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Eulachon: A Review of Biology and an Annotated Bibliography

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EULACHON: A REVIEW OF BIOLOGY AND

AN ANNOTATED BIBLIOGRAPHY

by

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PREFACE

This review and annotated bibliography was stimulated by the realization that while eulachon are an important forage fish, they are also under-studied. Historically, eulachon have had relatively little commercial value, compared to more widely known species such as herring. However, this oil-rich little fish has had an important role in the culture of Natives on the coast of southeast and south-central Alaska, and First Nations on the cost of British Columbia. Eulachon 'grease' was a major item of trade with Natives of Interior Alaska, as well as an important food source for coastal peoples. Subsistence use of eulachon continues, at least in some areas.

By the 1990s, the value of eulachon spawning runs to many wildlife species began to draw increased scientific attention, including several new studies of eulachon biology *per se*. Nevertheless, much remains to learn, not only about eulachon biology, but also about the ecological patterns and consequences for the predators of eulachon. The authors of this review hope that it will help stimulate research on the ecology and evolution of eulachon and their predators.

This review was completed in the fall of 2003. References from fall 2003 to date are listed in an addendum at the end of this manuscript.

Mary F. Willson
31 May 2006

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INTRODUCTION

The first known reference to eulachon in English is probably that of the Lewis and Clark expedition, overwintering near the mouth of the Columbia River in 1806. The eulachon began to run in late February, and the expedition traded for them from the Clatsop Tribe for a rich and welcome change in diet. Lewis found that the fish were so oily that no additional seasoning was needed and, indeed, they were the best fish he recalled ever eating (Ambrose 1996, p. 329, Ref. 16).

Eulachon have been of relatively little commercial importance and therefore less is known about them than more commercially important fishes, such as salmon. Their role in Native culture has been studied more than their basic biology and ecology. With increasing interest in the role of eulachon as important prey for many predators, including species such as Steller sea lions (*Eumetopius jubatus*) that are the focus of current conservation efforts, there is growing interest in knowing more about the biology and ecology of this small fish. This review is intended to bring together the available literature on eulachon and synthesize the information to provide a platform for the research that is needed to fill in the many gaps in our understanding of this species.

This annotated bibliography compiles the references we have found. The vast majority of the papers are in the "gray literature", not in refereed professional journals, which renders them less accessible to most investigators (including us); this also often makes them unacceptable, or only reluctantly acceptable, as citations for papers published in refereed professional journals. The information these "gray" papers contain

can be useful to researchers, however, particularly because these papers frequently represent the only written records about the species of interest. One problem with many of these gray papers is that they sometimes recycle lore or statements without attribution; it then can be hard to discern whether the information is original to that report or merely recycled from some other source. In other cases, such as web sites, the material is commonly recycled from other sources. There are a number of references for which we provide bibliographic information and keywords, but which we were unable to obtain through local library services or the Internet. The websites cited are those present when the review was published, but all websites are likely to be transient.

TAXONOMY

Scientific Nomenclature

Eulachon have been classified previously in various other ways and placed in different genera (e.g., Scott and Crossman 1973, Ref. 390), but the present systematic classification follows Mecklenburg et al. (2002, Ref. 306):

Phylum: Chordata

Subphylum: Vertebrata

Superclass: Gnathostomata

Grade: Teleostomi

Class: Actinopterygii

Subclass: Neopterygii

Division: Teleostei

Subdivision: Euteleostei

Superorder: Protacanthopterygii

Order: Osmeriformes

Suborder: Osmeroidei

Superfamily: Osmeroidea

Family: Osmeridae (smelts)

Genus and species: *Thaleichthys pacificus* (Richardson, 1836)

Common Names (Hart and McHugh 1944, Ref. 192)

English

Eulachon: derived from the Chinook language, a synthetic trading language derived from French, English, and various First Nations languages (Hay and McCarter 2000, Ref. 210); candlefish; less commonly salvation fish, saviour fish, fathom fish.

Native languages

Many variants of eulachon, including hoolakan, hooligan, hoolikan, olachan, ollachan, oolachan, oolichan, oulachan, oulachon, ulchen, ulichan, uthlecan; also yshuch, swavie, chucka, juk'wan or za'xwen meaning 'jittery fish' in Haisla language, saak in Tlingit.

DISTRIBUTION

Freshwater Distribution

Eulachon occur only on the coast of northwestern North America, from northern California to southwestern Alaska. They are anadromous fish, spawning in the lower reaches of mainland rivers in early spring; only a few island runs have been reported (Blackburn et al. 1981, Ref. 71). Spawning runs have been reported to occur in as few as

30 rivers (Hay et al. 1997, Ref. 202; Department of Fisheries and Oceans-Canada 1999, Ref. 122) or 50-60 rivers (Hay in Eulachon Research Council 2000, Ref. 145). Clearly, the number of runs depends, in part, on how they are counted: if every stream known to have a run is counted, the number is considerably larger than 60; but if one counts only the inlets, bays, and major rivers where the fish enter from the open sea, thence dispersing to the spawning sites, the number is much smaller. We have tabulated the rivers (along the coast from north and west to south and east, roughly) for which we have found records of eulachon spawning runs; rivers flowing into the same bay or inlet (or other limited area) are listed together (Table 1; Figs. 1-4). Undoubtedly, numerous other rivers are used by eulachon for spawning at least occasionally but remain undocumented. Many sources note that runs tend to be erratic, appearing in some years but not others, and appearing only rarely in some river systems. For example, eulachon failed to appear in the Cowlitz River in some years (Hinrichsen 1998, Ref. 216), but they may have run in other tributaries of the Columbia. Eulachon historically occurred in the Sacramento River system and even farther south along the California and Baja California coast, in areas where they have been extirpated (Minckley et al. 1986, Ref. 315).

Oceanic Distribution

Very little is known about the offshore distribution of adult or immature eulachon outside the spawning season, although abundances in particular locations show responses to oceanic conditions (Emmett and Brodeur 2000, Ref. 140). In addition to research surveys, eulachon are caught by shrimp trawls, so some, more localized, samples are available from trawl surveys or bycatch. A summary of offshore eulachon distribution derived from research surveys (1963-99) showed concentrations of fish between Haida

Gwai'i and the mainland, north of Vancouver Island, and on both sides of southern Vancouver Island (Hay and McCarter 2000, Ref. 210); however, relative search effort in the different areas is not given. One survey area west of Vancouver Island showed marked annual variation in abundance within the sample area (Hay et al. 1997, Ref. 202), but it may be possible that the fish simply moved outside that area. Eulachon may be the most abundant smelt near Haida Gwai'i (Gillespie and Westrheim 1997, Ref. 162). In the Bering Sea, eulachon are reported to be concentrated between the area around Unimak Island and the end of the Alaska Peninsula and the Pribilof Islands (P. J. Anderson, unpubl. data, Kodiak Laboratory, National Marine Fisheries Service). Eulachon abundance (measured as catch per unit effort, or CPUE) in the western Gulf of Alaska varied between 1971 and 1997, with little relationship noted to abundance of other fishes (Anderson and Piatt 1999, Ref. 18). Near the outer Kenai Peninsula and southwestern Prince William Sound, eulachon are found outside certain bays in summer and at the head of different bays in winter (Brown et al. 2002, Ref. 85). In northern Southeast Alaska, eulachon were widespread in trawl samples in the coastal fiords (Carlson et al. [no date], Ref. 95).

Eulachon appear to live near the ocean bottom, on the shelf, at moderate depths (commonly 20-200 m, but may occur as deep as 500 m) (Hay and McCarter 2000, Ref. 210; Anonymous in Eulachon Research Council 2000, Ref. 145) or as deep as 625 m (Allen and Smith 1988 [Ref. 13] in Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437). Eulachon were found with the use of hydroacoustics and trawl samples in various parts of Prince William Sound (Brown et al. 2002, Ref. 85), at depths from 30 to 180 m (Gotthardt 2001, Ref. 170).

They were reported in trawl samples at depths up to 500 m in the Gulf of Alaska (GOA), with considerable variation among portions of the GOA (Mueter and Norcross 2002, Ref. 328).

Population declines in the southern parts of the geographic range are generally attributed chiefly to shifting oceanic conditions (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437; Hay 1999 in op. cit.), probably with a contribution from overfishing (Hinrichsen 1998, Ref. 216).

MORPHOLOGY

General descriptions of adult eulachon can be found in Scott and Crossman (1973, Ref. 390), of larvae in Barraclough (1964, Ref. 45), and of embryos in Parente and Snyder (1970, Ref. 398). Here we mention only some salient features of particular interest.

The mouth is relatively large (Hart and McHugh 1944, Ref. 192; Scott and Crossman 1973, Ref. 390). Nonspawners have numerous teeth borne on several jaw bones, which tend to be lost in spawners (Hart and McHugh 1944, Ref. 192; Scott and Crossman 1973, Ref. 390), but perhaps are not completely lost in all populations (Hay and McCarter 2000, Ref. 210; Spangler 2002, Ref. 401). Minerals (e.g., Ca, P) may be resorbed from teeth and scales (Hay and McCarter 2000, Ref. 210; Spangler 2002, Ref. 401). Resorption is often thought to be greater in females than in males, but Spangler (2002, Ref. 401) found that tooth resorption was greater in males.

Sexual Dimorphism

Spawning male eulachon can be told readily from females by the rougher skin produced by tubercles on the scales, especially near the lateral line and on the head, by a more rigid body and less cylindrical cross section caused by a raised lateral ridge, and by slightly larger paired fins (Hart and McHugh 1944, Ref. 192; Hay and McCarter 2000, Ref. 210). Lewis et al. (2002, Ref. 269) note that in another species of smelt, the lateral ridges of the males are used to press females down to the substrate, perhaps encouraging extrusion of eggs. Females also have more abdominal vertebrae (Hart and McHugh 1944, Ref. 192). Males often tend to be slightly larger than females, even when controlling for age (Hart and McHugh 1944, Ref. 192; Prince Rupert Forest Region 1998, Ref. 364; Lewis et al. 2002, Ref. 269; Spangler 2002, Ref. 401; Moffitt et al. 2002, Ref. 317), but are not always larger (Warner and Shafford 1979, Ref. 436; Langer et al. (1977), Ref. 262). Morphological hermaphrodites are sometimes reported (Lewis et al. 2002, Ref. 269).

Annual and Population Differences

In addition to some annual variation in meristic characters (Hay and McCarter 2000, Ref. 210), there is some differentiation of morphology among runs. The number of vertebrae is greater for Columbia and Fraser River fish than for those from northern B.C. (Hart and McHugh 1944, Ref. 192; Hay and McCarter 2000, Ref. 210). Body length (at age) differed among some offshore samples from different places (Barraclough 1964, Ref. 45). Despite the broad latitudinal range of the known spawning rivers and some differences in body size among populations, relatively little genetic differentiation among

populations was detected using mitochondrial DNA (McLean et al. 1999, Ref. 301) or microsatellite DNA (McLean and Taylor 2001, Ref. 302), but additional genetic analyses would be desirable.

PREY

Eulachon are plankton-feeders, chiefly eating crustaceans such as copepods and euphausiids, for example, *Thysanoessa* (Barraclough 1964, Ref. 45; Hay and McCarter 2000, Ref. 210), euphausids and unidentified malacostracans (Sturdevant et al. 1999, Ref. 413), and cumaceans (Smith and Saalfeld 1955, Ref. 398). The majority of a small number of eulachon sampled in Prince William Sound in fall 1994-95 had empty stomachs, sugggesting that eulachon may not feed very actively at that time of year (Sturdevant et al. 1999, Ref. 413). Larvae and postlarvae eat phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, worm larvae, and eulachon larvae (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437). Adults and juveniles commonly forage at moderate depths in inshore waters (Hay and McCarter 2000, Ref. 210).

BODY COMPOSITION

Eulachon have a high energy density, averaging 7.7 kcal/g ash-free dry mass, markedly higher than herring (*Clupea pallasi*) and capelin (*Mallotus villosus*) (6.8 and 6.6 kcal/g, respectively) or cod, pollock, and arrowtooth flounder (5.5-5.8 kcal/g) (season and gender not specified; Perez 1994, Ref. 354). Specimens from the Gulf of Alaska had

significantly higher caloric content in March (7.8 kcal/g; before spawning, for most populations) than in August (7.5 kcal/g) (Perez 1994, Ref. 354).

Eulachon are notable for the high concentration of oils (mostly mono-unsaturated fatty acids, particularly oleic acid (Kuhnlein et al. 1982a, Ref. 257; Kuhnlein 2000, Ref. 260) in the body. Among the lipids occurring in eulachon is squalene, which is typical of elasmobranchs rather than teleosts (Ackman et al. 1968, Ref. 1). The fatty-acid 'signature' of eulachon is quite distinct from that of other species of forage fishes (Iverson et al. 2002, Ref. 227). Samples collected in March and April contained 18% lipids (wet mass; Kuhnlein et al. 1996, Ref. 259). There was a slight but significant increase in body lipids of Gulf of Alaska eulachon from February-March to June-September (Payne et al.1999, Ref. 350).

Samples obtained from February to June in the Gulf of Alaska contained 18-20% oil (wet mass), a value higher than that for other common forage fishes, such as sand lance (*Ammodytes hexapterus*; 3-6%) or capelin (2-10%) during the same time frame (Payne et al. 1999, Ref. 350). Iverson et al. (2002, Ref. 227) reported similar average values for spring samples from Prince William Sound (eulachon 19% lipid [wet mass], capelin 3%, but sand lance 1.5%). "Large" (>100 mm standard length) eulachon from the northern Gulf of Alaska, collected from May to September, contained 50% lipid (by dry mass; (approximately equivalent to 14.5% lipid by wet mass), similar to the lipid content of northern lampfish (*Stenobrachius leucopsarus*) but higher than lipid content from capelin, sand lance, or herring (Anthony et al. 2000, Ref. 37).

Protein content was slightly lower for eulachon (12-13%) than for the other species (13-15% for capelin, 16-18% for sand lance) (Payne et al. 1999, Ref. 350). When

samples from the Gulf of Alaska and the eastern Bering Sea were matched for body size and month, there were no differences in protein and lipid content (Payne et al. 1999, Ref. 350). Eulachon from the Columbia River were reported to have about 13-15% protein and 5-9% oil in muscle tissue (Stansby 1976, Ref. 406). Eulachon also contain high levels of vitamins A and E (Kuhnlein 2000, Ref. 260; Crissey et al. 1998, Ref. 113) and are good sources of calcium, iron, and zinc (Kuhnlein et al. 1996, Ref. 259).

Eulachon can take up and store pollutants from their spawning rivers, despite the fact that they do not feed in fresh water and remain there only a few weeks (Rogers et al. 1990, Ref. 375; Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437); eulachon avoid polluted waters when possible (Smith and Saalfeld 1955, Ref. 398). Specimens from the Cowlitz River in Washington contained phenolics derived from the eruption of Mount St. Helens (Campbell et al. 1982, Ref. 91). Eulachon returning to the lower Fraser River contained contaminants from wood-treatment processes (Rogers et al. 1990, Ref. 375), apparently acquired after river entry (Birtwell et al. 1988, Ref. 67; Rogers et al. 1990, Ref. 375). Concentrations of some contaminants differed between males and females and increased with increasing distance upstream (Rogers et al. 1990, Ref. 375). Industrial effluent into the Kitimat River after 1972 has tainted eulachon flesh and made it unpalatable (Mikkelson et al. 1996, Ref. 310; Pedersen et al. 1995, Ref. 351). Nass River eulachon acquired detectable levels of metals derived from mine tailings (Futer and Nassichuk 1983, Ref. 156). However, contaminant levels in eulachon (the edible portion only) from the Nass, Kitimat, Bella Coola, Kingcome, and Knights Inlet rivers were judged to be below the limits set by health

regulations, although they increased from north to south (Futer and Nassichuk 1983, Ref. 156; Chan et al. 1996, Ref. 99; Kuhnlein et al. 1996, Ref. 259).

AGE, GROWTH, AND MATURATION

Age determination of eulachon is reported to be difficult, because both otoliths and scales may yield inaccurate assessments, and age estimates from otoliths are commonly 1-3 years higher than estimates from scales (Ricker et al. 1954, Ref. 370; Hay and McCarter 2000, Ref. 210). This discrepancy occurred for Fraser River fish, but there was much better correspondence of age estimates from the two methods in eulachon from the Nass River (Langer et al.1977, Ref. 262). Methodological differences may account for some of the differences among reports in the age of eulachon at spawning.

Age at Spawning

Most studies conclude that eulachon commonly spawn at age 3 or 4, but some fish spawn at age 2 or age 5 (Barrett et al. 1984, Ref. 51; Barraclough 1964, Ref. 45; Parente and Snyder 1970, Ref. 348; Langer et al. (1977), Ref. 262; Hay and McCarter 2000, Ref. 210); some 9-year old adults are recorded from the Columbia River system (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437). The mean age of fish in the Meshik River was 3.1 years, with a few fish of ages 2, 4, and 5 years (based on otoliths,Warner and Shafford 1979, Ref. 436), and the dominant age class on the Susitna River was 3 years (Barrett et al. 1984, Ref. 51). Biologists on the Kalsin River in Kodiak reported, on the basis of otolith analysis, that most fish were 2 years old, some were 3 years old, and a few were 4 years old (Blackburn et al. 1981, Ref.

