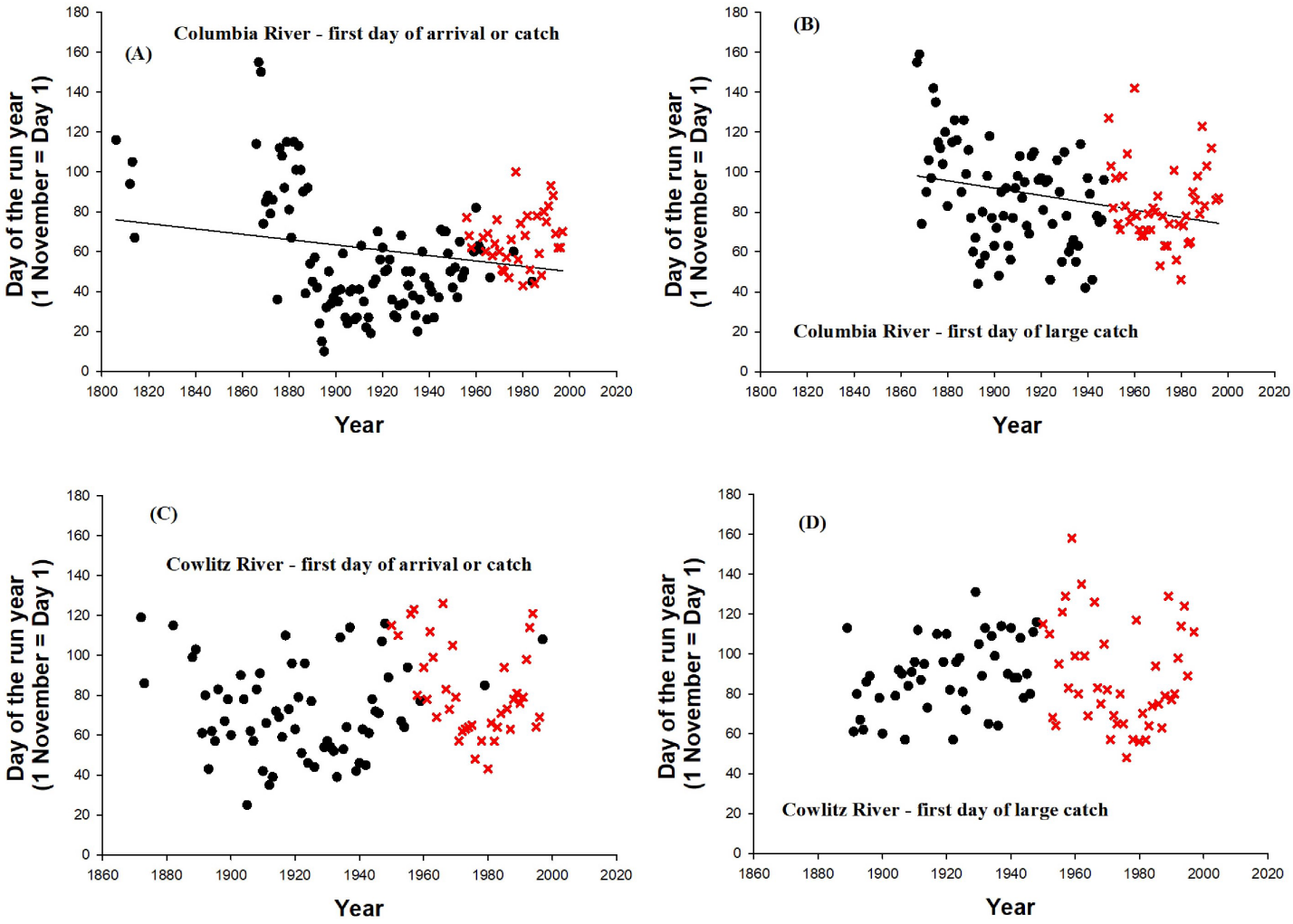

Figure 3. Migration timing of adult eulachon in Columbia River tributaries. Initial day of first yearly entry or catch of eulachon in (A) the Columbia River (1806–1997), (B) initial day of first yearly large commercial fishery catch of eulachon (>454 kg) in the Columbia River (1866–1997), (C) initial day of yearly first entry or catch of eulachon in the Cowlitz River (1872–1997), and (D) initial day of first yearly large commercial catch of eulachon (>454 kg) in the Cowlitz River (1889–1997). Data compiled from all historical written sources (black circles; Table S4) and recorded landings in the commercial fishery (red x symbols; Table S7). Dates have been converted to the day-of-the-run-year (DORY) beginning on 1 November, but referred to the year beginning on 1 January. Linear regression lines are shown when significant ($P < 0.05$) and are plotted using all data points.

Some portion of the observed trend in the mainstem Columbia River (Figure 3A) is probably due to 1) higher early fishing effort from the late 1890s to 1940, which was linked to the quest for the lucrative first smelt of the season, and 2) the intense local interest in both the commercial and recreational eulachon fisheries prior to the 1950s. These factors make it more likely that the first appearance of eulachon would be reported in local newspapers. Some variation in apparent migration timing may also be due to variable fishing effort, which can be influenced by weather events (e.g., floods, windstorms, river freeze-up, etc.), and variable market demand, which in turn is linked to changing consumer tastes and eulachon abundance.

We also recognize that adult longfin smelt (*Spirinchus thaleicthys*), a similar although smaller-bodied anadromous osmerid smelt, may have on occasion been misidentified as eulachon in the lower Columbia River basin. The impact of this possible misidentification on our estimates of initial migration timing of eulachon is unknown, but probably small, since longfin smelt are much less abundant in fishery catches.

Cowlitz River

Using a combination of historical newspaper records (Table S4) and first appearance in the Cowlitz River commercial fishery (Table S7), we found initial dates of appearance of eulachon in the Cowlitz River for 102 years from 1872–1997 (newspapers, $n = 63$; fishery landings, $n = 39$). There were several years when eulachon reportedly did not enter the Cowlitz River: 1902, 1927, 1928, 1938, 1951, 1965, and 1977. In addition, only a very small number of eulachon reportedly entered the Cowlitz River in 1949 and 1950 (Tables S4 and S7). Although there was a range of 101 days between the earliest and latest first day of entry of eulachon (Table 1), there was no statistically significant temporal trend in the timing of first entry of eulachon into the Cowlitz River (Table 1, Figure 3C). Similarly, we did not detect a statistically significant temporal trend in the timing of the first large catch of eulachon in the Cowlitz River commercial fishery (Table 1, Figure 3D) as identified in combined records of newspaper accounts from 1889–1948 (Table S4) and WDF/WDFW landings from 1949–97 (Table S7).

Some early return dates recorded for the Cowlitz River from 1900–40 (Figure 3C) may be due in part to increased fishing effort early in the season, as was the case for the mainstem Columbia River (see above). It is unclear why initial river entry timing of eulachon in the Cowlitz River has essentially remained unchanged over the past 120 years, while initial river entry is occurring significantly earlier in the run year in some other tributaries to the lower Columbia River basin.

Grays River

We found a limited number of newspaper accounts (Table S4) and commercial fishery landings (Table S7) recording earliest entry of eulachon into the Grays River—23 records between 1928 and 2002 (Figure 4A). These limited data did not indicate that first day of entry of eulachon into the Grays River has changed in any statistically significant manner over this period of time (Table 1, Figure 4A). Dates of first entry were similar in most cases to dates of first large catch of eulachon in the Grays River (Tables S4 and S7).

Kalama River

We found documentation in newspaper records of eulachon entering the Kalama River in February 1915, when it was remarked that this was "the first time since 1847" that eulachon had entered this river (*Morning Oregonian*, 15 February 1915, p. 9; Table S4). Subsequent newspaper records (Table S4) and WDFW commercial fisheries landings (Table S7) indicate that eulachon returned to the Kalama River in only 25 years from 1915–1995 (Table 1, Figure 4B). These limited data did not indicate that first day of entry of eulachon into the Kalama River had changed in any statistically significant manner over this period of time (Table 1, Figure 4B). Dates of first entry were similar in most cases to dates of first large catch of eulachon in the Kalama River (Tables S4 and S7).

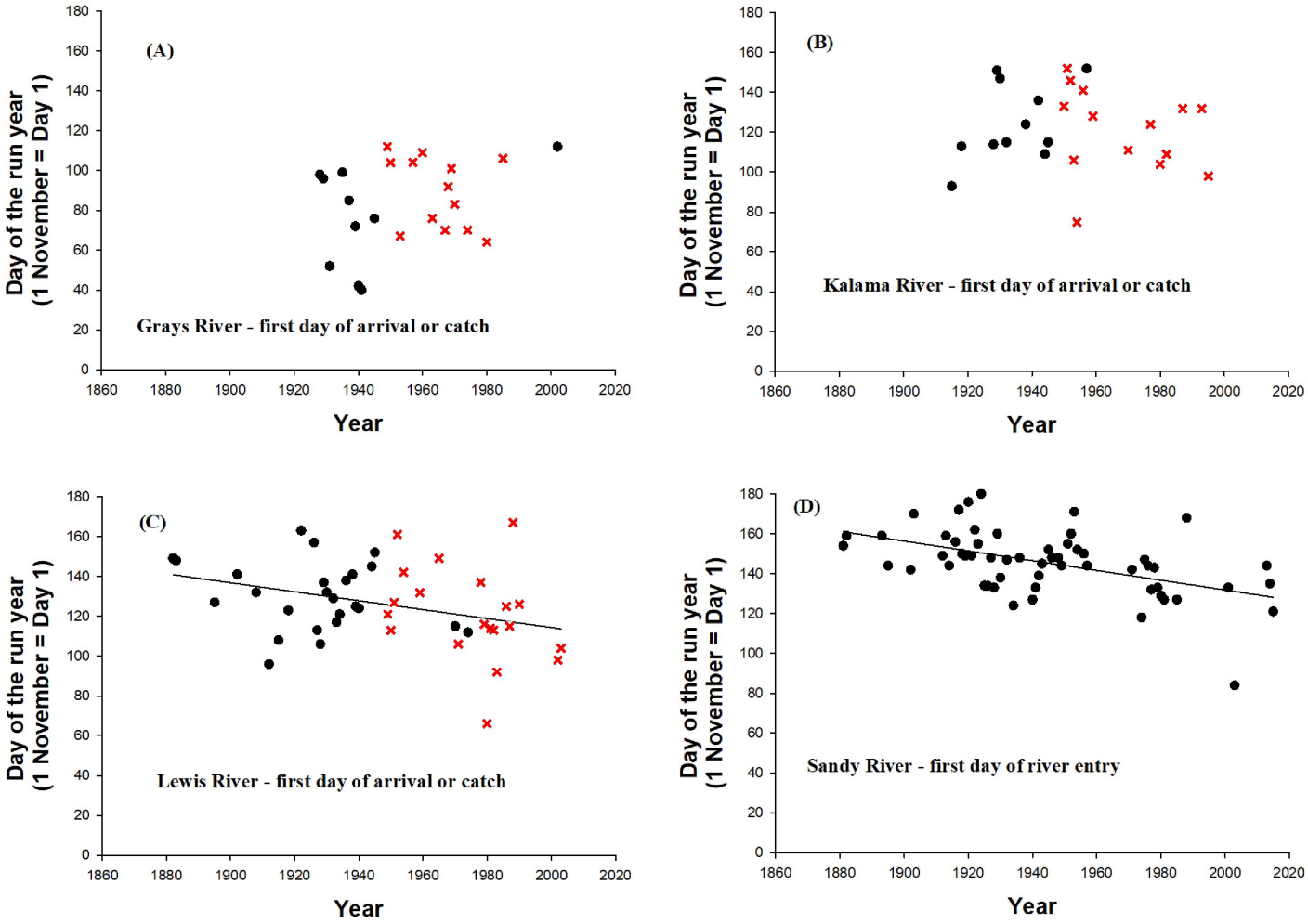

Figure 4. Migration timing of adult eulachon in Columbia River tributaries. Initial day of the run year of yearly river entry of eulachon in (A) the Grays River (1928–2002), (B) the Kalama River (1915–95), (C) the Lewis River (1882–2003), and (D) the Sandy River (1881–2015). Data compiled from all historical written sources (black circles; Tables S4, S8) and recorded landings in the commercial fishery (red x symbols; Table S7). Dates have been converted to the day-of-the-run-year (DORY) beginning on 1 November. Linear regression lines are shown when significant ($P < 0.05$) and are plotted using all data points.