71). On the Twentymile River, spawners ranged from age 2 to age 5 (and a few age-1 females in one year), but most spawners were age 3, with a broader distribution of ages in 2000 than in 2001 (Spangler 2002, Ref. 401). In the Copper River, spawning eulachon ranged from 2 to 6 years old, with age-4 fish predominant in one year and age-5 fish in another (Moffitt et al. 2002, Ref. 317). On the Stikine River, incoming fish were 2-4 years old; 3-year-olds were most common, and the frequency of 2- and 4-year-olds differed between sample years (based on otolith analysis; Franzel and Nelson 1981, Ref. 154; Beak Consultants Ltd. 1983 [Ref. 54] cited in Lewis et al. 2002, Ref. 269).

There was annual variation in the dominant year class of spawners in the Nass River also, with 3-year-olds dominant in one year and 4-year-olds in another (Langer et al. (1977), Ref. 262). Kitimat River female eulachon, aged by otoliths, were mostly age 3, with some age 4, 5, and 6 years (Pedersen et al. 1995, Ref. 357), but the dominant age class in the Kemano River was 4 years (range 2-7 years, Lewis et al. 2002, Ref. 269; Triton 1990 in Pedersen et al. 1995, Ref. 351). By scale and otolith analysis, most Fraser River fish spawned at age 2 and a few at age 3 according to Hart and McHugh (1944, Ref. 192), but most spawned at age 4-5 (and a few up to age 7) according to other researchers (otolith analysis; Higgins et al. 1987, Ref. 215; Rogers et al. 1990, Ref. 375). Most fish in the Columbia River were age 3-4, with some fish age 5 (based on otoliths: Smith and Saalfeld 1955, Ref. 398; Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437). Judging from research to date, the age distribution of eulachon in a spawning run probably varies among rivers. It also varies between sexes in some years and among years in the same river system (in the Kemano River, Lewis et al. 2002, Ref. 269).

Age and Length

It is difficult to compare body lengths among reports because different length measures (standard, fork, total) have been used. We lack the data to convert one measurement to another, and reports sometimes may not state which measurements were used, so here we merely summarize the findings. As expected, both length and body mass increase with age (Spangler 2002 [Ref. 401] and others cited below). Eulachon on the Twentymile River averaged about 180-200 mm and 40-58 g at age 2, to 220-225 mm and 80-90 g at age 5; at age 3, the most common age of spawners, fork length averaged about 200-215 mm and body mass averaged about 60-65 g (estimated from graph, Spangler 2002, Ref. 401). For the Fraser River population, fork-length distribution was as follows: age 0+ fish were about 20-50 mm, age 1+ about 50-80 mm, age 2+ about 75-105 mm, age 3+ about 105-135 mm, and age 4+ about 135-160 mm (estimated from graph; Barraclough 1964, Ref. 45). Eulachon in the Kemano, Kitimat, Nass, Stikine, and Columbia rivers reportedly have similar distributions of size-at-age, but the increase of size-at-age is small for both sexes (10 mm and 7.2 g from age 3 to 4, 4 mm and 3.1 g from age 4 to 5; Lewis et al. 2002, Ref. 269).

Body size information from several studies is summarized in Tables 2a-e. Despite the assorted measurements reported, it is clear that body size differs among river systems. Some reports indicate annual variation as well, so some of the apparent variation among river systems might also reflect differences among years. As noted by Spangler (2002, Ref. 401), body size of eulachon at the northern and western end of their geographic range seems to be greater than in the south and east. Average body length in

the Twentymile, Susitna, and Meshik rivers all exceed 200 m, whereas small samples from the Oregon coast indicate much smaller body lengths there.

Fecundity Versus Age and Body Size

As expected, fecundity was correlated with body length, body weight, or age in samples from the Columbia (Smith and Saalfeld 1955, Ref. 398), Kitimat (Pedersen et al. 1995, Ref. 357; Hay and McCarter 2000, Ref.210; Knight Inlet (Hay and McCarter 2000, Ref. 210), Kemano (Lewis et al. 2002, Ref. 269), Fraser (Hart and McHugh 1944, Ref. 192; Hay and McCarter 2000, Ref. 210), Stikine (Franzel and Nelson 1981, Ref. 154), Copper (Moffitt et al. 2002, Ref. 317), and Twentymile (Spangler 2002, Ref. 401) rivers. The slopes of these lines for different river systems have not been compared statistically in any source we have seen, but this would be a useful exercise. Fecundity ranges for various river systems are summarized in Table 3.

SEX RATIO

In most samples of eulachon, males outnumber females: males outnumber females 2-26:1 for the Stikine River (Franzel and Nelson 1981, Ref. 154), 3:1 for the Kitimat River (Pedersen et al. 1995, Ref. 351), about 3-12:1 in most samples from the Columbia River (Smith and Saalfeld 1955, Ref. 398), about 6:1 for the Kalsin River (Franzel and Nelson 1981, Ref. 154), about 1.2:1 for the Nass River (Orr 1984 in Pedersen et al. 1995, Ref. 351), about 1.56:1 (but up to 25:1 in some samples) for the Kemano River (Lewis et al. 2002, Ref. 269), 2.1-6.7:1 on the Twentymile River

(Spangler 2002, Ref. 401), and 2.5-4.5:1 in the Copper River (Moffitt et al. 2002, Ref. 317). Males are reported to enter the river first in the Chilkat River (Betts 1994, Ref. 63) and in the Fraser River (Bailey in Eulachon Research Council 2000, Ref. 145); thus, the sex ratio changes during the run (Pedersen et al. 1995, Ref. 351). In the Fraser River, April samples had 56-71% males, but May samples had 15-20% males (Hart and McHugh 1944, Ref. 192). Another April sample from the Fraser River exhibited a sex ratio of 3.4:1 (Higgins et al. 1987, Ref. 215; Rogers et al. 1990, Ref. 375). In contrast, male and female abundances were similar at the beginning of the run in the Kemano River, and male abundance declined more slowly than female abundance (Lewis et al. 2002, Ref. 269). Male and female eulachon in the Copper River were about equally abundant at the beginning of the run, but males outnumbered females from the midpoint of the run onward (Moffitt et al. 2002, Ref. 317). In the Nass River, sex ratios varied greatly with date and location (Langer et al. (1977), Ref. 262), but the sex ratio in the Twentymile River did not change significantly over the course of the run, although it favored males (Spangler 2002, Ref. 401). Females may enter the river in separate "waves" and may come in each night, retreating to the bay in the daytime (Lewis et al. 2002, Ref. 269). Apparent sex ratio also might vary with distribution of male and female fish in the river and hence with sampling techniques (Spangler 2002, Ref. 401). Some researchers suggest that the sex ratio may be close to equal overall (Hay and McCarter 2000, Ref. 210).

Differential timing of males and female eulachon would mean that many estimates of overall sex ratios are probably wrong, but it raises interesting questions about synchronization of spawning between males and females, particularly when

females are present only for 1 to 2 days (e.g., on the Kewano River, Bouillon in Eulachon Research Council 2000, Ref. 145) or 1-4 days on the Twentymile River (Spangler 2002, Ref. 401). Differential timing, and the slightly longer residence time in the river for males (on the Twentymile River, Spangler 2002, Ref. 401), could also expose males and female eulachon to differing risks of predation.

SPAWNING

Eulachon are fundamentally semelparous, although some individuals may spawn twice in a lifetime. The frequency of iteroparity might vary among populations—an issue still not completely resolved (Hay and McCarter 2000, Ref. 210; Lewis et al. 2002, Ref. 269; Barraclough 1964, Ref. 45; Blackburn et al. 1981, Ref. 71; Hart and McHugh 1944, Ref. 192).

Spawning appears to occur at night (Hay and McCarter 2000, Ref. 210; Parente and Snyder 1970, Ref. 348; Prince Rupert Forest Region 1998, Ref. 364; Lewis et al. 2002, Ref. 269) or possibly afternoon (Langer et al. (1977), Ref. 262). Spawning can occur at various depths: up to 25 ft in the Fraser River (Hart and McHugh 1944, Ref. 192), but much less in the Kemano River (0.2-4 m, Lewis et al. 2002, Ref. 269), the Susitna River (1-5 ft, Vincent-Lang and Queral 1984, Ref. 433) and Berners Bay rivers (M. F. Willson, pers. obs.). Smith and Saalfeld (1955, Ref. 398) recovered eggs from depths ranging from 3 in to greater than 20 ft and suspected that eggs were present at much greater depths. Egg deposition in the Nass River was greater at depths around 3.7-5.2 m than at shallower depths; deeper waters were not sampled (Langer et al. (1977), Ref. 262).

The sexes must synchronize their activities closely, unlike some other group spawners such as herring, because eulachon sperm are said to remain viable for only a short time, perhaps only minutes (Hay and McCarter 2000, Ref. 210). Males are reported to lie next to females, either beside or on top of them, in riffles (Lewis et al. 2002, Ref. 269). This description differs markedly from that in Langer et al. (1977, Ref. 262), in which males were said to congregate upstream of groups of females, releasing milt simultaneously, and females laid eggs as the milt drifted over them; the spent fish then drifted downstream.

Spawning substrates can range from silt, sand, or gravel to cobble and detritus (Barrett et al. 1984, Ref. 51; Vincent-Lang and Queral 1984, Ref. 433; Smith and Saalfeld 1955, Ref. 398), but sand appears to be most common (Langer et al. (1977), Ref. 262; Lewis et al. 2002, Ref. 269). It is possible that the substrate favored for the spawning events themselves may be different from those where the eggs accumulate (Langer et al. (1977), Ref. 262). Egg mortality was higher on silt or organic debris than on sand or gravel (Langer et al. (1977), Ref. 262).

Spawning rivers may be turbid or clear, but all are thought to have spring freshets, characteristic of rivers draining large snow packs or glaciers (Hay and McCarter 2000, Ref. 210). Many, but not all, of the reported spawning rivers in Alaska are glacial in origin, whereas the more southerly ones are not. In general, eulachon would spawn at low water levels before spring freshets (Lewis et al. 2002, Ref. 269), although runs in the Fraser River appear to occur at mid-levels of river discharge (Langer et al. (1977), Ref. 262). Most spawning in the Susitna River occurred at water velocities of 0.5-2.5 ft/s (Vincent-Lang and Queral 1984, Ref. 433). Spawning sites may vary among years within

the same river system (Hay and McCarter 2000, Ref. 210; Pedersen et al. 1995, Ref. 351; Moffitt et al. 2002, Ref. 317), and the age distribution of spawners may vary among sites within the same system (Moffitt et al. 2002, Ref. 317). Some small rivers near large runs may have occasional spawning populations (Prince Rupert Forest Region 1998, Ref. 364; McCarter and Hay 1999, Ref. 290).

In many rivers, the spawning reach is more or less limited to the part of the river that is influenced by tides (Lewis et al. 2002, Ref. 269). In the Berners Bay system, the greatest abundance of eulachon was observed in tidally-influenced reaches, but some fish ascended well beyond the tidal influence (M. F. Willson, pers. obs.). Eulachon are reported to go as far as 80 km up the Susitna River (Barrett et al. 1984, Ref. 51; Vincent-Lang and Queral 1984, Ref. 433), possibly because of a low gradient (Lewis et al. 2002, Ref. 269). Eulachon once ascended more than 160 km in the Columbia River system. There is some evidence that water velocity greater than 0.4 m/s begins to limit upstream movements, at least for a segment of the eulachon population (Lewis et al. 2002, Ref. 269).

Hay and McCarter (2000, Ref. 210) stated that no eulachon spawning runs are known on islands, although other reports show that runs occur on Kodiak Island (for at least several years, Blackburn et al. 1981, Ref. 71) and at least occasionally on Unimak Island and Vancouver Island (see elsewhere in this report).

Run Timing

Entry into the spawning rivers appears to be related to water temperature and the occurrence of high tides (Ricker et al. 1954, Ref. 370; Bargman in Eulachon Research Council 2000, Ref. 145; Prince Rupert Forest Region 1998, Ref. 364; Bishop et al.

1989b, Ref. 70; Lewis et al. 2002, Ref. 269; Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437; Spangler 2002, Ref. 401), except in the Susitna River (Vincent-Lang and Queral 1984, Ref. 433). In the Berners Bay rivers in 1996-98, runs appeared to begin during a period of higher tides, but not necessarily at the highest tide (>16 ft; M. F. Willson pers. obs). Low levels of river discharge may also contribute to the timing of in-migration (Spangler 2002, Ref. 401).

Spawning is reported to occur at temperatures from 4° to 10°C; colder temperatures may stop migration (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437), at least in some rivers. Run timing (as estimated from harvest rates) in the Fraser River tended to be earlier in years with somewhat warmer temperatures ($r = -0.47$; Ricker et al. 1954, Ref. 370). In the Nass River, peak eulachon in-migration occurred at temperatures between 0° and 2°C, noticeably colder than in most other rivers, and this run is earlier than the eulachon run that occurs at warmer temperatures in the Fraser River (Langer et al. (1977), Ref. 262). In the Stikine River, the eulachon run began at temperatures lower than about 2°C, corresponding to the breakup of ice, and peaked at about 2 - 3.5°C; some fish were still present at about 8°C (Franzel and Nelson 1981, Ref. 154). In the Kemano River, mean water temperature was 3.1°C (range 1.1 - 6.5°C) during spawning, 4.1°C (range 2.2 - 5.4°C) during incubation, but 5.9 - 6.0°C (range 0.0 - 8.2°C) during larval outmigration (Lewis et al. 2002, Ref. 269). Water temperatures at spawning sites in the Susitna River ranged from 6° to 11C° (Vincent-Lang and Queral 1984, Ref. 433) or 2 - 11°C (Barrett et al. 1984, Ref. 51), and in the Cowlitz River temperatures ranged from 39° to 45°F (Smith and Saalfeld 1955, Ref. 398). High water temperatures can be lethal, however. For fish

acclimated to 5°C, an increase to 11°C for several days resulted in 50% mortality and spawning failure (Blahm and McConnell 1971, Ref. 73). Langer et al. (1977, Ref. 262) suggested that the contrast between ocean and river temperatures might be more critical than river temperatures *per se*.

Catch per unit effort (CPUE), as a measure of abundance of incoming eulachon in the Twentymile River, was positively related to date, water temperature, tide height, and river discharge, but negatively related to light intensity (Spangler 2002, Ref. 401). In this model, water temperatures ranged from 0.5° to 12.7°C, with temperatures at 4.6 - 6.0°C at the peak of the run. However, because temperatures presumably increased during the season but the number of incoming fish obviously decreased toward the end of the run, the basis for the reported positive relationship between fish numbers and temperature needs further explication. Furthermore, the positive relationship reported for the model appears to contradict the later statement that peak migration of adults occurs when river discharge is low (Spangler 2002, Ref. 401). At the onset of this run, water temperatures ranged from 2.8° to 6.0°C.

Run timing of male eulachon in the Twentymile River was related to the age of the male fish: the frequency of age-2 males was higher early in the run and the frequency of age-4 and age-5 males was greater late in the run. The most common age class (age 3) of male eulachon was present throughout the run, and female eulachon age-frequency did not change during the run (Spangler 2002, Ref. 401).

Presumably as a result of temperature dependence and perhaps other factors, eulachon run timing does not show a simple latitudinal trend from early in the south to later in the north (Hay and McCarter 2000, Ref. 210). Spawning runs occur in January,

February, and March in the Columbia River system (Hay and McCarter 2000, Ref. 210; Bargman in Eulachon Research Council 2000, Ref. 145; Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 437) and in February in the Russian River of California (Horwood 1990, Ref. 219). The Fraser River runs occur in April (Northcote 1974 [Ref. 334] in Rogers et al. 1990, Ref. 375) or May, and the nearby Kliniklini River runs occur earlier than runs in the Fraser River (Hay and McCarter 2000, Ref. 210). Eulachon runs in central and northern British Columbia typically occur in late February or March (Hay and McCarter 2000, Ref. 210; Pedersen et al. 1995, Ref. 351; Lewis and O'Connor 2002, Ref. 270) or late March-early April (Kemano River, Bouillon in Eulachon Research Council 2000, Ref. 145; Langer et al. (1977), Ref. 262; Lewis et al. 2002, Ref. 269; Bella Coola River, Lewis and O'Connor 2002, Ref. 270). Stikine River runs occur in early to mid-April (Franzel and Nelson 1981, Ref. 154). Eulachon runs in rivers on the Yakutat forelands occur in late February to early April, or even January (Catterson and Lucey 2002, Ref. 97; Lucey 2001, Ref. 275), markedly earlier than runs in Berners Bay rivers (mid-April to early May, see below). The principal run in the Copper River occurred from mid-May to late May over four sampling years, with peaks from 23 to 28 May, but timing sometimes differed in other streams on the Copper River Delta (Moffitt et al. 2002, Ref. 317). Susitna River runs occur in May and June (Vincent-Lang and Queral 1984, Ref. 433), and runs on the Alaska Peninsula occur in June and early July (Warner and Shafford 1979, Ref. 436).