Lewis River

The fitted regression line for the plot of the earliest arrival dates of eulachon in the Lewis River, based on combined newspaper records from 1882–2003 (Table S4) and fishery landings from 1949–2003 (Table S7) shows a statistically significant temporal trend toward earlier return timing (Table 1, Figure 4C). From 1882–2003, eulachon were reported in the Lewis River in 45 years. These data indicate that eulachon are returning to the Lewis River about 0.22 days earlier each year and about 27 days earlier over the full time period from 1882–2003 (Table 1, Figure 4C).

Sandy River

Initial arrival dates of eulachon in the Sandy River from 1913–2003 were tabulated by the Troutdale Historical Society (Nesbit 2007). In the present study, we found additional newspaper accounts, beginning as early as 1881, reporting on the first yearly appearance of eulachon in the Sandy River (Tables S4 and S8). Eulachon were reported in the Sandy River in 57 years from 1881–2015 (Tables S1 and S8, Figure 4D). The fitted regression line for a plot of the earliest arrival dates in the Sandy River shows a highly significant temporal trend toward earlier yearly return timing (Table 1). These data suggest that eulachon are returning to the Sandy River about 0.25 days earlier per year and 32.8 days earlier over the full time period of the data from 1881–2015 (Table 1, Figure 4D).

It is apparent that, with the exception of the Grays River (average return date of 23 January), there is a direct correlation with distance from the ocean and the average date of first return of eulachon to the major Columbia River tributaries that support eulachon spawning: Cowlitz River (14 January), Kalama River (2 March), Lewis River (6 March), and Sandy River (25 March; Table 1). 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 date of initial landings in the commercial fishery in the Cowlitz River (21 January) and average arrival in the Sandy River (25 March) also supports this observation (Tables S7 and S8).

Umpqua River

Newspaper sources (Table S5) revealed that an extensive recreational fishery for eulachon occurred in the lower Umpqua River from 1969 to 1982 during the months of January to April. However, an article in the *Eugene Register-Guard* for 21 February 1969 (p. 5; Table S5) stated that "judging from past years," eulachon spawning was expected to "continue at least another two weeks," indicating eulachon had been observed in the Umpqua River prior to 1969. A plot of the earliest arrival dates of eulachon in the Umpqua River over this 14-year period, together with the date of the first observation of eulachon in the Umpqua River in 1936, indicated that migration timing had not changed in any statistically significant manner over this limited time (Table 1, Figure 5A).

Klamath River

We found 44 newspaper accounts, beginning in 1895, reporting on the first yearly appearance of eulachon in the Klamath River (Table S6, Figure 5B). For 41 of these 44 years, newspaper accounts were the only documentary evidence that a eulachon run occurred in the Klamath River. Yurok Tribe studies of eulachon provided an additional four years of recent (2011–14) return-timing data in the Klamath River (see Gustafson et al. 2022, p. 36). The fitted regression line for the full relationship (1895–2014) is not significant (Table 1, Figure 5B). The most southern extant population of eulachon in the Klamath River has a relatively late average date of initial river entry of 8 March. The late dates of initial appearance of eulachon in the Fraser (8 April) and Klamath Rivers are inconsistent with the overall rangewide pattern of eulachon spawning earlier in the south and later in the north (Hay and McCarter 2000).

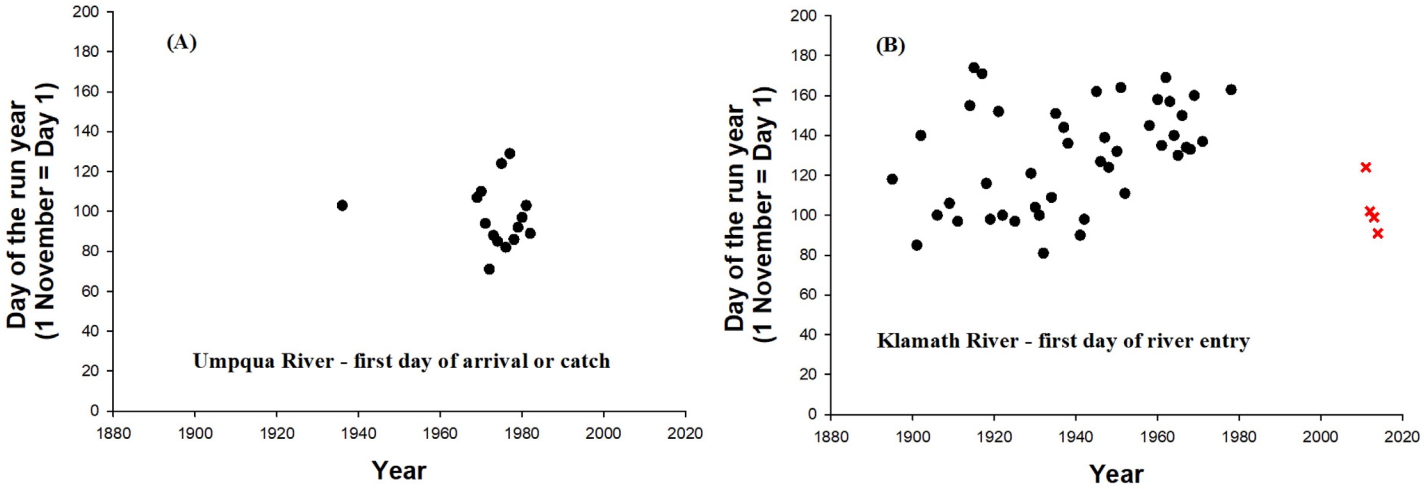

Figure 5. Initial day of yearly river entry of eulachon in (A) the Umpqua River from 1936–82 and (B) the Klamath River from 1895–2014, compiled from local newspaper records (Table S5, S6). Dates of initial river entry have been converted to the day-of-the-run-year (DORY) beginning on 1 November.

Earlier Migration Timing in Some Rivers

Several previous researchers have also shown that eulachon spawning migrations are occurring earlier in the year in recent decades in some rivers in our study area compared to historical conditions (Moody and Pitcher 2010, COSEWIC 2011). It is possible that earlier return timing of eulachon results from changes in climate that have led to higher in-river temperatures and altered stream flow timing (Moody and Pitcher 2010). Howell and Uusitalo (2000, their Figure 2) published a graph of eulachon yearly arrival dates in the Columbia River based on initial dates of commercial landings (1949–2000), but did not comment upon the apparent temporal change in migration timing. Moody and Pitcher (2010, p. 113, their Figure 75) presented historical descriptions of migration timing for the Bella Coola River, on the central coast of British Columbia, that indicated "the peak of [the] Bella Coola [River] eulachon run has begun to arrive earlier in the last few decades." COSEWIC (2011, p. 22) interpreted these same data to suggest that "mean spawning has shifted earlier in recent years, from about day of the year (DOY) 100–110 to about DOY 85–95 in the last decade."