Attempts to characterize eulachon run timing are complicated, however, by marked annual variation in timing. For example, in 1989, the Chilkat River run began about 26 April and peaked in early May, but in previous years the peak was around 23 -

24 May (Bishop et al. 1989b, Ref. 70). Eulachon entered the Twentymile River on 4 May in 2000 and on 17 April in 2001 (Spangler 2002, Ref. 401). Similarly, runs in Berners Bay rivers occurred in early May for several years, but more recently have happened in mid-April to late April (Marston et al. 2002, Ref. 280; J. N. Womble, NPS Glacier Bay Field Station, pers. comm.). Run timing on the Kemano River, the Yakutat forelands, and the Twentymile River also varies from year-to-year (Catterson and Lucey 2002, Ref. 97; Lewis et al. 2002, Ref. 269; Lucey 2001, Ref. 275; Kitto in Eulachon Research Council 2000, Ref. 145).

Some eulachon runs are very reliable from year to year; others occur more sporadically (Stacey 1995, Ref. 405; Hinrichsen 1998, Ref. 216; Hay and McCarter 2000, Ref. 210; Eulachon Research Council 2000, Ref. 145; Smith and Saalfeld 1955, Ref. 398). Some rivers have two eulachon runs per year. For example, the Chilkat River has a regular run in May and possibly a smaller, more sporadic one in February (Bishop et al. 1989b, Ref. 70; Betts 1994, Ref. 63; Staska 1995 in Anonymous no date, Ref. 36). The Nass River has (or had) a run in March and a smaller one in June (Langer et al. (1977), Ref. 262), and the Dean and Susitna rivers also have two runs (Pootlass and Siwallace in Eulachon Research Council 2000, Ref. 145; Vincent-Lang and Queral 1984, Ref. 433; Barrett et al. 1984, Ref. 51). The Twentymile River has pulses of eulachon spawners in May and June (Kitto in Eulachon Research Council 2000, Ref. 145), and a run duration longer than most others reported (Spangler 2002, Ref. 401). The Copper River system has a small but prolonged winter run and a substantial run in May and June; run timing tends to differ among the sloughs and river outlets in this area (S. Moffitt, Alaska Department of Fish and Game, pers. comm.; Moffitt et al. 2002, Ref. 317). Occasional or anomalous

eulachon runs in some streams could be straying from regular sites; for example, a report of spawning in the Somass and Nimpkish rivers on Vancouver Island is attributed to a "mistake" (Hay and McCarter 2000, Ref. 210).

Eggs and Larvae

Eggs are greater than 1 mm in diameter, averaging about 0.43 g; however, egg weight varied linearly from 10 mg in small fish to almost 30 mg in fish of 180-190 mm standard length from the Fraser River (Hay and McCarter 2000, Ref. 210). Eggs are enclosed in a double membrane; the outer membrane breaks and turns inside out, making a sticky stalk by which the egg adheres to sand grains and small gravels (Hay and McCarter 2000, Ref. 210; Hart and McHugh 1944, Ref. 192). Eggs do not adhere to sand immediately but drift downstream for a short time; even after adherence, water velocity can move the sand grains farther downstream (Lewis et al. 2002, Ref. 269). Incubation is temperature-dependent, and so incubation times can differ among rivers and years (Table 4).

Eggs can accumulate on the substrate at densities of several to many thousand per square meter (Lewis et al. 2002, Ref. 269). Very large masses of eggs (up to 500 eggs/ml) sometimes accumulate in areas of low water velocity and may cover many square meters (Lewis et al. 2002, Ref. 269). Survival of eggs during the first 10 days of incubation in these masses is very low (< 1%). In contrast, early survival of "drifting eggs" averaged from 69% to 82% in some years, with as much as 97% survival in some locations; however, in another year, average survival was only 9% (up to 23% in some locations; Lewis et al. 2002, Ref. 269). Overall egg-to-larva survival was estimated as 2.9 - 4.8% in the Kemano River, but less than 1% in the adjacent Wahoo River (Lewis et al. 2002, Ref.

269). Egg survival is greatly influenced by salinity: exposure to salt water, especially salinity greater than 16 ppt, can be lethal (Farara 1996 [Ref. 150] cited in Lewis et al. 2002, Ref. 269). Major temperature changes also affect survival (e.g., a change from 5° to 11°C; Lewis et al. 2002, Ref. 269).

Hatching and early development are described briefly by Parente and Snyder (1970, Ref. 348) and DeLacy and Batts (1963, Ref. 120). The "diaphanous" (Smith and Saalfeld 1955, Ref. 398) larvae, 4-8 mm long, are immediately carried by currents to the sea and may rear in estuaries (Hay and McCarter 2000, Ref. 210; Lewis et al. 2002, Ref. 269). Peaks in larval outmigration are thought to occur during periods of relatively stable water temperatures and at low light intensities (Spangler 2002, Ref. 401). Out-migrating larvae may be damaged by dredging operations (Dutta 1976, Ref. 131).

Young eulachon appear to occupy a variety of depths in the water column.Yolk-sac fry captured at the mouth of the Cowlitz River were found near the bottom or at intermediate depths (Smith and Saalfeld 1955, Ref. 398), but larval eulachon were distributed through the water column in the Fraser River estuary (Levings 1980, Ref. 266). Larvae and young juveniles become widely distributed in coastal waters, mostly at depths up to 15 m (Hay and McCarter 2000, Ref. 210) but sometimes as deep as 182 m (Barraclough 1964, Ref. 45). Larvae from southern British Columbia rivers reach the west coast of Vancouver Island by midsummer (Hay et al. 1992, Ref. 208). Young eulachon may occur in extensive mixed-species schools with young herring and anchovy (Hay et al. 1992, Ref. 208). Larvae turn up in ichthyoplankton surveys in rivers and bays even when few or no adults have been observed. Thus, larvae found near a spawning river may not have originated from that river (Hay and McCarter 2000, Ref. 210); larvae

might originate from undocumented spawning streams or be brought in by oceanic currents.

PREDATORS

Several sources provide general lists of predators of eulachon (Hart and McHugh 1944, Ref. 192; Scott and Crossman 1973, Ref. 370; Jones and Geen 1977, Ref. 232; Langer et al. (1977), Ref. 262; Brown and Okey no date, web site Ref. 4; Prince Rupert Forest Region 1998, Ref. 364; Miller and Moffitt 1999, Ref. 312; Moffitt et al. 2002, Ref. 317; Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 439; Spangler 2002, Ref. 401). Predators include fish (white sturgeon, spiny dogfish, sablefish, salmon sharks, arrowtooth flounder, salmon, Dolly Varden, Pacific halibut, Pacific cod), sea birds (harlequin ducks, pigeon guillemots, common murres (Scott 1973, Ref. 387), mergansers, cormorants, gulls, eagles), marine mammals (baleen whales, orcas, dolphins, pinnipeds, belugas (Kajimura et al. 1980, Ref. 241; Huntington 2000, Ref. 223; Speckman and Piatt 2000, Ref. 402), and terrestrial mammals (brown bears, wolves). Predation by sturgeon is interesting, in part because there is a fishery for sturgeon (Rosenau, Bailey in Eulachon Research Council 2000, Ref. 145). More importantly, sturgeon are reported to get very thin (“like snakes”) when not feeding on eulachon (Bailey in Eulachon Research Council 2000, Ref. 145) and some sturgeon migrations in the Fraser River are thought to be associated with the availability of eulachon (Hart 1973, p. 84, Ref. 190). Eulachon eggs were an important spring prey for white sturgeon in the Columbia River (McCabe et al. 1993, Ref. 288). Hake, which have been expanding northward, can be very abundant and may be significant predators

as well (Outram and Haegele 1972, Ref. 346; Hay and McCarter 2000, Ref. 210; Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 347). Eulachon are among the important prey of wintering and migrating waterfowl on the Fraser River delta (Butler and Campbell 2000, Ref. 90).

Predators commonly congregate at eulachon spawning runs (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2001, Ref. 347). Local observers often judge arrival of fish by the conspicuous arrival of many predators (eagles, gulls, seals: Bishop et al. 1989b, Ref. 70; Betts 1994, Ref. 63; Department of Fisheries and Oceans-Canada 1999, Ref. 122; Pedersen et al. 1995, Ref. 351; Bailey in Eulachon Research Council 2000, Ref. 145). Predators also may follow the fish into the bay and estuary (Lewis et al. 2002, Ref. 269) and up the lower reaches of the river (Marston et al. 2002, Ref. 280). On the Kitimat River, predator abundance peaked on 20-23 March in 1993, toward the early part of the run (Pedersen et al. 1995, Ref. 351).

The best-documented (but still inadequately reported) responses of predators to eulachon spawning runs are those of pinnipeds. Harbor seals (*Phoca vitulina*) congregated at the early June spawning run in the Copper River (Imler and Sarber 1947, Ref. 224), apparently feeding exclusively on eulachon. Steve Moffitt (Alaska Department of Fish and Game; pers. comm.) reported that harbor seals outnumber Steller sea lions at eulachon runs in the Copper River area. In the Gulf of Alaska, eulachon was one of the top five prey of harbor seals (by volume, most samples from April to June) but was well behind pollock and octopus as a prey source for harbor seals (Pitcher 1980, Ref. 360). Harbor seals congregate on the Yakutat forelands near eulachon spawning runs in the Alsek and Akwe rivers (Lucey 2001, Ref. 275; Catterson and Lucey 2002, Ref. 97), and

hundreds of harbor seals are present for the eulachon runs in Berners Bay (Marston et al. 2002, Ref. 280). Harbor seals eat eulachon "in season" in the Columbia River (Jeffries 1984, Ref. 229). Harbor seals ate large numbers of "smelt" (including eulachon) on the lower Columbia River in spring, summer, and fall, but the importance of eulachon *per se* was not distinguished (Laake et al. 2002, Ref. 261; Browne et al. 2002, Ref. 88). Seal scat samples from the lower Columbia River showed that eulachon was the most frequent prey, occurring in 84% of the scats in spring, but was not detected later in the year (Riemer and Brown 1997, Ref. 371). Harbor seals in Johnstone Strait in summer consumed eulachon (Olesiuk et al. 1990, Ref. 341). Smelt, mostly eulachon, comprised less than 1% of annual diet (based on scat samples) of harbor seals in the Strait of Georgia (Olesiuk 1993, Ref. 340), which does not reflect the possible seasonal importance of eulachon spawning runs.

Steller sea lions also aggregate near eulachon spawning runs at several locations in northern Southeast Alaska (Womble 2003, Ref. 449). At the Akwe and Alsek rivers, sea lions establish temporary haulouts at the time of eulachon runs (the Akwe earlier than the Alsek), and large numbers are seen at haulouts close to other eulachon runs (Lucey 2001, Ref. 275; Catterson and Lucey 2002, Ref. 97; Womble 2003, Ref. 449). Near the mouth of the Fraser River, the abundance of sea lions attending the eulachon spawning run peaked in late April to early May, although sea lions were present in lower numbers from mid-March to late May (Bigg 1988, Ref. 66). In Berners Bay in Southeast Alaska, the number of sea lions present is greatest just before the majority of eulachon enter the rivers (Marston et al. 2002, Ref. 280; J. N. Womble and M. F. Willson, pers. obs.); as many as 500-900 sea lions may be present (Marston et al. 2002, Ref. 280; Womble 2003,

Ref. 449). Sea lions sometimes forage cooperatively at this time, with gangs of 50-300 sea lions chasing groups of fish (Gende et al. 2001, Ref. 159; J. N. Womble, NPS glacier Bay Field Station, pers. comm). In Knight Inlet in 1950 and 1951, many sea lions were shot as they aggregated at the eulachon run (Common Resources 1998, Ref. 106).

The response of gulls (*Larus* spp.) and bald eagles (*Haliaetus leucocephalus*) to eulachon runs can be dramatic (Drew and Lepp 1996, Ref. 127; Marston et al. 2002, Ref. 280). When the eulachon run began in Berners Bay, the number of gulls increased from a few thousand to more than 40,000 in just a few days, and the total number of eagles probably exceeded 1,000 as the run peaked and declined. In contrast, eagle concentrations increased with CPUE of eulachon on the Twentymile River, and the peak count of eagles occurred just before the peak of the spawning run (Spangler 2002, Ref. 401). Adult gulls in Berners Bay were more successful than immatures at capturing fish by diving (> 56% vs. < 56%, respectively, Willson and Marston 2002, Ref. 446). Attempts at pirating fish from other birds were common, but piracy success was low (< 23%) in all gull species and age groups. The frequency of piracy attempts was correlated with the availability of fish captured by other birds (Willson and Marston 2002, Ref. 446). On the Stikine River, well over a thousand eagles and tens of thousands of gulls gathered at the spawning run (Drew and Lepp 1996, Ref. 127).

In contrast to the above observations, at a large eulachon run on the Alaska Peninsula so many fish died that the water was polluted and piles of dead fish lined the banks several inches deep and fouled the ocean floor just offshore (Warner and Shafford 1979, Ref. 436). The accumulation of carcasses from this run suggests that predators and scavengers were too few to take advantage of the run.

PARASITES

The following parasites have been reported from eulachon. Digenetic trematodes occur in the stomach and intestine (*Lecithaster gibbosus*), and in the pyloric caeca and intestine (*Pronoprymna petrowi*), cestode plerocercoids occur in the pyloric caeca and intestine (*Phyllobothrium* sp.), nematodes are encapsulated on the mesenteries (*Contracaecum* sp.) and in the body cavity and encapsulated in the mesenteries and viscera (*Anisakis simplex* larvae), and copepods occur in the gills (*Haemobaphus diceraus* and *H. disphaerocephalus*) (McDonald and Margolis 1995, Ref. 293; A. Moles, ABL, pers. comm.).

EULACHON FISHERIES

Because fisheries can alter biology by changing densities or exerting selection pressures, we include a brief summary here. Several eulachon rivers have been subject to commercial harvests at various times, and many have been subject to traditional First Nations harvests (e.g., Stacey 1995, Ref. 405).

Eulachon populations in California have declined in the past several decades (Jennings 1996, Ref. 230), and fisheries biologists in Oregon have noted apparent declines since the 1970s. At least in some of these rivers, small fisheries were operated in the past. Commercial harvests have concentrated on major southern runs, such as in the Columbia and Fraser rivers, with principal markets for feeding captive animals (e.g., in fur farms). Historically, the largest eulachon stock, judging from the size of the harvest, was in the Columbia River system, where commercial harvest began in the 1880s

(Bargman in Eulachon Research Council 2000, Ref. 145; Smith and Saalfeld 1955, Ref. 398; Hinrichsen 1998, Ref. 216). Annual harvests from this system ranged from 500 to 2000 tons in most years between 1940 and 1990 (Hay et al. 1997, Ref. 202; Hay and McCarter 2000, Ref. 210; Department of Fisheries and Oceans-Canada Science 1999, Ref. 122), with a peak of about 3000 tons in 1945 (Browning 1974, Ref. 89). After 1992 or 1993 the catch declined sharply and the fishery was closed in 1997 and 1998 (Bargmann in Hay and McCarter 2000, Ref. 210). A "sportfish" harvest was estimated to equal commercial harvest (Department of Fisheries and Oceans-Canada 1999, Ref. 122; Bargmann in Eulachon Research Council 2000, Ref. 145).

The principal commercial fishery in British Columbia has occurred on the Fraser River since the 1920s, with a harvest of 100-216 tons/year in the 1960s and about 30-40 metric tons/year in the 1980s and 1990s (Department of Fisheries and Oceans-Canada Science 1999, Ref. 122). Records kept since the 1940s show population declines since 1994, and there has been no fishery since 1996 (Hay in Eulachon Research Council 2000, Ref. 145). However, Hay (1998b, Ref. 199) suggested that eulachon abundance in the Strait of Georgia may be similar to that of 100 years ago.

The Nass River has been harvested for eulachon since 1877, with harvests at first for oil to export (First Nations bought it all), and later for smoked (> 45,000 lbs in 1903), salted (> 4,000 barrels in 1903), or fresh fish (>1 million lbs in 1903) (Hart and McHugh 1944, Ref. 192). Both before the arrival of European peoples and after, the Nass River fishery was important to First Nations. More than 300 tons were harvested the 1890s and in most years between about 1903 and 1917 (Hart and McHugh 1944, Ref. 192; Department of Fisheries and Oceans-Canada 1999, Ref. 122). The catch declined from

2250 tons in 1953 to less than 500 tons after 1956, and stayed low until 2000 (Hay and McCarter 2000, Ref. 210; Barner in Eulachon Research Council 2000, Ref. 145). Owing to marked population declines since the mid-1990s, some eulachon fisheries in British Columbia were closed in the late 1990s (Department of Fisheries and Oceans-Canada 1999, Ref. 122).

In Alaska, small commercial eulachon harvests occur in the Stikine, Unuk and Chickamin, and Bradfield river systems, at least in some years (Alaska Department of Fish and Game 2000, Ref. 11). In 1975 and 1976, 23,000-29,000 lbs of eulachon were harvested on the Stikine River, but in many other years no fish were harvested (Walker 2001, Ref. 434). Almost 35,000 lbs of eulachon were harvested from the Unuk and Chickamin rivers in 1984 and 10,000-28,000 lbs in some other years, but in some years no fish have been harvested and sometimes the runs appear to fail completely (Miller and Moffitt 1999, Ref. 312; Walker 2001, Ref. 434). A small commercial fishery opened on the Copper River in 1998 (Miller and Moffitt 1999, Ref. 312, Moffitt et al. 2002, Ref. 317). Subsistence and personal use fishing for eulachon is recorded in the Chilkat and Chilkoot rivers (Betts 1994, Ref. 64; Magdanz 1988, Ref. 278; Mills 1982, Ref. 313; Reeves 2001, Ref. 367), the Nass River (Nass means “food depot” in Tlingit; Hart and McHugh 1944, Ref. 192), the Bella Coola River (10-50 tons/year for most years between 1948 and 1983; Hay and McCarter 2000, Ref. 210), the Knight Inlet river systems (up to 100 tons/year in some years in the 1950s and 1960s; Hay and McCarter 2000, Ref. 210), and the Berners Bay river systems (M. F. Willson, pers. obs.). Another First Nation fishery operates in the Gardner Canal-Douglas Channel area. Traditional harvests also occurred in the Dean-Kimsquit-South Bentinck river systems (Pootlass and Siwallace in

Eulachon Research Council 2000, Ref. 145). Such use must occur in many other rivers as well, but this is not recorded in the references at hand. Sharp declines in many of the British Columbia eulachon runs in the 1990s has caused concern for both traditional uses and for conservation of eulachon (Hay and McCarter 2000, Ref. 210; Eulachon Research Council 2000, Ref. 145).

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Table 1. -- Eulachon spawning rivers. Not all rivers are used every year. See also Figures 1-4.

Alaska

Western -- **(**Lindsey and McPhail 1986, Ref. 273; S. Moffitt, Alaska Department of Fish and Game, pers. commun.; Miller and Moffitt 1999, Ref. 312; Moffitt et al. 2002, Ref. 317; B. H. Marston, Alaska Department of Fish and Game, pers. commun.):

Pribilof Islands (no specifics available)

Nushagak R. (Bristol Bay)

glacial river on Unimak Island (Urilla Bay)

King Salmon R. (Bristol Bay)

Meshik R., Sandy R., Bear R., Milky R. (Bristol Bay; western Alaska Peninsula)

Three Star R. (Gulf of Alaska)

Kametolook R. (Gulf of Alaska)

Southcentral -- (S. Moffitt, Alaska Department of Fish and Game, pers. commun.; Vincent-Lang and Queral 1984, Ref. 433; E. Spangler, United States Fish and Wildlife Service, pers. commun.):

Susitna R., Yentna R., Beluga R., Kenai R. (Cook Inlet)

Twentymile R., Portage Cr., Placer R., Chickaloon R., Virgin Cr. (Turnagain Arm)

Resurrection R. (Resurrection Bay); possibly also a stream in Harris Bay

Martin R., Alaganic Slough, Ibeck Slough, Eyak R., Scott R., Copper R. (Copper River Delta)

Pillar Cr., Kalsin R. (Kodiak Island)

Yakutat forelands and other outer coast -- (Catterson and Lucey 2002, Ref. 97; Womble 2003, Ref. 449; L. Sharman, Glacier Bay National Park, pers. commun.):

Lost R.

Situk R., Ahrnklin R., Tawah Cr.

Dangerous R., Italio R.
Akwe R.

Alsek R., Clear Cr.

Doame R. (possibly not any more)

Sea Otter Cr.

Fairweather Slough

Dixon R.

Southeast -- (Alaska Department of Fish and Game 2000, Ref. 11; Womble 2003, Ref. 449):

Adams Inlet (Glacier Bay)

Excursion R.

Endicott R.

Chilkat R.

Chilkoot R., Ferebee R. (Lutak Inlet)

Taiya R.

Skagway R.

Katzehin R.

Berners R., Lace R., Antler R. (Berners Bay)

Eagle R.

Mendenhall R.

Taku R.

Speel R.,Whiting R. (Port Snettisham)

Bradfield R.

Hulakon R., Grant Cr. (Bradfield Canal)

Stikine R.

Unuk R., Klahini R., Eulachon R. (Burroughs Bay)

Chickamin R.

Wilson R., Blossom R. (Smeaton Bay)

British Columbia -- (McPhail and Lindsey 1986, Ref. 305; Eulachon Research Council 2000, Ref. 145; Department of Fisheries and Oceans-Canada 1999, Ref. 122; Hay and McCarter 2000, Ref. 210 list some other rivers that may have spawning runs but are unconfirmed):

unnamed rivers on Haida G'waii

Stewart R.

Nass R.

Skeena R.

Kitimat R., Kildala R., Dala R., Giltoyees Inlet, Foch Lagoon (Douglas Channel)

Kitlope R., Kowesis R., Kemano R. (including Wahoo; Gardner Canal)
Kimsquit R., Kwatna R., Dean R., South Benttinck Arm (Dean Channel)

Bella Coola R., Paisla Cr., Taleomey (Burke Inlet)

Chuckwalla, Kilbella R., Oweekeno R. (= Owikeno,Whonnock, Wannock), Moses Inlet systems (not used by eulachon since 1940s according to Johnson and Hause in Eulachon Research Council 2000, Ref. 145; Rivers Inlet)

Kingcome R.

Klinaklini R., Franklin R. (Knight Inlet)

Kokish (Vancouver Is.)

Homathko R. (Bute Inlet)

Squamish R.

Fraser R.

Washington -- (Anonymous no date, Ref. 36; Washington Department of Fish and Game and Oregon Department of Fish and Game 2001, Ref. 437; Browning 1974, Ref. 89; DeLacy and Batts 1963b, Ref. 121):

Nooksack R.

Bogachiel R.

Queets R.

Quinalt R.

Moclips R.

Copalis R.

Humptulips R., Chehalis R., Aberdeen R., Wynoochie R. (Gray's Harbor)

North R., Nacelle R., Nemah R., Bear R., Willapa R. (Willapa Bay)

Columbia R. system, including Grays R., Skamokawa R., Cowlitz R., Kalama R., Lewis R., and others; Elochoman R.

Oregon -- (fish biologists of Oregon Department of Fish and Wildlife, pers. commun.; Anonymous 1991, Ref. 34):

Columbia R. system: Sandy R.

Yaquina R.

Ten Mile Cr. (near Yachats)

Siuslaw R., Umpqua R.

Tenmile Cr. (from lake system)

Coos R.

Coquille R.

Sixes R.

Elk R.

Euchre Cr.

Rogue R.

Hunter Cr.

Pistol R.

Chetco R.

Winchuck R.

California -- (Odemar 1964, Ref. 164; Jennings 1996, Ref. 230):

Klamath R.

Redwood Cr.

Mad R. (entered Humboldt Bay until about 2000 yrs ago; Jennings 1996, Ref. 230)

Jolly Giant Cr., Jacoby Cr. (Humboldt Bay)

Russian R.

Table 2a. -- Summary of eulachon body-size data for different river systems.

System	Measurement (mm)	Mean length (range)	Mass (g)	Reference
Yaquina Bay	fork	137 (Feb., n = 28)	--	L. Zumbrunnen, Oregon Dept. of Fish & Wildlife, pers. commun.
Winchester Bay	fork	123 (July, n = 18)	--	L. Zumbrunnen, pers. commun.
Coquille R.	fork	111 (Sept.; n = 20)	--	L. Zumbrunnen, pers. commun.
Columbia R.	?	150-185 (males); annual variation	--	Smith and Saalfeld 1955, Ref. 398
Fraser R.	standard	158-160 (140-200)*	--	Hart and McHugh 1944, Ref. 192
Fraser R.	fork	181±13.8 (males) 161±23.5 (females)	--	Higgins et al. 1987, Ref. 215
Kemano R.	fork	182 (unspawned)	45.6	Lewis et al. 2002, Ref. 269
Kitimat R.	standard	170 (females)	45	Pedersen et al. 1995, Ref. 351
Berners Bay	--	--	33	Marston et al. 2002, Ref. 280
Copper R.	standard	174-183	47-57	Moffitt et al. 2002, Ref. 317
Kalsin R.	?	175-214; most between 190-204	--	Blackburn et al. 1981, Ref. 71
Susitna R.	?	206-213 (1982, 1983)	72, 64	Barrett et al. 1984, Ref. 51
Gulf of Alaska	standard	155-178 (summer)	28-44	Anthony et al. 2000, Ref. 37

Meshik R.	fork	224	94	Warner and Shafford 1979, Ref. 436

*estimated from graph (see Hart and McHugh 1944, Ref. 192)

Table 2b. -- Body size of male eulachon from the Stikine River (Franzel and Nelson 1981, Ref. 154).*

Year	Age	Fork length (mm)		Mass (g)	
		range	mean	range	mean
1979	2	141-197	180	18-50	38
	3	165-210	190	28-60	46
	4	173-213	194	34-58	52
1980	2	155-179	172	30-42	35
	3	162-208	186	32-60	46
	4	195-208	201	52-64	58

*Franzel and Nelson state that 3-year-old Stikine River fish were larger than fish of the same age in the Columbia River, but also that age, fork length, and weight distributions in the Stikine River were similar to those in the Fraser and Columbia rivers.

Table 2c. -- Eulachon body size data (standard lengths; average and S. E.) from the Nass River for two years (Langer et al. (1977), Ref. 262).*

Age	Year	Male	Female
2	1971	155 mm (10.9)	144 mm (6.9)
3	1970	173 (11.3)	171 (16.2)
	1971	167 (16.2)	157 (16.2)
4	1970	179 (11.2)	181 (11.8)
	1971	174 (10.2)	171 (10.3)
5	1970	188 (6.1)	192 (3.5)
	1971	188 (19.8)	183 (11.3)

*Overall mean lengths for the Nass River eulachon samples were 161 mm in 1969, 177 mm in 1970, and 165 mm in 1971, with 1970 fish significantly larger than 1971 fish, and no significant differences between males and females (Langer et al. (1977), Ref. 262).

Table 2d. -- Fork lengths and body masses for eulachon in the Twentymile River (Spangler 2002, Ref. 401).

Gender	Length (mm)		Body mass (g)	
	mean, S. E.	range	mean, S. E.	range
Male, 2000	215.4 ± 0.9	166-242	69.9 ± 1.0	26.5-100
Male, 2001	209.1 ± 0.5	100-241	65.8 ± 0.5	6-106
Female, 2000	202.1 ± 3.0	143-324	60.0 ± 2.8	29-101
Female, 2001	202.5 ± 0.6	99-253	60.1 ± 0.5	28-122

Table 2e. -- Standard lengths and weights of eulachon from the Copper River, for four years (Moffitt et al. 2002, Ref. 317).*

Gender	Length (mm)		Weight (g)	
	mean (S. D.)	range	mean (S. D.)	range
Male, 1998	183 (8)	153-216	55 (8)	33-96
Male, 2000	175 (10)	146-208	47 (10)	24-83
Male, 2001	177 (10)	149-208	50 (9)	29-91
Male, 2002	183 (9)	153-222	57 (9)	31-94
Female, 1998	177 (9)	145-209	51 (9)	27-93
Female, 2000	170 (12)	137-204	44 (11)	22-83
Female, 2001	169 (11)	143-198	46 (9)	28-78
Female, 2002	178 (9)	151-203	52 (8)	35-92

*Males average longer and heavier than females in each year. There was annual variation in average size of both males and females.

Table 3. -- Fecundity of eulachon from different river systems.

Location	Number of eggs	Reference
Columbia R.	7,000-31,000	Parente and Snyder 1970, Ref. 348; Washington and Oregon Department of Fish and Wildlife 2001, Ref. 437
	20,000-60,000	Smith and Saalfeld 1955, Ref. 398
Fraser R.	20,000-40,000	Hart and McHugh 1944, Ref. 192
	8,000-55,000	Hay and McCarter 2000, Ref. 210
Kitimat R.	3,200-48,000 (mean 22,900)	Pedersen et al. 1995, Ref. 351
Kemano R.	6,700-57,000 (mean 27,900)	Pedersen et al. 1995, Ref. 351; Lewis et al. 2002, Ref. 269
Stikine R.	18,000-43,600	Franzel and Nelson 1981, Ref. 154
Copper R.	12,200-62,800	Moffitt et al. 2002, Ref. 317
Twentymile R.	8,500-67,500	Spangler 2002, Ref. 401
Meshik R.	3,400-57,000	Warner and Shafford 1979, Ref. 436

Table 4. -- Water temperature and incubation times of eulachon eggs in different river systems.

Temperature or ATU*	Incubation time	Location	Reference
6.5-9°C	~3 weeks	Columbia R.	Parente and Snyder 1970, Ref. 348
4-5°C	~4 weeks	Fraser R.	Hay and McCarter 2000, Ref. 210
4.4-7.2°C	30-40 days	Fraser R.?	Hart 1973 (Ref. 190) in Miller and Moffitt 1999, Ref. 312
235-340	50-73 days (50% hatch); annual variation	Kemano R.	Lewis et al. 2002, Ref. 269
~168-307	35-51 days (87% hatch)	Kitimat R.	Pedersen et al. 1995, Ref. 351
4-7°C	almost 6 weeks	Kitimat R.	Farara in Eulachon Research Council 2000, Ref. 145
370-387	19 days	hatchery	Smith and Saalfeld 1955, Ref. 398
~4.5-7°C	30-49 days	Cowlitz R., estimated	Smith and Saalfeld 1955, Ref. 398
349-389	--	hatchery	DeLacey and Batts 1963a, Ref. 120
~303	--	Twentymile R.	Spangler 2002, Ref. 401

* ATU = accumulated thermal units (= degree-days; 1 thermal unit = average temperature in degrees centigrade per 24 hours).

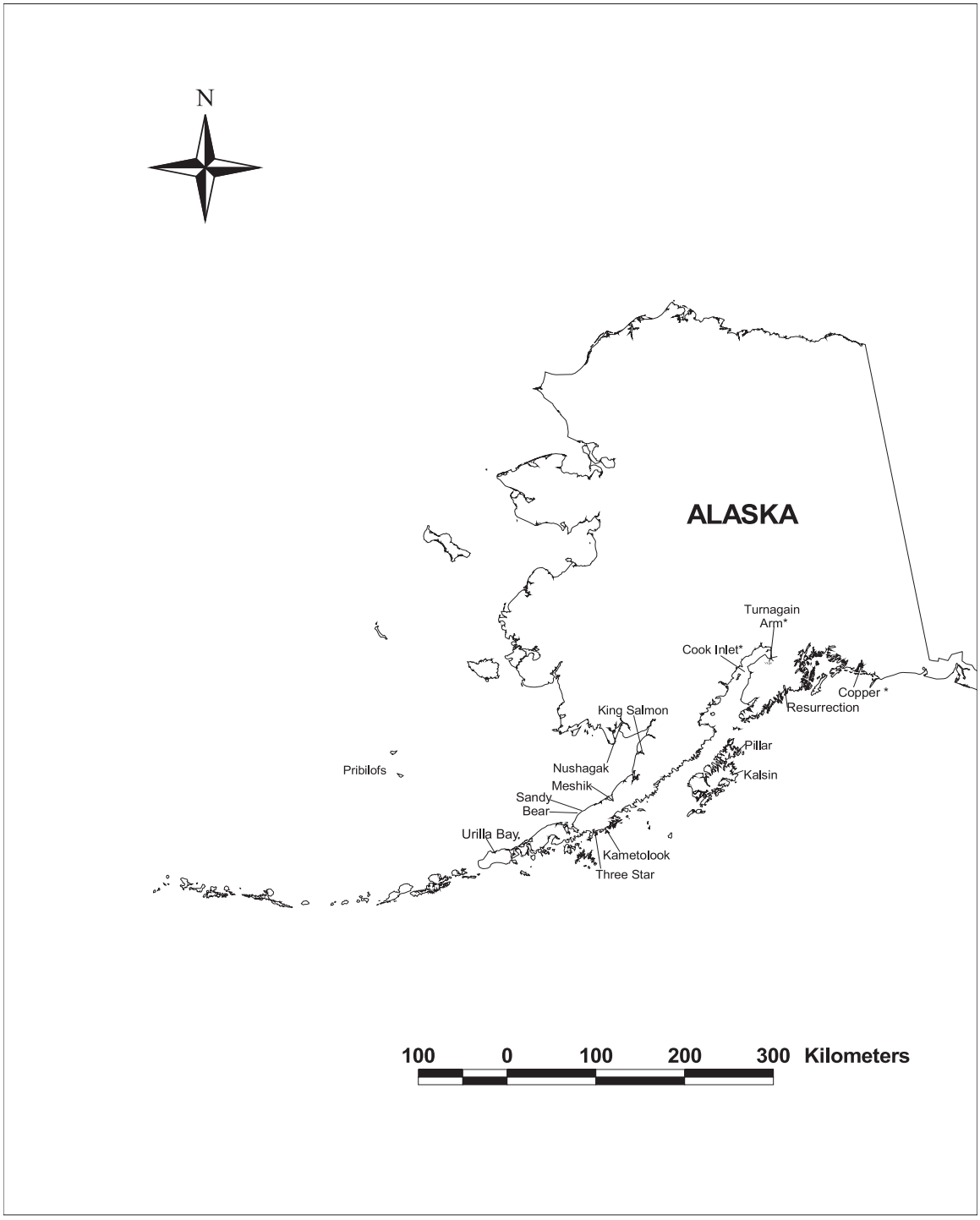

Figure 1. -- Eulachon spawning sites west of Cape Suckling in Alaska. Sites marked with an asterisk (*) have more than one stream that supported a eulachon run. See text.