Both water temperature and river discharge rate have been 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). In the Columbia River, eulachon are reported to spawn at temperatures between 4°C and 10°C, and spawning migration is reportedly inhibited at temperatures less than 4°C (WDFW and ODFW 2001). Smith and Saalfeld (1955) stated that

> In 1953, an extremely mild winter, no temperatures below 40°F were recorded and smelt were abundant in the Cowlitz on January 3, the date when the fishery first operated. Conversely, the years 1947 to 1950 presented low January and February water temperatures and smelt delayed upstream movement until well into March, again when the water reached 40°.

However, no clear pattern exists between eulachon spawning or migration timing and latitude (Gustafson et al. 2010), as would be expected if timing was directly controlled by seasonal changes in water temperature. Analysis of eulachon spawn timing is also complicated by the presence of multiple spawning runs in some rivers (Willson et al. 2006).

Previous researchers have correlated earlier migration timing of sockeye salmon (Quinn and Adams 1996, Quinn et al. 1997, Crozier et al. 2008, Crozier et al. 2011), summer-run steelhead (Robards and Quinn 2002), spring Chinook salmon (Keefer et al. 2008), and Pacific lamprey (Keefer et al. 2009) in the Columbia River with changes in water temperature and discharge rates during late spring to summer. Crozier et al. (2011, p. 756) showed that sockeye salmon in 2010 were migrating past Bonneville Dam (river kilometer 235) on the lower Columbia River 10.3 days earlier on average than they did in the 1940s, and that this was correlated with "a rise of 2.6°C in mean July temperature since 1949."

There are relatively few water temperature datasets for the Columbia River that can be similarly compared with long-term migration trends for eulachon, since seasonal records outside of the April–August salmon migration period are rare, and water temperature data for the lower Columbia River do not predate 1938. However, during the late fall to winter eulachon migration season, significant long-term increasing trends (1939–2017) in average monthly temperatures taken at 14 m depth near the turbine intakes in the forebay of Bonneville Dam amount to 3.2°C in November, 1.6°C in December, and 1.4°C in January (Figure S1a–f; Moore 1968). In addition, Moore (1968) found significant correlations between monthly mean water temperature at Bonneville Dam and monthly mean air temperature. This is significant because Pacific Northwest regional air temperatures have increased "substantially—nearly 2°F since 1900" (May et al. 2018, p. 1041). These long-term increases in air temperature are likely paralleled by water temperature increases. Long-term warming is also indicated by the fact that the Columbia River froze over from bank to bank in the winter below the current location of Bonneville Dam in at least 11 years between 1854 and 1930, but has never frozen to this degree since Bonneville Dam began operation in 1938 (Hatton 2005).

The natural hydrologic pattern of the Columbia River has also changed from historical conditions. Comparison of pre-1900 (1858–99) conditions to the 1970–2004 period indicates that maximum spring freshet flow and mean seasonal (May–July) spring freshet flow have been reduced by 45 and 48%, respectively (Naik and Jay 2011). Mean maximum flow now occurs about two weeks earlier in the year, on 29 May, compared to the historical mean date of 12 June (Bottom et al. 2005, Naik and Jay 2011). These changes are due to a combination of water withdrawals for irrigation, operation of 28 mainstem dams (Sherwood et al. 1990, Bottom et al. 2005, Naik and Jay 2011), and changes in climate (see climate references in Gustafson et al. 2010, Naik and Jay 2011).

Similar to some of our findings, COSEWIC (2011, p. 22, their Figure 6b) described a temporal trend toward earlier return timing of eulachon in the Fraser River by comparison of the timing of the eulachon fishery catch data from 1941–53 (Ricker et al. 1954) with the timing of catches in the test fishery from 1995–2005. This analysis suggests that the range of dates over which eulachon spawning occurred in the Fraser River was approximately 10 days earlier in the year in the more recent period compared to 1941–53 (see COSEWIC 2011, their

Appendix 3). Although we did not locate long-term water temperature records for the Fraser River in March–May, when eulachon are migrating in this system, mean water temperatures during the summer salmon migration period (July–September) were shown to have increased by 0.02°C per year from 1953–98 at Hell's Gate on the Fraser River (Morrison et al. 2002). In addition, the British Columbia Ministry of Environment (2016) stated that "in central, interior and southeastern BC, average winter [air] temperatures have warmed 1.5°C to 1.7°C per century" and "spring [air temperature] has warmed by 1.0°C per century in both the coastal and southern interior mountains." Spring freshets throughout British Columbia are also reported to be occurring earlier in the year in snow-fed rivers (Déry et al. 2009).

Our analyses indicate that first yearly entry of eulachon to the Klamath River has not changed from historical conditions (Figure 5B), even though simulated water temperatures for 1962–2001 in the Klamath River and local estimated air temperatures from 1962–93 have both increased significantly (Bartholow 2005). Release of cool reservoir water from mid-January to April from several hydroelectric dams in the Klamath River basin has resulted in a shift to cooler water temperatures below the dams than would naturally occur, by about 1.0–2.5°C. However, these temperature shifts probably do not extend far enough downstream to affect the river reach where eulachon spawn (USDOI and CDFG 2012). The natural hydrologic pattern of the lowermost Klamath River has changed from historical conditions. National Research Council (2004, p. 177) stated, "there has been a noticeable shift in the timing of runoff" in the lower part of the river, with peak annual runoff occurring in "March instead of April and the flows of late spring and early summer tend to be lower than they were historically." However, our data on eulachon return timing do not appear to reflect these changes in flow in the lower Klamath River.

Historical Fisheries Catch

Although nonindigenous fishers have exploited eulachon populations for over two centuries, only limited recording of past catches occurred. 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. In this study, we compiled historical commercial catch data for adult eulachon in the Fraser River, coastal British Columbia, and the Columbia River basin using newspapers and archival records.

Fraser River

Commercial fishery landings—and occasionally, recreational and indigenous peoples' catches—of eulachon in the Fraser River were first reported by the federal fisheries agency in 1881 (Parliament of Canada 1882, Hart and McHugh 1944; Table S9). We summarized these and more recent Fraser River catch data, converted to metric tons (mt), from original sources where they

were reported as either fresh eulachon in pounds (lb) or short hundredweight, salted in barrels (200 lb salted eulachon/barrel), or smoked in boxes (10 lb smoked eulachon/box; Table S9). In this study, we found local newspaper sources indicating that commercial sales of Fraser River eulachon in fish markets in New Westminster commenced as early as 1868 (Table S3).

Aspects of the early history of the Fraser River commercial eulachon fishery are detailed in McHugh (1939), Hart and McHugh (1944), Ricker et al. (1954), and Moody and Pitcher (2010). Hart and McHugh (1944, their Figure 12) presented a graph of eulachon commercial catch statistics in hundredweight for the Fraser River from 1881 to 1941. We have summarized these and more recent Fraser River catch data in Table S9. Although newspapers in the Columbia River basin commonly reported quantitative results of local eulachon commercial fisheries (Tables S4 and S11), we found only a few newspaper records documenting daily eulachon catches amounting to one to three thousand pounds for commercial fishermen on the Fraser River prior to the 1930s (Table S3). Moody and Pitcher (2010) presented landings data in recreational and indigenous peoples (First Nations) fisheries for some years between 1956 and 1992, but earlier records for these fisheries are sparse (Table S10).

Although outside our study area, we also compiled historical fishery landings for eulachon in British Columbia north of the Fraser River (Table S9), first reported by the federal fisheries agency in 1877 (Parliament of Canada 1878, Hart and McHugh 1944). We converted data that were originally reported as fresh eulachon in pounds or short hundredweight, salted in barrels, salted in kitts (20 lb salted eulachon/kitt), smoked in boxes, and rendered into eulachon oil, into metric tons (Table S9).

Columbia River basin

Craig and Hacker (1940, p. 209) found "no definite information available as to the exact time when smelt became commercially important" in the Columbia River. In this study, we found local newspaper sources indicating that commercial eulachon fisheries in the Columbia River, and sales of eulachon in fish markets in Portland, were in operation by at least 1866 (Table S4). Additional articles and advertisements occurring in local newspapers indicate that a large active commercial eulachon fishery has existed since at least 1871 in the Columbia River (Tables S4 and S11). The first unequivocal mention of eulachon commercial harvests occurring in the tributary Cowlitz River appeared in the *Kalama Beacon* (Kalama, Washington Territory) for 8 February 1873 (Table S4); however, commercial fisheries were likely in operation several years before this time on the Cowlitz River.

Commercial fishery landings for eulachon in the Columbia River basin were first reported by federal and state fisheries agencies in 1888 (Table S11). Craig and Hacker (1940) and Smith and Saalfeld (1955) were unable to locate commercial eulachon catch records from the Columbia River for 13 years between 1888 and 1935. However, we found an unbroken record of significant eulachon commercial fishery landings in the Columbia River from 1888–2010 using archived state and federal agency records; these data are presented in Gustafson et al. (2010, their Tables 7 and 9 and their Figure 22). Long-term landings data indicate that commercial catch levels were consistently high (>500 mt and often >1,000 mt) for three-quarters of a century from about 1915 to 1992 (Table S11). Catches declined to an average of less than 40 mt between 1994 and 2000. Fishing restrictions were instituted in 1995 (Gustafson et al. 2010), so low catches after that time are in part due to these restrictions (Table S11).

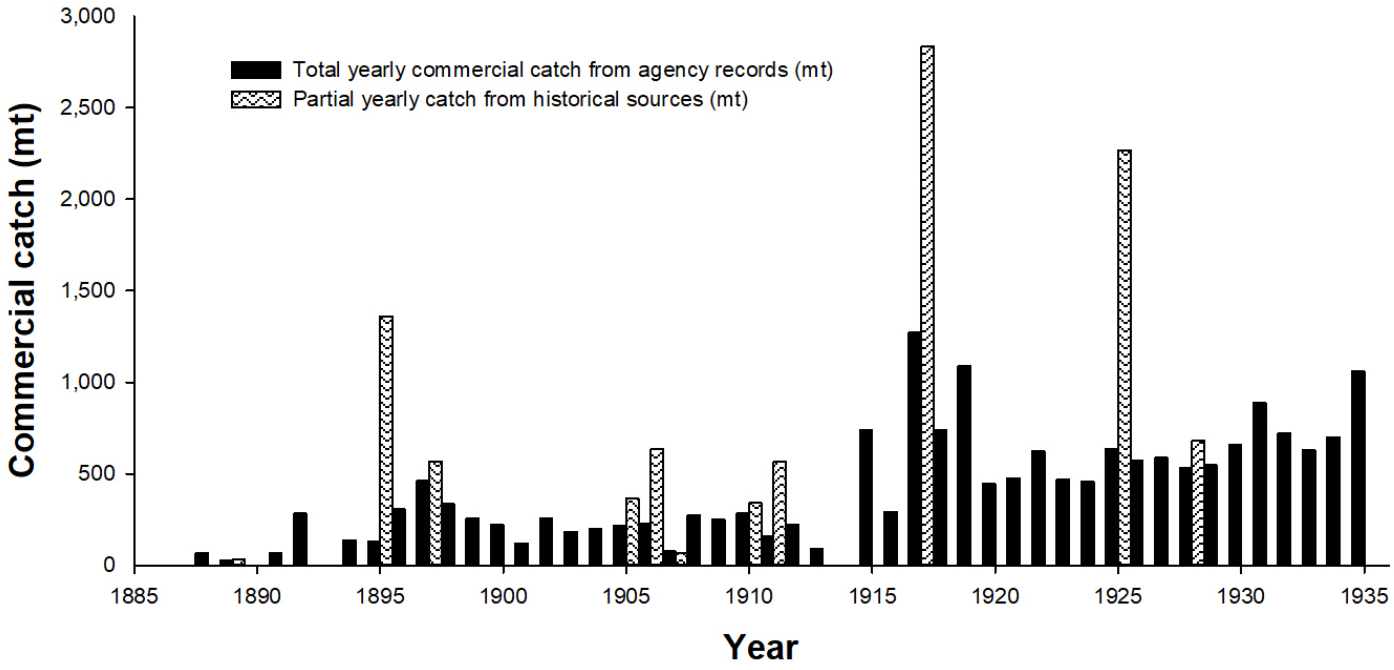

Figure 6. Commercial eulachon fishery catch in the Columbia River and its tributaries from 1888 to 1935, as recorded in official state and federal records and in unofficial newspaper records.