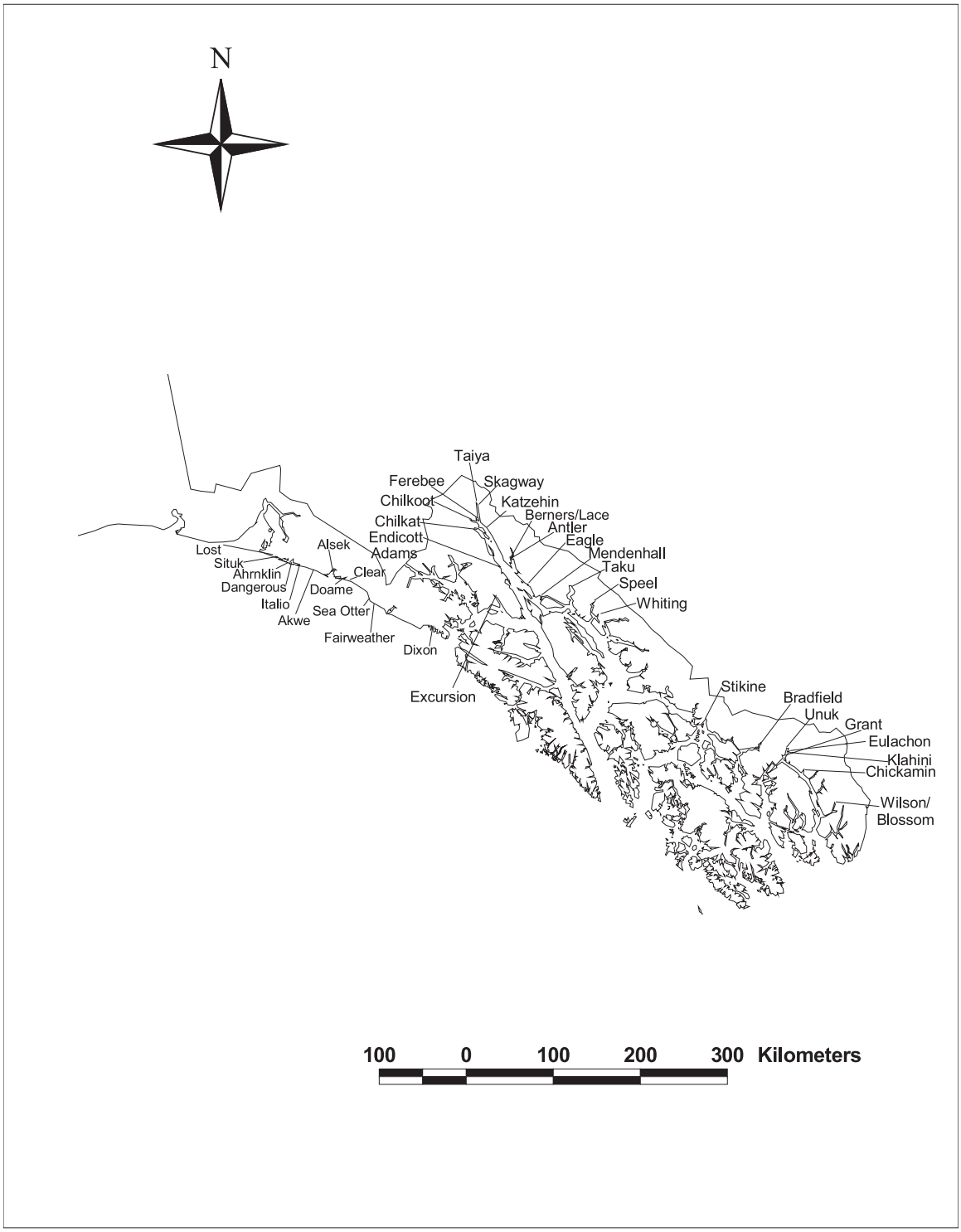

Figure 2. -- Eulachon spawning sites in Southeast Alaska (compiled by J. N. Womble).

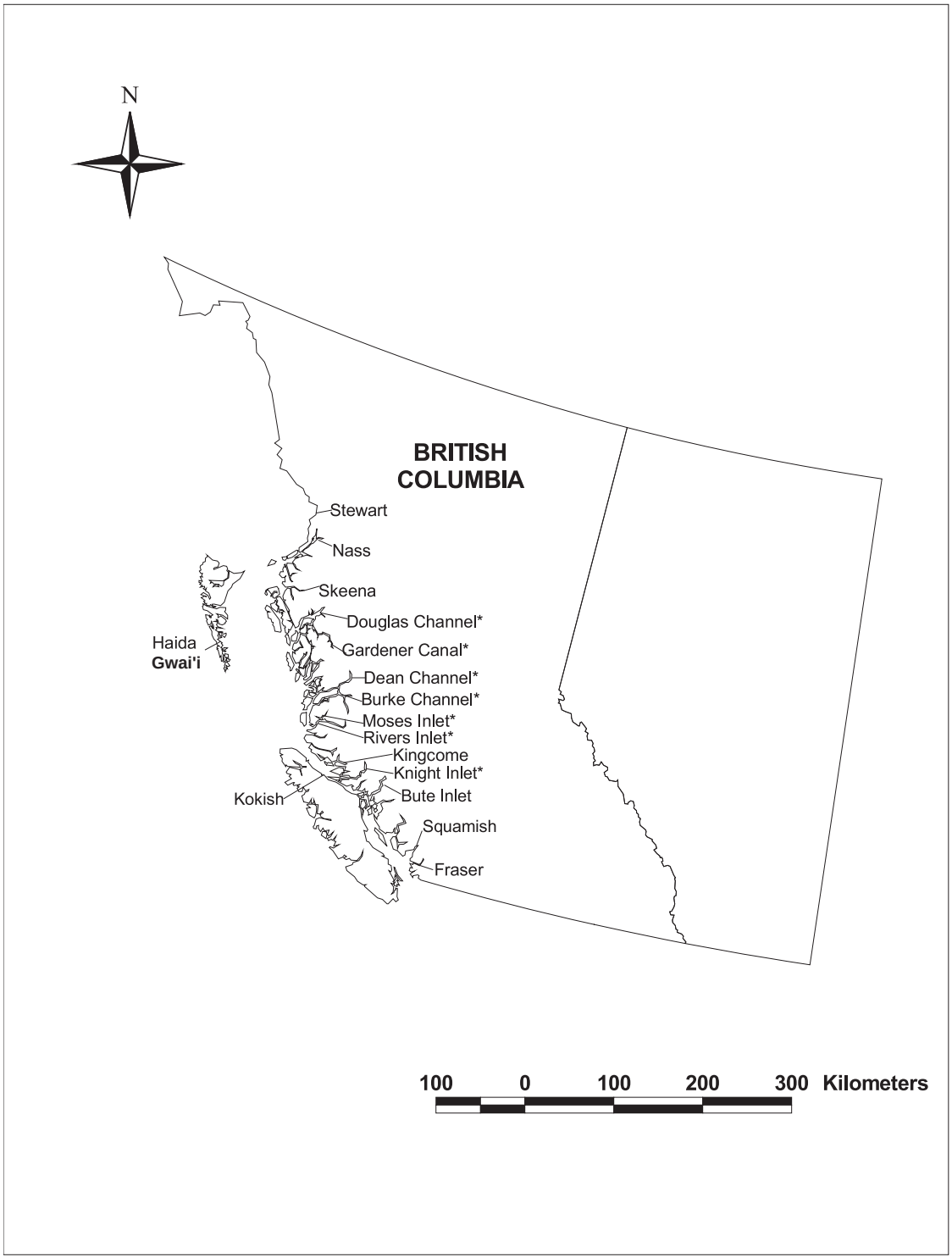

Figure 3. -- Eulachon spawning sites in British Columbia. Sites marked with an asterisk (*) have more than one stream that supported a eulachon run. See text.

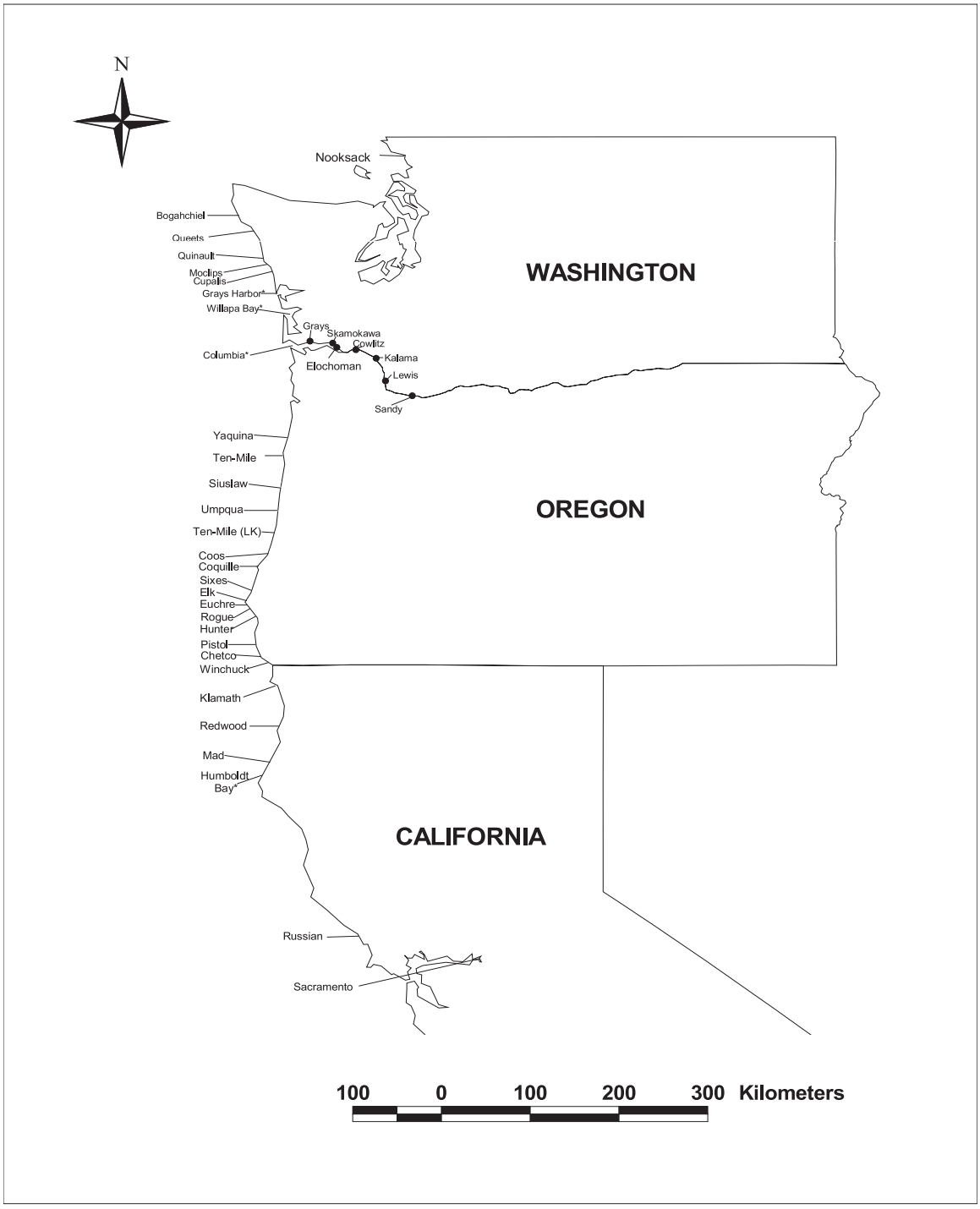

Figure 4. -- Eulachon spawning sites in Washington, Oregon, and California. Sites marked with an asterisk (*) have more than one stream that supported a eulachon run. See text.

Annotated Bibliography

INTRODUCTION

This bibliography contains more than 400 published and unpublished references on eulachon (*Thaleichthys pacificus*). The references are alphabetical by author and then by year of publication.

Abstracts and summaries are included for the references that we have reviewed and for those that were provided electronically by our data sources. Abstracts using the words of the original authors or electronic abstracting services are within quotation marks; abstracts not in quotation marks were written by the compilers of this bibliography.

For each reference we provide keywords. References associated with each keyword are listed by reference number in the keyword index. References we were not able to review personally may contain information on additional aspects of eulachon not mentioned in the index.

Web sites found to be active at the time this bibliography was compiled are listed in a separate section following the print references. Because the content of web sites changes frequently, we have not provided keywords or abstracts in this section.

DATA SOURCES

This annotated bibliography was compiled from a number of sources.

- We searched 63 online databases for references on eulachon. The most useful were Agricola, Alaska Statewide Databases, Aquatic Sciences and Fisheries

Abstracts, Article First, Basic Biosis, Biological Sciences, Biology Digest, Cambridge Scientific, Conference Papers Index, Dissertations, Environmental Sciences and Pollution Mgmt, Graylit, and World Cat.

- We searched the World Wide Web for references on eulachon.
- We also searched the literature cited sections of all the reports that we received via interlibrary loan and from others. This method turned up a surprising number of references on eulachon not picked up by the various databases.

Three other sources were particularly helpful: Jamie Womble had obtained a number of references for her master's thesis on Steller sea lions and eulachon, and she kindly loaned these to us for review. The bibliography of the smelt family by Gruchy and McAllister (1972) suggested a number of references on eulachon, particularly older ones. The report on the Biology of the Nass River Eulachon (Langer et al. (1977)) included an annotated bibliography, from which we included, with credit, a few annotative notes we thought might prove useful. We also thank Andrew Eller who provided a number of references.

FORMAT

This bibliography was compiled using ProCite version 5 from ISI Researchsoft, then output into Microsoft Word 2002.

BIBLIOGRAPHY

1. Ackman, R. G., Addison, R. F., and Eaton, C. A. 1968. Unusual occurrence of squalene in a fish, eulachon, *Thaleichthys pacificus*. Nature 220:1033-34.

Keywords: British Columbia, Barclay Sound, contaminants, lipid content, squalene

Abstract: The authors found significant amounts of squaline in eulachon and concluded that it is a normal major component in eulachon lipids, although it is seldom found in teleost fishes.

2. Alaska Department of Fish and Game. 1966. Inventory and cataloging of sport fish and sport fish waters in the Cook Inlet Drainage. (11-A):169-82.

Keywords: Alaska, Cook Inlet

3. Alaska Department of Fish and Game. 1973. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna River and Central Cook Inlet drainages. (14):53-54, 66-71.

Keywords: Alaska, Cook Inlet, Susitna River

4. Alaska Department of Fish and Game. 1974. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna River and Central Cook Inlet drainages. (15):161-62, 170-72.

Keywords: Alaska, Cook Inlet, Susitna River

5. Alaska Department of Fish and Game. 1976. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna River and Central Cook Inlet drainages. (17):131-32, 139, 147.

Keywords: Alaska, Cook Inlet, Susitna River

6. Alaska Department of Fish and Game. 1977. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna River and Central Cook Inlet drainages. (18):27-30, 37-38, 50.

Keywords: Alaska, Cook Inlet, Susitna River

7. Alaska Department of Fish and Game. 1978. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna River and Central Cook Inlet drainages. (19):47-71.

Keywords: Alaska, Cook Inlet, Susitna River

8. Alaska Department of Fish and Game. 1983a. Aquatic habitat and instream flow studies, 1982. Vol. 4 of Phase II basic data report. Susitna Hydro Aquatic Studies Program. Anchorage.

Keywords: Alaska, Susitna River, habitat

9. Alaska Department of Fish and Game. 1983b. Adult anadromous fish studies, 1982. Vol. 2 of Phase II final report. Susitna Hydro Aquatic Studies Program. Anchorage.

Keywords: Alaska, Susitna River

10. Alaska Department of Fish and Game. 1992. Community Profile Database, Vol. 1, Southeast Region. Juneau: Division of Subsistence.

Keywords: Southeast Alaska, fisheries, subsistence

11. Alaska Department of Fish and Game. 2000. Unuk, Chickamin, Bradfield and Stikine Rivers 2000 smelt fishery. Juneau: Commercial Fisheries Division news release, March 2.

Keywords: Southeast Alaska, Chickamin River, Bradfield River, Stikine River, Unuk River, distribution, geographic, fisheries (commercial), management

12. Alaska Department of Transportation and Public Facilities. 1990. Haines Airport Eulachon Study 1990: Final Report. Juneau.

Keywords: Alaska, Chilkat River

13. Allen, M. J., and Smith, G. B. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, U.S. Department of Commerce, NOAA Technical Report NMFS 66. 151 p.

Keywords: Alaska, Bering Sea, Pacific Ocean, zoogeography

14. Allyn, R. 1951. A dictionary of fishes. St. Petersburg, FL: The Great Outdoors Association.

Keywords: general references on fish, illustrations

Abstract: Note from Gruchy and McAllister 1972: “illustrations and notes on importance.”

15. Altman, P. L., and Dittmer, D. S. 1962. Growth: Including reproduction and morphological development. Biological Handbook Series. Washington, D.C.: Federation of American Societies for Experimental Biology. 608 p.

Keywords: spawning

Abstract: Note from Gruchy and McAllister 1972: “propagation data for --4 sp.”