We also found numerous newspaper records containing quantitative information that either contradicted the available official eulachon landings after 1888 or added to the available catch records prior to 1887 (Tables S4 and S11, Figure 6). For instance, biomass of the eulachon catch in the Cowlitz River reported for the years 1905, 1906, 1910, 1911, and 1917 in newspaper and *Pacific Fisherman* articles was 66, 186, 20, 258, and 123% greater, respectively, than the reported state fisheries agency eulachon catch in those years (Table S11, Figure 6). Newspaper records serve to quantitatively document commercial eulachon catch in 1871, 1873, 1876, 1878–83, and 1886–87, prior to the first state agency catch reports beginning in 1888 (Tables S4 and S11). Although most of the newspaper records prior to 1888 document only daily eulachon catch or catch from a single fisherman of a few metric tons, these catch levels were likely sufficient to supply the market, since the human population of the major local market, Portland, was only around 46,000 prior to the 1890s (Figure S2).

Although we were unable to locate federal or state fishery agency reports of eulachon landings in either 1893 or 1914, local newspaper records indicate that eulachon were very abundant in the Columbia River in both years. For example, the *Oregonian* (Portland) for 3 April 1893 (Table S4) stated:

> The shoals of smelt which have visited the Columbia this season are something wonderful. They appeared in the market here earlier in December than ever known before, and, except for about two weeks while there was snow on the ground, they have been offered for sale ever since. There seems to be no end of them….

On 14 January 1914, the *Olympia Daily Recorder* (Table S3) stated:

> The greatest run of smelt ever in the Columbia River is now being harvested…. The market is glutted. Such heavy catches by gillnetters of the lower Columbia River were never before seen in this market.

In each of these two years, new political administrations had recently assumed management responsibilities for reporting fishery landings in Washington State and official records are consequently incomplete for 1893 and 1914. Throughout the history of the Columbia River eulachon commercial fishery, extensive recreational harvest of eulachon was also occurring. Although there are no quantitative records of the magnitude of this recreational harvest, it has been estimated to have equaled the commercial catch (WDFW and ODFW 2001).

Numerous newspaper records indicate that only small numbers of eulachon were reported for sale in Portland markets in 1885. For instance, the *Vancouver Independent* for 2 April 1885 (Table S4) stated, "No smelt have yet appeared in the Columbia River this season, and there will be no regular run, the first failure of this fish since 1862." Similar to the situation in the Columbia River, newspaper records reveal that eulachon runs in the Fraser River and in northern British Columbia were also severely depressed in 1885 (Table S3). For instance, the *Victoria Daily Colonist* (Victoria, BC) for 22 April 1885 (Table S3) reported that "oolachan fishing… [in the Nass River] has proven a failure this year" and the *Daily Astorian* (Astoria, Oregon) for 17 May 1885 (Table S4) stated, "Oolachans are reported scarce in the Fraser River this spring." In addition, the 1885 Annual Report of the Canadian Department of Fisheries (Parliament of Canada 1886, p. 277) stated that "Mr. F. Morrison, fishery guardian at Port Essington, on the coast [on the south bank of the Skeena River], in his report states the [1885] Oolahan fishery was to all intents a failure" (also see Hart and McHugh 1944, p. 14). However, 9,300 pounds (4,218 kg) were taken commercially at Port Essington in 1885 (Parliament of Canada 1886).

Although limited to the Columbia River basin, numerous historical sources (Suckley 1860, Lord 1866, Anderson 1872, 1877, Crawford 1878, Huntington 1963) also indicate a major decline in eulachon abundance occurred between the mid–late 1830s and mid–late 1860s. This early decline in Columbia River eulachon abundance has been widely documented in recent secondary references (Hinrichsen 1998, Martin 2014).

Temporal Trends in Monetary Market Value of Eulachon

We compiled the price per pound of eulachon in the Portland fish markets as stated in over 740 newspaper accounts or advertisements of market prices ranging from 1896–1992. All dollar values provided in the text are converted to 2021 U.S. dollars (see Materials and Methods). The assembled data were sufficient to track the seasonal high and low advertised price per pound of eulachon (Table S4, Figure 7). Typically, the first eulachon of the season were caught in the mainstem Columbia River gill-net fishery and were the most expensive (Figure 7). The price per pound declined by up to two orders of magnitude as the spawning run became more abundant and commercial dip-net fisheries began operation in the tributary Cowlitz, Lewis, Kalama, or Sandy Rivers (Table S4, Figure 7). The *Oregon Journal* (Portland) for 27 November 1904 (p. 11, column 7; Table S4) stated,

> The first shipment arrived yesterday from the Cowlitz River and were immediately sold to a retailer at 50 cents a pound. He in turn found plenty of orders for the fish at 75 cents. This is somewhat early for smelt, the run

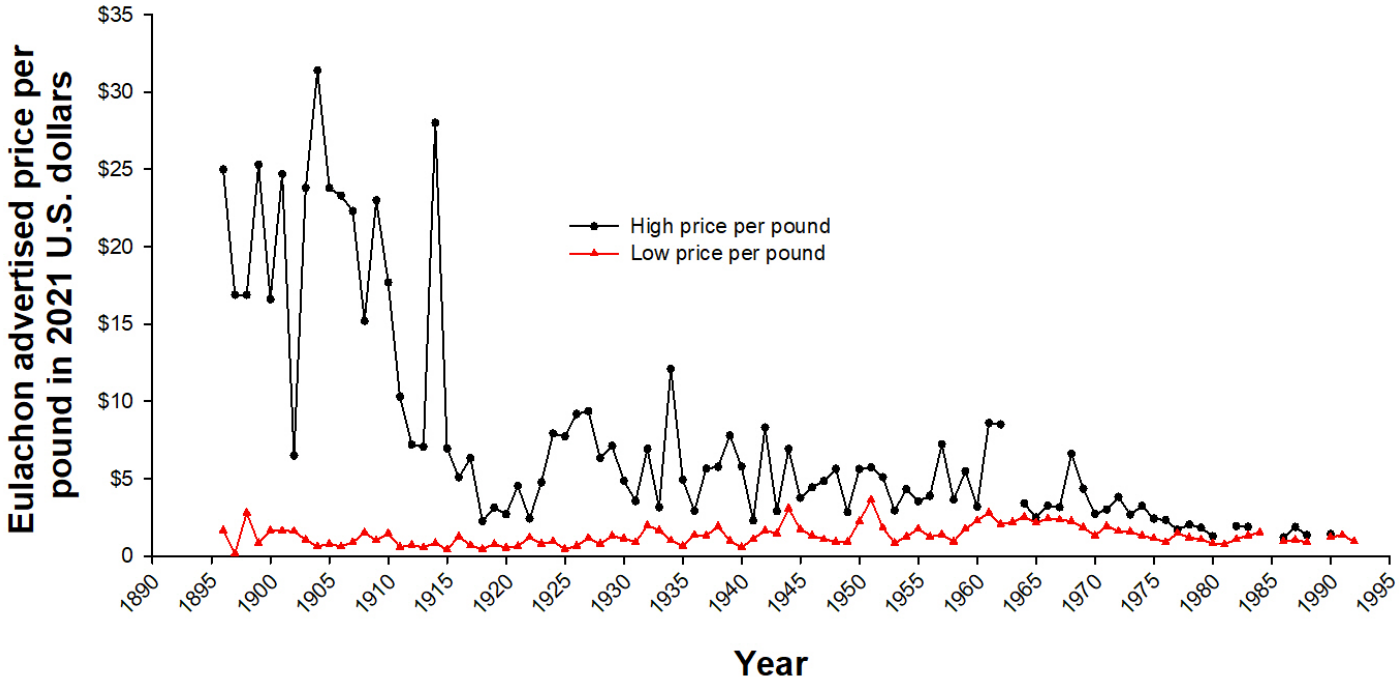

Figure 7. High and low price per pound for whole eulachon as reported in newspaper advertisements from 1896–1992 in the Columbia River basin (Table S4). Price per pound values have been converted to 2021 U.S. dollar equivalents using the purchasing power calculator available at https://www.measuringworth.com/calculators/ppowerus/ (Williamson 2018).

> generally beginning after the first of December. Within a few weeks after that the receipts become so large that hawkers established everywhere throughout the city sell the fish for as low as 1 cents [sic] a pound. Along the Cowlitz they become so plentiful that farmers drive their teams into the river and shovel the fish into their wagon. On the farms they are used as fertilizers.

The year-by-year spread of high and low prices for eulachon indicates that eulachon were much more highly valued prior to about 1915, when the price per pound for the first eulachon of the season commonly ranged from over $10 to as much as $31.40 per pound ($22–$61/kg; Figure 7). In more recent years (e.g., 1966–78), even the first eulachon of the season were rarely valued at over $2 to $3 per pound ($4–$7/kg). Likewise, the differential between the seasonal high and low price per pound for eulachon drastically declined from 1896–1992 (Figure 7).

The dramatic decline in the relative monetary value of eulachon from the 1890s to the 1970s (Figure 7) was likely influenced by a combination of eulachon abundance, catchability, economic conditions, and, most importantly, consumer preference. The highest yearly advertised price per pound for eulachon from 1896–1905 averaged over $19 per pound ($42/kg; Figure 7). In the next ten-year period, the average high price was over $14.5 per pound ($32/kg), but in subsequent decades until 1978, the high average price plummeted, ranging from $6.6 to $2.5 per pound ($14.5–$5.5/kg; Figure 7).

Changes in Sociocultural Perceptions of Eulachon

Contemporary first-person narratives of early nonindigenous visitors to the Pacific Northwest and anecdotal descriptions in over 15 decades of local newspaper records document a dramatic shift in nonindigenous societal–cultural perceptions of eulachon over the past two centuries, particularly in the lower Columbia River basin. Written narratives from the early contact period to the 1860s extolled the importance of eulachon to indigenous peoples (Tables 2, S3, and S4). Eulachon were known as the "salvation" or "savior" fish to many indigenous peoples as they were the first anadromous fish to return after a long winter period when most of the stored food supplies had been depleted (Boyd and Hajda 1987, Byram and Lewis 2001). Examination of the number of yearly newspaper articles that mention eulachon in the Columbia River basin, exclusive of simple advertisements and repeat articles (Table S4, Figure 8), shows fluctuating societal interest in this species, with high interest reflecting periods of scarcity or abundance (Figure 8). Many of these articles from the 1880s to the 1950s mention eulachon as a highly sought-after food fish and the foundation of a large, economically important commercial food fishery on the Columbia River and its lower tributaries (Tables 2 and S4, Figure 8). However, from 1895–1915 articles frequently mention farmers gathering eulachon for farm fertilizer, before recreational harvest limits in Washington and Oregon essentially put a stop to this practice. Contrastingly, more recent newspaper articles, particularly after the 1960s, commonly refer to eulachon as "sturgeon bait" or "baitfish," and mention of eulachon as a gourmet food item becomes rare or nonexistent (Tables 2 and S4, Figure 8). We found over 1,700 newspaper articles from sources in the lower Columbia River basin that mentioned eulachon: 1) as vital in the nutrition of indigenous peoples, 2) as a gourmet food fish for nonindigenous peoples, 3) as the basis of a large, economically important commercial fishery, 4) as fertilizer for farmers, or 5) as a baitfish for other fisheries, such as sturgeon (Table 2, Tables S3 and S4, Figure 8). This degradation of the original positive societal view of eulachon—from savior fish to baitfish—parallels the declining trend in the monetary value of eulachon (Figure 7).

In a similar vein, Taylor (1999, p. 3) documented how societal perceptions of the various species of salmon in the Pacific Northwest have also "changed radically over time," from a resource that

> …once sustained aboriginal societies and later enriched industrial and sports fisheries, but now their scarcity threatens lives and communities. Salmon are still revered and coveted by some, but others fear and dismiss them.

Although some perceptions of eulachon as a commercial commodity have changed over time in the Columbia River basin, there has always remained a strong interest in eulachon by tribal fishers for subsistence and ceremonial purposes, and by nonindigenous recreational dip-net fishers as a food fish. However, other recreational fishers often view eulachon as "in great demand for sturgeon bait" (JCRMS 2015, p. 25). Currently, eulachon are sometimes described as having little commercial importance (Armstrong and Hermans 2007, Benson et al. 2019); however, they and other forage fish are increasingly being recognized as playing a crucial role as prey for many species in marine food webs (Marston et al. 2002, Sigler et al. 2004, Womble et al. 2005, Armstrong and Hermans 2007, Osgood et al. 2016, Benson et al. 2019).

Table 2. Examples of historical observations on the value of eulachon, illustrating changing sociocultural perceptions. Full quotes available in Table S4 in online supporting files.