16. Ambrose, S. E. 1996. Undaunted courage, p. 329. New York: Touchstone.

Keywords: Columbia River, historical

17. Anderson, P. J., Blackburn, J. E., and Johnson, B. A. 1997. Declines of forage species in the Gulf of Alaska, 1972-1995, as an indicator of regime shift. *In* Forage fishes in marine ecosystems, p. 531-543. Proceedings of the Wakefield Fisheries Symposium, Alaska Sea Grant College Program 97-01. Fairbanks: University of Alaska.

Keywords: Alaska, Gulf of Alaska, population status

18. Anderson, P. J., and Piatt, J. F. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Marine Ecology Progress Series 189:117-23.

Keywords: Alaska, Gulf of Alaska, abundance, seasonal variation

Abstract: This report presents the catch per unit of effort in small-mesh trawl surveys for eulachon from 1973 to 1997 in the Gulf of Alaska.

19. Andriashev, A. P. 1939. An outline of the zoogeography and origin of the fish fauna of the Bering Sea and neighbouring waters [in Russian]. Iznadie Leningrad Gosudavst. University of Leningrad. 187 p.

Keywords: Alaska, Bering Sea, zoogeography

20. Andriashev, A. P. [1937] 1955. A contribution to the knowledge of the fishes from the Bering and Chukchi Seas. Explorat. Mers URSS. 25, Inst. Hydrobiol. Leningrad:292-255. Trans. L. Lanz, and N. J. Willimovsky. U.S. Fish and Wildlife Service Spec. Sci. Rep. Fish No. 145.

Keywords: Alaska, Bering Sea

21. Anonymous. 1865. The lamp fish. All the Year Round (March 23):199-201.

Keywords: historical population status, subsistence

Abstract: Note from Langer et al. (1977): “Good review of early native fishing and rendering methods; also notes extinction of southerly runs.”

22. Anonymous. 1879. Der kerzenfisch. Natur. N. Ser. 5:182.

Keywords: historical population status

23. Anonymous. 1931. The smelt fishery. *In* Canadian Fisheries Manual, p. 87.

Keywords: Canada, historical population status

24. Anonymous. 1932. Smelt menace commercial fishing. Fisherman 1(3):10.

Keywords: historical population status

25. Anonymous. 1933. Smelt laws liberalized. Fisherman 2(8):12.

Keywords: historical population status

26. Anonymous. 1934a. The fisheries of Canada. *In* Canadian Fisheries Manual, p. 27-51.

Keywords: Canada, historical population status

27. Anonymous. 1934b. Smelt provide livelihood. Fisherman 3(1):16.

Keywords: historical population status

28. Anonymous. 1953. When Kitimat was a eulachon village. Western Fish. Per. (January):38.

Keywords: British Columbia, Kitimat, fisheries (subsistence), historical population status, subsistence

Abstract: Note from Langer et al. (1977): “Popular general account of eulachons.”

29. Anonymous. 1955. Wash tubs, dip nets, lanterns and fish. Conservation 24(2):30.

Keywords: historical fisheries, subsistence

30. Anonymous. 1967. Eulachon, anchovy and pilchard. Fisheries of Canada Vol. 19 No. 10:14-15.

Keywords: Canada, fisheries, population status

31. Anonymous. 1969. Smelts expand into coastal streams. Headlight Herald, Tillamook Oregon. April 24.

Keywords: Oregon, distribution, geographic, population status

Abstract: Note from Langer et al. (1977): "Report of eulachon spawning in small coastal streams."

32. Anonymous. 1970. Offshore herring survey. News item memo, Fisheries Research Board of Canada Biological Station.

Keywords: Canada, distribution, geographic, population status

Abstract: Note in Langer et al. (1977): "Eulachons caught in low numbers to Queen Charlotte Sound."

33. Anonymous. 1981. Kleena. Videocassette (VHS). Vancouver, B.C.: Macubah Productions. Distributed by Image Media Services. 20 min.

Keywords: British Columbia, subsistence

Abstract: "An actual trip from Alert Bay, B.C. of a small group of Kwakiutl Indians to catch and render eulachon (oolichan) to grease (Kleena) on hereditary eulachon fishing grounds."

34. Anonymous. 1991. Eulachon (*Thaleichthys pacificus*). *In* Distribution and abundance of fishes and invertebrates in west coast estuaries, p. 178-180. Vol. 2: Species life history summaries. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA's Estuarine Living Marine Resources

Program.

Keywords: distribution, geographic, life history

35. Anonymous. 1993. Nisga'a: People of the Nass River. H. MacDonald Printing. Canada: Douglas and McIntyre Ltd.

Keywords: Canada, Nass River, subsistence

36. Anonymous. [no date]. List of names for eulachon—source not known—1-10-96.

Abstract: "Hooligan (*Thaleichthys pacificus*). Other names eulachon, hoolakan, hoolikan, olachan, ollachan, oolachan, oolichin, oulachan, oulachon, oulacon, ulchen, ulichan, uthlecan, yshuh, swavie, chucka, candle fish, fathom fish, small fish, salvation fish (Hart, J. L., and J.L. McHugh 1944), Saak, (Betts, M. 1994)."

37. Anthony, J. A., Roby, D. D., and Turco, K. R. 2000. Lipid content and energy density of forage fishes from the northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology 248:53-78.

Keywords: Alaska, Gulf of Alaska, AFLDM, energy density, length, lipid content, proximate composition

Abstract: "Piscivorous predators can experience multi-fold differences in energy intake rates based solely on the types of fishes consumed. We estimated energy density of 1151 fish from 39 species by proximate analysis of lipid, water, ash-free lean dry matter, and ash contents and evaluated factors contributing to variation in composition. Lipid content was the primary determinant of energy density, ranging from 2 to 61% dry mass and resulting in a five-fold difference in energy density of individuals (2.0-10.8 kJg^{-1} wet mass). Energy density varied widely within and between species. Schooling pelagic fishes had relatively high

or low values, whereas nearshore demersal fishes were intermediate. Pelagic species maturing at a smaller size had higher and more variable energy density than pelagic or nearshore species maturing larger. High-lipid fishes had less water and more protein than low-lipid fishes. In some forage fishes, size, month, reproductive status, or location contributed significantly to intraspecific variation in energy density. Differences in quality are sufficient to potentially affect diet selection of breeding seabirds, especially when transporting food for their young to the nest site."

38. Aplin, J. A. 1949. Whitebait. California Department of Fish and Game Fishery Bulletin 74:142-44.

    Keywords: California, fisheries (subsistence), historical

    Notes: cited in Gruchy and McAllister; demand, catch, Indian fishing methods of osmerids

39. Arndt, K. L., Sackett, R. H., and Ketz, J. A. 1987. A cultural resource overview of the Tongass National Forest, Alaska. Part 1: Overview. Juneau: U.S. Department of Agriculture, Forest Service, Tongass National Forest.

    Keywords: Alaska, Southeast, subsistence

40. Bailey, B. E. 1952. Marine oils, with special reference to those of Canada. Fisheries Research Board of Canada Bulletin No. 89:1-413

    Keywords: Canada, oil, vitamins

    Abstract: Note from Langer et al. (1977): "p. 346 gives characteristics of eulachon oil, and notes por vitamin A and D content, in spite of claims of its medicianal properties."

41. Bargmann, G. 1998. Columbia River eulachon fact sheet 1998. Presented at Eulachon Research Council March 1998 meeting. 2 p.

Keywords: Columbia River

42. Barner, L. W., Taylor, F. H. C., Bennett, D. M. A., and Thompson, J. M. 1979. Midwater and bottom trawl tows and catches made by M/V *Nemesis* No. 78-1, July 5-23, 1978, in Dixon Entrance. Edited by N. Balch, T. Amaratunga, and R. K. O'Dor. Fisheries and Marine Service (Canada) Data Report No. 135. Nanaimo, B.C.: Pacific Biological Station.

Keywords: British Columbia, distribution, geographic, length, sex ratio

Abstract: "This report gives the midwater and bottom trawl catches, fishing positions and biological sampling data obtained during the M/V *Nemesis* cruise. The tows were made to identify the species encountered during an acoustical survey. The survey was made to determine the distribution and abundance of fish within the area. Sex and length data were obtained for *Oncorhynchus tshawytscha*, *Squalus acanthias*, *Thaleichthys pacificus*, *Hippoglossus stenolepis*, *Ophiodon elongatus*, *Gadus macrocephalus*, *Theragra chalcogramma*, *Anoplopoma fimbria*, Pleuronectidae and *Sebastes*."

43. Barnett, H. G. 1955. The Coast Salish of British Columbia. Eugene: University of Oregon Press.

Keywords: British Columbia, subsistence

44. Barnhart, R. A., Boyd, M. J., and Pequegnat, J. E. 1992. The ecology of Humboldt Bay, California: An estuarine profile. U.S. Fish and Wildlife Service Biological

Report No. 1.

Keywords: California, Humboldt Bay

45. Barraclough, W. E. 1964. Contribution to the marine life history of the eulachon *Thaleichthys pacificus*. Journal of the Fisheries Research Board of Canada 21(5):1333-1337.

Keywords: British Columbia, age at spawning, food and feeding habits, illustrations, larvae, length, spawning

Abstract: "Of particular interest is the coastal distribution of juvenile eulachon during their first 2 years of life in the sea. The wide distribution of eulachon in their first year of life in the Strait of Georgia is probably the result of the dispersion of larvae from the Fraser River by the general counterclockwise circulation of water in the Strait. The occurrence of larval fish (23 mm fork length) off Race Rocks in April may be attributed to the rapid spring flushing of the newly hatched larvae from the Fraser River, and their direct transport by the surface water runoff across the Strait of Georgia. Evidence of this rapid flushing is seen in the lower salinities in the surface layer in the southern Strait of Georgia during the spring season (Anonymous, 1946-1960; Hollister, MS, 1960-63). The capture of larval and juvenile eulachon in the echo scattering layers in coastal waters at various seasons of the year suggests that they spend a considerable portion of their first 2 years of life in the sea in these food-rich zones. The stomachs of juveniles were found to contain chiefly euphausiids which are very abundant in these echo scattering layers."

46. Barraclough, W. E. 1967a. Data record: Number, size, and food of larval and juvenile fish caught with a two boat surface trawl in the Strait of Georgia April 25-29, 1966. Fisheries Research Board of Canada. Manuscript Report Ser. No. 922.

Keywords: British Columbia, Fraser River, food and feeding habits, larvae

Abstract: Note from Langer et al. (1977): "Total of 18 eulachons caught off Fraser River; stomach contents included copepods, copepod eggs, and sand grains."

47. Barraclough, W. E. 1967b. Data record: Number, size and food of larval and juvenile fish caught with an Issacs-Kidd trawl in the surface waters of the Strait of Georgia, April 25-29, 1966. Fisheries Research Board of Canada. Manuscript Report Ser. No. 926.

Keywords: British Columbia, Fraser River, food and feeding habits, larvae

Abstract: Note from Langer et al. (1977): "Total of 6 eulachons caught off Fraser River; one had eaten copepods, the rest were empty."

48. Barraclough, W. E. 1967c. Data record: Number, size composition, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, June 6-8, 1966. Fisheries Research Board of Canada. Manuscript Report Ser. No. 928.

Keywords: British Columbia, Strait of Georgia, food and feeding habits, larvae

Abstract: Note from Langer et al. (1977): "Several thousand eulachons (mainly larva) caught; stomach contents included phytoplankton, copepods and eggs, cladocerans, trematode parasites, and smaller eulachons. Pacific sandlance, and chinook, sockeye, and chum salmon noted as predators of eulachons."

49. Barraclough, W. E., and Fulton, J. D. 1967. Data record: Number, size composition, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, July 4-8, 1966. Fisheries Research Board of Canada. Manuscript Report Ser. No. 940.

Keywords: British Columbia, Strait of Georgia, food and feeding habits, larvae

Abstract: Note from Langer et al. (1977): "Total of 218 eulachons caught; feeding on copepods, phytoplankton."

50. Barraclough, W. E., Robinson, D. G., and Fulton, J. D. 1968. Data record: Number, size composition, weight, and food of larval and juvenile fish caught with a two-boat surface trawl in Saanich Inlet, April 23-July 21, 1968. Fisheries Research Board of Canada. Manuscript Report Ser. No. 1004.

Keywords: British Columbia, Saanich Inlet, food and feeding habits, predators (fish)

Abstract: Note from Langer et al. (1977): "Total of 994 eulachons; only copepods in stomachs. Predators of eulachons included sockeye, pink, and chum salmon, and sticklebacks."

51. Barrett, B. M., Thompson, F. M., and Wick, S. N. 1984. Adult anadromous fish investigations: May-October 1983. Susitna Hydro Aquatic Studies, report No. 1. APA Document No. 1450. Anchorage: Alaska Department of Fish and Game.

Keywords: Alaska, Susitna River, abundance, age at spawning, fisheries (sport), length, migration, run timing, sex ratio, spawning, weight

Abstract: "For the last two years (1982-83), two eulachon migrations have entered the Susitna River. In 1982 the first migration passed through the intertidal reach

(RM 0-7) after ice breakup, in late May (5, 16-30). A second migration followed in early June (6, 1-8). In 1983, the first migration occurred in mid May (5, 10-17) followed by a second migration in mid May and early June (5, 19-6, 6)."

"In 1982 eulachon entered the Susitna River at a river temperature range of 2 degrees to 10 degrees C and in 1983, 3 degrees to 11 degrees C. This is similar to the 2 degrees to 10 degrees C temperature range of the Columbia River (Washington) when eulachon enter that system (Smith and Saalfeld, 1955). No correlation was found between daily fluctuations in Susitna River temperature or Cook Inlet high tide level and eulachon abundance in the intertidal reach (RM 0-7)."

"The upper distance of eulachon migration in the Susitna River was about 50 miles in 1982 and 1983. The first migration reached RM 40.5 in 1982 and RM 28.5 in 1983. The second migration reached RM 48.5 and 50.5 in 1982 and 1983, respectively. The largest concentrations of first and second migration eulachon in both years remained in the initial 29 miles of the Susitna River main channel."

"Eulachon started spawning in the Susitna River main channel within about five days of entering the river in 1982 and 1983. First migration fish spawned in 1982 between May 21 and 31 and in 1983, between May 15 and 22. Second migration eulachon spawned in 1982 between June 4 and 9 and in 1983, between May 23 and June 5."

"In 1982 and 1983, first and second migration eulachon generally spawned in the same habitat type in the Susitna River main channel. In both years major spawning occurred near cut banks and riffle areas with loose sand and gravel

substrate and moderate water velocity (approximately 1.5 ft/sec)."

"Water temperatures were colder in the Susitna River when first and second migration eulachon spawned in 1982 as compared to 1983. First migration fish spawned at temperatures averaging 5.8 degrees C (1982) and 7.3 degrees C (1983). Temperatures averaged 7.5 degrees C (1982) and 8.3 degrees C (1983) when the second migration spawned."

"In 1982 and 1983, eulachon did not spawn in clear water tributaries or sloughs associated with the Susitna River. Spawning occurred in both years in the glacial Yentna River tributary but the extent was not determined."

"Eulachon age, length and weight data were collected in 1982 and 1983. The two eulachon migrations in both years were comprised mainly of three year old fish (80-90%). Overall the eulachon were larger in 1982 as compared to 1983. The average fish length in 1982 for combined first and second migration eulachon was 213 mm and in 1983, 206 mm. Average fish weight in 1982 was 72 g and in 1983, 64 g."

"In both years (1982-83) male eulachon ripened earlier and remained in spawning condition longer than females. Also, they lived longer. In 1982 the average pre-spawning condition male to female ratio was 1.6:1 in the first migration and 1.3:1 in the second migration. In 1983 the respective ratios were 1.2:1 and 0.6:1. These ratios were dissimilar to the male to female spawning and post-spawning condition ratios which were biased toward males due to female eulachon having a shorter stream life."

"The Susitna River eulachon population supported a limited sport fishery in both

years (1982-83). The 1982 harvest was in the range of 3,000 to 5,000 fish and in 1983, 500 to 2,000 fish."

"In 1982 and 1983 the Susitna River escapement of first migration eulachon was in the range of several hundred thousand fish. The second migration escapement was in the range of several million eulachon in both years."

52. Bartlett, L. 1994. Eulachon. Wildlife Notebook Series, Alaska Department of Fish and Game.

Keywords: Alaska

53. Beach, R. J., Geiger, A. C., Jeffries, S. J., Treacy, S. D., and Troutman, B. L. 1985. Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980-82. Final report to the National Oceanic and Atmospheric Administration, National Marine Mammal Laboratory, Seattle, in fulfillment of requirements for NOAA, NMFS Grant No. 80-ADB-0012.

Keywords: Columbia River, fisheries (commercial), predators (mammals)

54. Beak Consultants. 1983. Analysis of the potential impacts of hydroelectric development of the Stikine River system in Alaska. Addenda on eulachon spawning. Prepared for B.C. Hydro, Vancouver, B.C.

Keywords: Alaska, Stikine River, spawning

55. Beak Consultants. 1991. Fish tainting potential of Eurocan effluent in the Kitimat River, British Columbia. Report prepared for Eurocan Pulp and Paper Co., Kitimat, British Columbia. Beak References: 2623.1. 31 p.

Keywords: British Columbia, Kitimat River, water pollution effects

56. Beak Consultants. 1998. 1998 eulachon tainting evaluation. A report prepared for Eurocan Pulp and Paper Co., Kitimat, British Columbia. Brampton, Ontario, Canada: Beak International, Incorporated.

Keywords: British Columbia, Kitimat River, water pollution effects

57. Beamish, R. J., and Bouillon, D. R. 1995. Marine fish production trends off the Pacific coast of Canada and the United States. *In* Climate change and northern fish populations, p. 585-591. Edited by R. J. Beamish. Canadian Special Publications, Fisheries and Aquatic Sciences No. 121.

Keywords: Pacific Ocean, population status

58. Begley, S. 1999. Drama in an untamed ecosystem. National Wildlife. April, May 37(3):18.

Keywords: Alaska, Copper River, predators (birds)

Abstract: "Eagles are attracted to the Copper River Delta by huge runs of little schooling fish called eulachon (pronounced 'hooligan')."

59. Berry, M. 1996a. Eulachon research on the Kingcome and Wannock Rivers. Final report to the Science Council of British Columbia (SCBC #FR 96, 97-715). 62 p.

Keywords: British Columbia, Kingcome River, Wannock River

60. Berry, M. 1996b. Meeting of the British Columbia Eulachon Research Council minutes, November 6.

Keywords: British Columbia

61. Berry, M. D. 1996. Knight Inlet-Klinaklini R. eulachons—1995. Draft report submitted for the Tanakteuk First Nation, Alert Bay, BC. 17 p.

Keywords: British Columbia, Klinaklini River, Knight Inlet

62. Betts, M. 1990. Chilkat and Chilkoot Rivers subsistence eulachon harvest, May 1990: Interim Report. Douglas, AK: Alaska Department of Fish and Game, Division of Subsistence.

Keywords: Alaska, Chilkat River, Chilkoot River, fisheries (subsistence)

63. Betts, M. F. 1994. The subsistence hooligan fishery of the Chilkat and Chilkoot Rivers. Technical Paper No. 213. Juneau: Alaska Department of Fish and Game, Division of Subsistence. 69 p.

Keywords: Alaska, Chilkat River, Chilkoot River, historical, run timing, subsistence

Abstract: “This report presents the findings of an ethnographic study of the subsistence hooligan fishery of the Chilkat and Chilkoot rivers in southeast Alaska. Research was initiated to address local concern over perceived low hooligan stocks and potential impacts of Haines airport construction on Chilkat River hooligan subsistence fishing. The study, which took place in 1990 and 1991, had two primary goals. The first was to document contemporary fishing patterns on the rivers, including cultural context and traditional knowledge, timing of harvest, means and methods of harvest and processing, locations of harvest and processing, organization of labor, and exchange and distribution patterns. A second purpose was to examine conditions that lead [sic] to changes in the fishery, particularly in harvest and processing locations over time, as access to traditional hooligan camps declined and strength of the stocks and migration patterns fluctuated.”

“The study found that the contemporary hooligan fishery was conducted primarily

by the Chilkat (Jilka'at) and Chilkoot (Lkoot) Tlingits of Klukwan and Haines. They fished largely in order to produce oil for distribution and exchange. The fishery was grounded in Tlingit cultural mythology and world view. Locations of fishing and processing were organized by clan affiliation. In addition, certain adaptations have occurred. People have adopted new tools of production and organized labor to fit contemporary family and household structures. Geographic adjustments have been made to accommodate reduced processing areas as well. Local participants have had to shift processing to fewer site locations as development and privatization of land have increased in the area over the 20th century."

"In practice, the fishery primarily is regulated by local rules developed by the Tlingit harvesters, rather than by external state or federal regulations. The success of these local management rules in the midst of state and federal management programs is due in part to the cultural cohesion of the participants, and to the presence of a single use (subsistence), rather than multiple uses (such as commercial and recreational uses) of the Chilkat and Chilkoot hooligan stocks."

64. Beverton, R. J. H. 1990. Small marine pelagic fish and the threat of fishing: Are they endangered? Journal of Fish Biology 37(A):5-16.

Keywords: population status

65. Bigg, M. A. 1985. Sighting and kill data of Steller sea lions (*Eumetopias jubatus*) and California sea lions (*Zalophus californianus*) from British Columbia during 1892-1982, with some records from Washington and southeastern Alaska. Canadian

Data Report, Fisheries and Aquatic Sciences No. 460.

Keywords: historical, predators (mammals)

66. Bigg, M. A. 1988. Status of the Steller Sea Lion, *Eumetopias jubatus*, in Canada. Canadian Field-Naturalist 102(2):315-36.

Keywords: British Columbia, Fraser River, predators (mammals)

Abstract: "A unique local movement schedule for up to at least 60 individuals was recorded during 1978 to 1982 at Sand Heads near the mouth of the Fraser River. Fishery officers and lighthouse keepers reported that Steller Sea Lions arrived in mid-March, reached a peak in numbers in late April-early May, and left by late May. The species visited the site apparently to feed mainly on Eulachon (*Thaleichthys pacificus*) that spawn in the river at this time. Fishery officers also noted that the species entered numerous long inlets throughout the mainland coast of British Columbia during February-April to feed on spawning Pacific Herring (*Clupea harengus pallasi*) and Eulachon (Bigg 1984)."

67. Birtwell, I. K., Levings, C. D., Macdonald, J. S., and Rogers, I. H. 1988. A review of fish habitat issues in the Fraser River system. Water Pollution Research Journal of Canada 23:1-30.

Keywords: British Columbia, Fraser River, contaminants

Abstract: "In 1986 and 1988, we examined eulachons (*Thaleichthys pacificus*) migrating through the Fraser River estuary to their spawning reaches. Organic contaminants were generally in higher concentrations in those fish which were captured after passage through the estuary than in those captured at the river mouth (DFO, unpublished information). The significance of the uptake of

contaminants is unknown, but exposure to wastes from the GVRD [Greater Vancouver Regional District] may well affect fish survival."

68. Bishop, D. M. 1982. A report on water temperature of West Creek and Taiya River and possible effects of West Creek Hydroelectric Project on existing eulachon runs in Taiya River. Juneau: ENVIRONAID.

Keywords: Alaska, Taiya River, water temperature

69. Bishop, D. M., Carstensen, R. L., and Bishop, G. H. 1989a. A report on environmental studies concerning the proposed Haines airport reconstruction. ENVIRONAID consultants report to Alaska Department of Transportation and Public Facilities. Juneau.

Keywords: Alaska, Chilkat River, spawning, subsistence

Abstract: "Eulachon are reported to take one month for hatching, after which they outmigrate almost immediately. As spawning peaks May 15, eulachon larvae probably outmigrate around June 15. A late February run of eulachon up the Chilkat River was documented in 1882 by A. Krause, who perfectly described the fish. Austin Hammond, in a recent interview mentioned, without prompting, that in his lifetime eulachon used to migrate in February, March on both Chilkat and Chilkoot Rivers. It is not known if this is/was a different stock that has been reduced or if the timing of the run has changed."

"Eulachon fishing and historical use: Eulachon, an anadromous species, spawn and are harvested in the lower Chilkat River. The eulachon enter the river in late May; fishers are alerted to the beginning of the run by increased bird activity. Fish are harvested by dip net from points where the main channel is adjacent to the

shore. They are then rendered for oil, smoked or frozen to eat whole. Eulachon oil is also an important trade item between the Chilkat Tlingit with Tlingits of the rest of Southeast Alaska with whom it is traded for other traditional products such as seaweed or seal oil."

"Harvest of eulachon continues to the present with the primary site being at Four-Mile Point. Few fish are caught at the Doc Point camp. In 1988, Chilkat eulachon did not show up well at Four-Mile Point; birds were seen on the south side of the river and some people had good luck fishing on that side. There seems to be the trend of eulachon changing to the south side for the past four years (Austin Hammond, personal communication). This may be associated with uplift occurring in the Airport and Sawmill Wetlands, with the result of gradual shifting in channel locations. Furthermore there is a trend of desertion of upriver camps which could be accounted for by uplift processes pushing the river mouth seaward. The magnitude of eulachon runs, past or present has never been quantified."

70. Bishop, D. M., Carstensen, R. L., and Bishop, G. H. 1989b. Report on environmental studies concerning the proposed Haines airport reconstruction: [Revision of Section A, Hydrology], second phase. ENVIRONAID consultants report to Alaska Department of Transportation and Public Facilities. Juneau.

Keywords: Alaska, Chilkat River, predators (birds), run timing, sex ratio, subsistence

Abstract: "ENVIRONAID work indicated that eulachon harvest on the Chilkat River traditionally occurred from 4 to 9-mile Haines Highway but that in recent

years harvest had occurred primarily at 4-mile point with little use of upriver sites. The eulachon abundance was low in 1988 and several Haines fishers thought that eulachon were shifting to the other side of the river (from observations of gull distribution). An examination of Klukwan subsistence harvest of Eulachon for the years 1982, 1987 and 1988, presented in Table 8 appears to indicate a relatively stable harvest. How this relates to fish abundance is uncertain as effort information is unavailable."

"The 1989 Eulachon run was early; fish showed up around April 26, peaking May 6-8 compared with a peak May 23-24 as reported by Bishop (1982). The early run was predicted by experienced fishers because of the high tides at the beginning of the month. The observed peaks of abundance coincided with 18.9-20.0 ft predicted tides. At low tide, the fish appear to 'hold' at the mouth of the river waiting to enter as evidenced by feeding behavior and abundance of seals and sea lions at Pyramid Island. They subsequently entered the river at high tide and peak fishing at 4-mile occurred shortly thereafter. Eulachon abundance at 8-mile did not appear tidally influenced."

"Major gull and eagle feeding activity was on the McClellan flats. Early in the run gulls fed on eulachon immigrating across these shallow channels. Gull abundance in the lower river peaked May 6 and 7 (Table 9, Figures 17-18). Gulls were abundant on the far side of the river at this time. A significant part of the eulachon population may move up the opposite shore, particularly in the lower river. However, a large number still also runs on the near side of the river, as evidenced by good catches at 4-mile Point this year. It is unsure what the proportion on

either side is. If a significantly larger proportion run on the other side of the river fish may be more difficult to catch on low-abundance years."

71. Blackburn, J. E., Jackson, P. B., Warner, I. M., and Dick, M. H. 1981. A survey for spawning forage fish on the east side of the Kodiak Archipelago by air and boat during spring and summer 1979, p. 309-376. Final report, Outer Continental Shelf Environmental Assessment Program (OCSEAP), Research Unit 552, Alaska Department of Fish and Game.

    Keywords: Alaska, Kodiak Island, Kalsin River, Pillar Creek, abundance, age at spawning, distribution, geographic, length, spawning

    Abstract: Fig. 22 shows age-frequency distribution of spawning eulachon (*Thaleichthys pacificus*) dip-netted from the Kalsin River, Kodiak Island, May, 1979.

    "The importance of eulachon as a forage fish in the study area is uncertain. During other OCSEAP research along the east coast of Kodiak Island, eulachon were listed as an occasional member of the nearshore finfish community (Blackburn 1978). Our study showed them to be of minor significance compared to herring, capelin and sand lance, although catches during 1980 shrimp research cruises resulted in consistent numbers of this species in deep (i.e. more than 50 meters) nearshore waters along the study area."

    "Eulachon have a life history in the Kodiak area similar to that of more southern populations. They are an anadromous smelt, ascending rivers to spawn in the spring. In Chiniak Bay they utilize Kalsin River, and in Marmot, Pillar Creek. Both of these rivers have runs dating back at least seven years (Blondin, pers.

comm.). These two systems were examined soon after the eulachon had spawned in 1979, but no carcasses were found. It is not known if adults all die after spawning, although it is assumed in the literature that some survive (Smith and Saalfeld 1955). Our surveys of the two spawning streams indicate that post-spawning adults live at least long enough to swim back into the sea. Although four year old fish from Kalsin River were examined, it could not be determined if these were repeat spawners. Eulachon in Kalsin River were spawn ready; a few fish accompanying ripe spawners were not close to spawning condition."

"Eulachon in Alaska may attain high population densities some years (Warner and Shafford 1979). Runs have been described of such magnitude that they clog a river system and pollute the mouth of the river with organic waste resulting from the decomposition of dead fish (Ibid.). Such anecdotal information of strong runs is lacking in the study area."

"Eulachon, once up a spawning river, would be unaffected by a petroleum spill, though their access into or from the river might be impeded, and larvae returning to the sea could be affected."

72. Blackman, M. B. 1990. Haida: Traditional culture. *In* Handbook of North American Indians, Vol. 7: Northwest coast. Edited by W.C. Sturtevant and W. Suttles. Washington, D.C.: Smithsonian Institution.

    Keywords: subsistence

73. Blahm, T. H., and McConnell, R. J. 1971. Mortality of adult eulachon (*Thaleichthys pacificus*) subjected to sudden increases in water temperature. Northwest Science 45(3):178-82.

Keywords: Columbia River, Cowlitz River, run timing, thermal tolerance

Abstract: “An exposure to a temperature increase of +6 C above 5 C ambient for 8940 minutes resulted in a 50 percent mortality. As the test temperature increased, the temperature “dose” causing 50 percent mortality was reached in less time.”

“At the higher temperatures, 23 through 29 C, the fish exhibited a stress-panic reaction and their swimming movements were not directional. At 26 and 29 C, 100 percent mortality occurred in 1.5 minutes or less; it is doubtful if any of these fish could have escaped from a thermal plume by their own volition.”

“It was noted that the temperature-treated females had retained their eggs at death or at the conclusion of the tests; however, the control group had deposited sperm and eggs in the control tank. Approximately 1000 fish (not used in these tests) had been held at river temperature during the test period in 1969. These animals spawned in the tank; fertilized and developing eggs were found as were newly hatched larvae. This indicates that the increased temperature had affected the spawning cycle of the test fish.”

74. Bland, H. [no date]. The oolachon or candle fish. British Columbia Magazine [no volume]:703-4.

Keywords: historical

75. Boas, F. 1909. The Kwakiutl of Vancouver Island. Memoir of the American Museum of Natural History 5(2):465-69.

Keywords: British Columbia, historical

76. Boas, F. 1916. Tsimshian Mythology. Bureau of American Ethnology Annual Report 1909-10. Washington, D.C.: U.S. Government Printing Office.

Keywords: British Columbia, historical

77. Boas, F. 1966. Kwakiutl enthnography. Edited by Helen Codere. Chicago: University of Chicago Press.

Keywords: British Columbia, historical

78. Bohn, B. R., and McIsaac, D. 1986. Columbia River fish runs and fisheries 1960-85. Clackamas, OR: Oregon Department of Fish and Wildlife, and Washington Department of Fisheries. 77 p.

Keywords: Columbia River, fisheries

79. Bond, C. 1996. The biology of fishes. Corvallis, OR: Oregon State University. 750 p.

Keywords: biology, general references on fish

80. Boutillier, J. A., Harling, W. R., and Young, D. E. 1990. F.V. *SHARLENE K* shrimp survey 89-S-1, west coast of Vancouver Island, May 10-16, 1989. Canadian Data Report, Fisheries and Aquatic Sciences No. 807. 83 p.

Keywords: British Columbia, distribution, geographic

81. Boutillier, J. A., Yates, A. N., and Butler, T. H. 1977. *G.B. REED* shrimp cruise 77-5-1, May 3-14, 1977. Fisheries and Marine Service Data Report No. 37, Environment Canada. 42 p.

Keywords: British Columbia, distribution, geographic

82. Bowen, W. D. 2000. Reconstruction of pinniped diets: Accounting for complete digestion of otoliths and cephalopod beaks. Canadian Journal of Fisheries and Aquatic Sciences 57:898-905.

Keywords: otoliths

Abstract: This paper discusses the relationship between number of fish prey consumed and the number of otoliths recovered in pinniped stomach contents. The author determined that a mean correction factor of 2.9 should be multiplied times the number of eulachon otoliths found in harbor seals.

83. Breder, C. M., Jr., and Rosen, D. E. 1966. Modes of reproduction in fishes. Garden City, NY: Natural History Press. 941 p.

Keywords: biology, general references on fish

84. Brocklesby, H. N., and Denstedt, O. F. 1933. The industrial chemistry of fish oils with special reference to those of British Columbia, p. 1-150. Fisheries Research Board of Canada Bulletin No. 37.

Keywords: British Columbia, oil

85. Brown, E. D., Seitz, J., Norcross, B. L., and Huntington, H. P. 2002. Ecology of herring and other forage fish as recorded by resource users of Prince William Sound and the Outer Kenai Peninsula, Alaska. Alaska Fishery Research Bulletin 9(2):75-101.

Keywords: Alaska, Prince William Sound, distribution, geographic

Abstract: “Eulachon were reported in the southwestern passes of PWS and off the southern tip of Montague Island adjacent to the Gulf of Alaska (Fig. 8c). Some residents used gillnets to capture smelt for sport fishing bait, and one respondent recalled seeing them regularly in the Cordova small boat harbor during the winter.”

"Eulachon were reported outside of Aialik and Harris Bays during the summer and at the head of Resurrection Bay during the winter."