Value	Source type	Source and date	Quote
Salvation fish	Personal journal	Simpson 1847, p. 122	"…the ullachan, whose oil… [serves] not only as a luxury for the great, but also as a necessary of life to all classes…."
Salvation fish	Journal article	Brown 1868, p. 584	"…if we consider its importance to the Indians… [it would] be ranked as one of the most valuable products of the western shores of America…."
Food fish	Newspaper	*Oregonian* 18 January 1904, p. 7, col. 3	"…when the rush is on and smelt are very plentiful and very cheap, the public practically lives on them for a time…."
Food fish	Newspaper	*Oregonian* 19 February 1944, p. 6, col. 2	"…eulachon surely ranks well to the fore among the most superior and delicate of all the food fishes of the planet."
Commercial fishery	Newspaper	*St. Helens Mist* 4 May 1917, p. 6, col. 6	"The last shipments of smelt were made from Kelso last week…. [A]pproximately 125,000 boxes of 50 pounds each were dispatched. This is equivalent to 3,125 tons…."
Commercial fishery	Newspaper	*The Kelsonian Tribune* 22 February 1945, p. 1, col. 3	"2,000 Boxes Taken by Dipnetters Tuesday Night: About 250 licensed fishermen are now engaged in fishing in the [Cowlitz] River…. Most of the fish are going to the freezing plants for the military forces."
Fertilizer	Periodical	*Pacific Fisherman* June 1910, p. 15	"So plentiful have smelt been at times [that] farmers and others… pile the fish into the beds of their wagons, from which they are dumped into the fields to serve as fertilizer."
Fertilizer	Newspaper	*Sunday Oregonian* 8 April 1945, p. 17, col. 1	"It is to prevent the widespread use of smelt for fertilizer that a 50-pound limit is placed on the catch…."
Bait	Newspaper	*Oregonian* 11 January 1985, p. 63, col. 1–2	"Fresh smelt are in greater demand for bait than for the dinner table…."
Little commercial value	Newspaper	*Oregonian* 5 May 1994, p. E06	"…smelt have little commercial value. There is a small local market for fresh smelt; most of the commercial catch goes to zoos and marine parks to feed seals and dolphins."

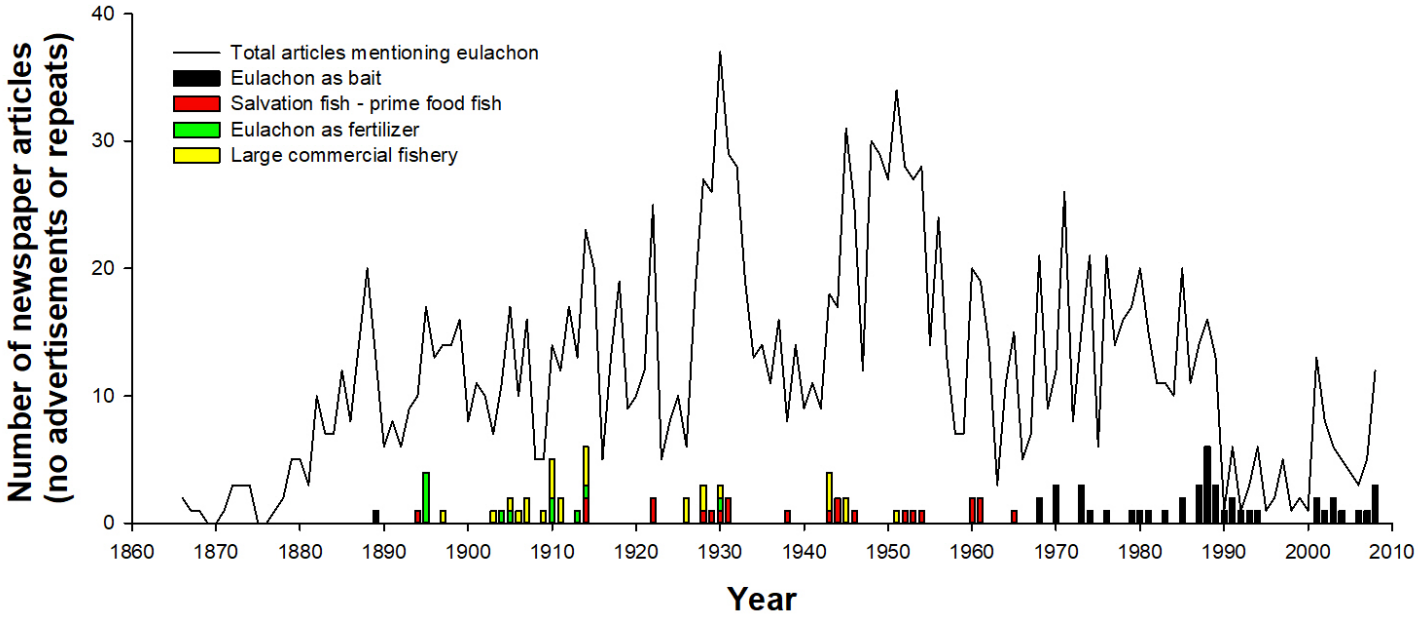

Figure 8. Number of yearly newspaper articles that mention eulachon in the Columbia River basin, exclusive of simple advertisements and repeat articles (1866–2008; Table S4). Also indicated are subsets of these articles that explicitly mention eulachon: 1) as "salvation fish" or a prime food fish, 2) as fertilizer, 3) as supporting an economically important commercial fishery, or 4) as bait for sturgeon or other fish.

The enduring popularity of the eulachon recreational dip-net fishery in the Columbia River basin is demonstrated by the 9,800 and 16,000 fishers that participated in single-day five-hour openings on the Cowlitz River in 2021 and 2022, harvesting 35,000 and 91,000 lb (15.9 and 41.3 mt) of eulachon, respectively (JCRMS 2022, 2023). Maintaining these limited fishing opportunities, when conservation concerns allow, supports "the cultural traditions of Northwest tribes who rely on eulachon as a seasonally important food source," and sustains "a connection between people and the eulachon resource," which "is important to sustaining public engagement in eulachon conservation and recovery" (NMFS 2017, p. 23). Hopefully, the present contribution and others (Hinrichsen 1998, Martin 2014), which have highlighted the rich cultural history of past interactions of people and eulachon, can assist in altering some nonindigenous societal perceptions of eulachon as nothing more than bait, and engage both scientists and the public to strive toward conservation and recovery of what Sergeant Patrick Gass of the 1805–06 Lewis and Clark Expedition termed a "small fish, of a very excellent kind" (Moulton 1996, p. 194).

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