86. Brown, R. 1868a. Observations on the medicinal and economical value of the oulachan (*Osmerus pacificus* Richardson). Pharmaceutical Journal and Transactions 9:583.

    Keywords: historical

87. Brown, R. 1868b. Observations on the medical and economic value of the oulachon, a fish belonging to the family salmonidae found on the Northwest Coast of America. Pharmaceutical Journal (June):4.

    Keywords: historical

88. Browne, P., Laake, J. L., and DeLong, R. L. 2002. Improving pinniped diet analyses through identification of multiple skeletal structures in fecal samples. Fishery Bulletin 100:423-33.

    Keywords: Columbia River, otoliths, predators (mammals)

    Abstract: "Smelts (Osmerids) were pooled by family and mass was estimated from whitebait smelt (*Allosmerus elongatus*) the most abundant species by distinguishable otoliths, and eulachon (*Thaleichthys pacificus*), although longfin smelt (*Spirinchus thaleichthys*) and surf smelt (*Hypomesus pretiosus*) were occasionally identified in harbor seal scats. Although smelt otoliths could be distinguished by species, smelt bone could not. Smelt mass estimates were based on eulachon (in their relative proportion) and white-bait smelt because although less common than the other three similar size species, eulachon were much larger."

89. Browning, R. J. 1974. Smelt. *In* Fisheries of the North Pacific: History, species, gear and processes, p. 54-57. Anchorage: Alaska Northwest Publishing Company.

Keywords: Columbia River, fisheries (commercial), fisheries (sport), fisheries (subsistence), historical, spawning, subsistence

Abstract: The commercial fishery for eulachon reached 6 million pounds in 1945 and every year since has exceeded 1 million pounds in the lower Columbia River system. Eulachon spawn in late winter and early spring in the Columbia. They enter the river in vast schools and can travel upstream at 25-35 miles/day. They spawn chiefly in tributaries such as the Grays, Cowlitz, Kalama, Lewis, and Sandy rivers. Eggs are shed and fertilized over gravel beds where the sticky eggs settle and cling until hatching time (about 30 days). The river current immediately carries the tiny larvae seaward.

90. Butler, R. W., and Campbell, R. W. 1987. The birds of the Fraser River delta: Populations, ecology and international significance. Canadian Wildlife Service Occasional Paper No. 65. 71 p.

Keywords: British Columbia, Fraser River, predators (birds), predators (mammals)

Abstract: "Over half of the freshwater species of fish in British Columbia have been recorded in the Fraser River, and, at most times of year, one or more fish species are moving through the river to spawn. The fish species most important to birds are the eulachon (*Thaleichthys pacificus*), herring (*Clupea harengus pallasi*), flounders (Pleuronectidae) and sculpins (Cottidae). In spring, during the herring spawning season, thousands of ducks and gulls gather in Boundary Bay.

At the same time, spawning eulachons attract birds, sea lions, seals and whales into the river. Flounders and sculpins provide food for diving and wading birds."

91. Campbell, K. P., Johnson, S. R., and Wolniakowski, K. U. 1982. A pilot study of potential phenolic contamination of fishes in the Columbia River and tributaries in the vicinity of Mount St. Helens: Final report from Beak Consultants, Portland, OR to Office of Water Research and Technology, Washington, D.C. National Technical Information Service, Springfield, VA PB83-146357. 28 p.

    Keywords: Washington, Cowlitz River, contaminants

    Abstract: "Pentachlorophenol was confirmed in 11 samples with concentrations ranging from 75 ng,/g to 324 ng/g. These specimens consisted of eulachon from the Cowlitz River and salmonids from Deer Creek, a tributary of the North Fork Toutle River in the area affected by the mud flow."

    "The reported levels of phenolics are no cause for concern from a public health standpoint."

92. Canada Department of Fisheries. 1939. Report on eulachon investigation, 1939. National Archives, Burnaby, RG23, Vol. 1826, file 769-11-29, part I.

    Keywords: Canada, historical

93. Carl, G. C. 1964. Some common marine fishes of British Columbia. British Columbia Provincial Museum Handbook Ser. No. 23. Victoria.

    Keywords: British Columbia, biology

94. Carl, G. C., Clemens, W. A., and Lindsey, C. C. 1959. The fresh-water fishes of British Columbia. British Columbia Provincial Museum Handbook 5 (and earlier

editions).Victoria. 1-192

Keywords: British Columbia, biology

95. Carlson, H. R., Haight, R. E., and Krieger, K. J. [no date]. Species composition and relative abundance of demersal marine life in waters of southeastern Alaska, 1969-77. Unpublished report. Juneau: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Auke Bay Laboratory.

Keywords: Alaska, Southeast, distribution

Abstract: Trawl samples in many coastal fiords of northern Southeast Alaska documented the widespread but relatively rare occurrence of eulachon.

96. Carolsfeld, J., and Hay, D. E. 1998. Fish-forest interactions: Eulachon stock structure examined by elemental analyses of otoliths. Report submitted to the B.C. Science Council, February 7, 1998.

Keywords: otoliths, population structure

97. Catterson, N., and Lucey, B. 2002. Seasonal abundance of Steller sea lions at Dry Bay, Alaska. U.S. Department of Agriculture, Forest Service, Tongass National Forest, Yakutat Ranger District. 7 p.

Keywords: Alaska, Akwe River, Alsek River, Situk River, Tawah Creek, distribution, geographic, predators (mammals), run timing, spawning

Abstract: “[Steller sea lions] haul-out at the mouth of the Alsek River, or occasionally on gravel islands one or two miles upriver from the mouth. Steller Sea Lions may be using Dry Bay as a seasonal feeding area, as they are usually present when eulachon (*Thaleichthys pacificus*) are spawning from February to May.”

"In 2001, sea lion peak abundance on the Akwe River coincided with the eulachon run that occurred in early February. The earliest documented run of eulachon on the forelands were observed in Tawah Creek, a tributary to the Situk Ahrnklin Estuary, on January 20, 2001 by Mike Freeman, a local Alaska Department of Fish and Game employee. During the study period, eulachon were most abundant in late March, though the run on the Akwe and Alsek Rivers lasted until early June. The Situk River had very few fish return, and those that returned to the Situk, Ahrnklin Estuary arrived in Late May several weeks past their normal run-timing."

98. CCN Newswire. 2001. Dhaliwal announces $452,000 for the conservation and protection of eulachon, northern abalone and white sturgeon in B.C. Canadian Corporate News, sec. November 23.

Keywords: British Columbia, conservation

Abstract: VANCOUVER, BRITISH COLUMBIA, NOVEMBER 23, 2001 (CCN Newswire via COMTEX) The Honourable Herb Dhaliwal, Minister of Fisheries and Oceans and MP for Vancouver-South Burnaby, announced a grant from the Habitat Stewardship Program for the conservation and protection of three British Columbian species at risk, including eulachon. Three projects related to eulachon received financial support: 1) Eulachon Population Assessment by First Nations—Community groups will conduct annual surveys of eulachon runs to compare with data from the Kemano, Kitimat, Balla Coola, and Knight Inlet/Kingcome rivers. 2) Traditional Knowledge and the Use of Eulachon by First Nations—This project will collect traditional knowledge of First Nations to

help estimate historic run sizes. Local film studens will produce a video to increase Canadian awareness about eulachon. 3) Eulachon Outreach and Watershed Planning—A third project continues a stewardship initiative in the Kildala and Kemano watersheds; educational material regarding local eulachon conservation will go to schools and special interest groups.

99. Chan, H. M., El Khoury, M., Sedgemore, M., Sedgemore, S., and Kuhnlein, H. V. 1996. Organochlorine pesticides and polychlorinated biphenyl congeners in ooligan grease: A traditional food fat of British Columbia first nations. Journal of Food Composition and Analysis 9(1):32-42.

Keywords: British Columbia, Bella Coola, Kingcome Inlet, Kitimaat, Nass River, Rivers Inlet, congeners, contaminants, ethnic foods, geographical variation, grease, proximate composition

Abstract: "Levels of persistent organic pollutants including dichlorodiphenyltrichloroethane, hexachlorobenzene, hexachlorohexanes, dieldrin, chlordane, mirex, and polychlorinated biphenyls (PCB) were measured in ooligan fish (*Thaleichthys pacificus*) prepared in the way usually consumed and in ooligan grease collected from five communities (Nass River, Kitimaat, Bella Coola, Kingcome Inlet, and Knights Inlet) in the coastal area of British Columbia, Canada. Levels of chlorinated pesticides and PCB increased from the north to the south, with the lowest from Nass River and highest from Knights Inlet. Average levels of persistent organic pollutants (110 ng/g lipid of total chlorinated pesticide and 30 ng/g lipid of PCB) were lower than those reported in fish from the Great Lakes and similar to those from the Arctic and were below the regulation limits

established by Health Canada. Therefore, consumption of ooligan grease presents minimal health risk from organochlorine exposure."

100. Chapman, W. M. 1939. Eleven new species and three new genera of oceanic fish as collected by the International Fisheries Commission from the north-eastern Pacific, p. 501-542. Proceedings of the U.S. National Museum No. 86.

Keywords: taxonomy

101. Chatwin, B. M., and Forrester, C. R. 1953. Feeding habits of dogfish (*Squalus suckleyi* Girrard). Fisheries Research Board of Canada Pacific Progress Report 95:35-38.

Keywords: British Columbia, Fraser River, predators (fish)

Abstract: Note from Langer et al. (1977): "Noted dogfish concentrations off the Fraser River in spring. Of 249 stomachs examined in 1953, 100 percent contained eulachon remains. Dogfish abundance appeared to be linked to eulachon abundance in other years."

102. Clemens, W. A., Hart, J. L., and Wilby, G. V. 1936. Analysis of stomach contents of fur seals taken off the west coast of Vancouver Island in April and May, 1935. Stud. Sta. Biol. Bd. Canada No. 160. Ottawa: Canada Department of Fisheries. 20 p.

Keywords: British Columbia, predators (mammals)

Abstract: Note from Langer et al. (1977): "Of 193 stomachs containing food, 30 contained eulachon remains (for an average of 3 percent by volume)."

103. Clemens, W. A., and Wilby, G. V. 1961. Fishes of the Pacific coast of Canada. Second edition. Fisheries Research Board of Canada Bulletin No. 68 (rev.). 443 p.
Keywords: British Columbia, biology, taxonomy

104. Codere, H. 1990. Kwakiutl: Traditional culture. *In* Handbook of North American Indians, Vol. 7: Northwest coast. Edited by W.C. Sturtevant and W. Suttles. Washington, D.C.: Smithsonian Institution.
Keywords: British Columbia, fisheries (subsistence)

105. Collison, H. A. 1941. The oolichan fishery. British Columbia Historical Quarterly 5 (Jan):25-31.
Keywords: British Columbia, Nass River, fisheries (subsistence)
Abstract: Note from Langer et al. (1977): "good review of historical native fishery on the Nass."

106. Common Resources Consulting Ltd. 1998. An historic overview of the Kwawkewlth, Knight, and Kingcome Inlet eulachon fishery. Prepared for Department of Fisheries and Oceans Canada, Aboriginal Fisheries.
Keywords: British Columbia, Knight Inlet, Kingcome Inlet, abundance, fisheries (commercial), fisheries (subsistence), historical, migration

107. Convey, L., Lessard, J., Harbo, R., and Boutillier, J. 2000. Shrimp trawl fishery—1999, 2000. (PSARC) Fishery Update.
Keywords: British Columbia, distribution, geographic

108. Cottrell, P. E., Trites, A. W., and Miller, E. H. 1996. Assessing the use of hard parts in faeces to identify harbour seal prey: Results of captive-feeding trials. Canadian

Journal of Zoology 74:875-80.

Keywords: predators (mammals)

109. Craig, G. R., and Stasiak, M. 1993. Fish tainting chemicals—Separation, isolation and identification of compounds from pulp and paper effluent. *In* Abstract book from SETAC 14th annual meeting, Houston, Texas. 128 p.

Keywords: water pollution effects

110. Craig, J. A., and Hacker, R. L. 1940. The history and development of the fisheries of the Columbia River. U.S. Bureau of Fisheries Bulletin No. 49 (32):132-216.

Keywords: Columbia River, fisheries (commercial), historical

111. Cranmer, B. 1999. T'Lina: The rendering of wealth. Videocassette. Montreal: National Film Board of Canada. 50 min.

Keywords: British Columbia, oil, subsistence

Abstract: "The filmmaker travels with her family and friends on their annual journey to their sacred place known as Dzawadi. Here, in British Columbia's Knight Inlet, they practice the traditional rendering of oil, t'lina, from the tiny eulachon fish. Traded throughout the Pacific Northwest for thousands of years, t'lina remains a vital food staple, trade good, and symbol of cultural wealth."

112. Crawford, D. R. 1925. Spawning grounds of smelt. Seattle: Washington Department of Fisheries.

Keywords: Washington, spawning

113. Crissey, S. D., McGill, P., and Simeone, A.-M. 1998. Influence of dietary vitamins A and E on serum alpha- and gamma-tocopherols, retinol, retinyl palmitate and carotenoid concentrations in Humboldt penguins (*Spheniscus humboldti*).

Comparative Biochemistry and Physiology 121A(4):333-39.

Keywords: Columbia River, carotenoids, proximate composition, vitamins

Abstract: “Serum retinol, retinyl palmitate, beta-carotene, cryptoxanthin, lutein, alpha-tocopherol and gamma-tocopherol were measured in 18 captive Humboldt penguins (*Spheniscus humboldti*) prior to and following the removal of Columbia River (CR) smelt (*Thaleichthys pacificus*) from the diet. Dietary vitamin A was reduced from 59.8 to 13.5 IU g^{-1} (dry matter basis) when CR smelt was removed from the diet. Minimal changes were noted in dietary vitamin E. Serum samples Without-CR smelt had significantly lower circulating retinol (1.19 plus or minus 0.09 vs 1.94 plus or minus 0.08 mu g ml^{-1}) and retinyl palmitate (0.033 plus or minus 0.012 vs 0.105 plus or minus 0.004 mu g ml^{-1}) compared to samples With-CR. The Without-CR smelt diet resulted in increased serum alpha-tocopherol from 26.4 plus or minus 0.94 to 39.1 plus or minus 3.72 mu g ml^{-1}). More serum samples taken Without-CR smelt had detectable levels of gamma-tocopherol than those With-CR smelt. Serum lutein was higher for the samples taken Without versus With-CR smelt. Serum cryptoxanthin did not differ. Beta-Carotene was not detected. Data indicate that high levels of dietary vitamin A can affect circulating levels of retinol, retinyl palmitate and vitamin E. Thus, dietary vitamin A and the interrelationship between vitamins A and E should be considered when assessing captive penguins.”

114. Curtis, E. S. [1915] 1970. The North American Indian, Vol. 10, p. 22-24. New York: Johnson Reprint Corporation.

Keywords: historical

Abstract: Note from Langer et al. (1977): "Apparently briefly describes native rendering methods."

115. Dall, W. H. 1870. The food fishes of Alaska, p. 375-392. Rep. U.S. Comm. Agr. 1870 (1871).

Keywords: Alaska, historical

116. Davis, J. C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: A review. Journal of the Fisheries Research Board of Canada 32:2295-332.

Keywords: Canada, biology

117. de Laguna, F. 1972. Under Mt. St. Elias: The history and culture of the Yakutat Tlingit. Part I. Smithsonian Contributions to Anthropology Vol. 7. Washington, D.C.: Smithsonian Institution Press.

Keywords: Alaska, Yakutat, historical

118. de Laguna, F. 1983. Aboriginal sociopolitical organization. *In* The development of political organization in native North America. 1979 proceedings of the American Ethnological Society. Edited by E. Tooker. Washington, D.C.: The American Ethnological Society.

Keywords: Alaska, historical

119. de Laguna, F. 1990. Tlingit. *In* Handbook of North American Indians, Vol. 7: Northwest Coast. Edited by W. C. Sturtevant and W. Suttles. Washington, D.C.: Smithsonian Institution.

Keywords: Alaska, historical

120. DeLacy, A. C., and Batts, B. S. 1963a. Possible population heterogeneity in the Columbia River smelt. Fisheries Research Institute Circular No. 198. Seattle: University of Washington College of Fisheries.

Keywords: Columbia River, population structure

121. DeLacy, A. C., and Batts, B. S. 1963b. A search for racial characteristics in the Columbia River smelt, p. 30-32. Research in Fisheries, Fisheries Research Institute, University of Washington College of Fisheries, Contribution No. 147.

Keywords: Oregon, Washington, Columbia River, Cowlitz River, Elochoman River, Grays River, Lewis River, Kalama River, Sandy River, eggs, larvae, myotomes, racial characteristics, skeleton

Abstract: “Numerous samples of adult smelt were collected throughout the 1962 commercial fishing season in the Cowlitz River. On several occasions three to five samples were obtained on the same date at well separated localities. Adult smelt were also collected from the main Columbia River and from the Elochoman River.”

“From dissected specimens of these adult smelt, the number of myotomes from the head to the posterior margin of the stomach was counted. These counts were similar to those obtained from the prolarvae, indicating that the number of myotomes may remain constant after the prolarval stage in the smelt. More extensive observations will be needed to determine the utility of this characteristic for racial purposes.”

“Intensive study is being conducted on vertebral counts. During this study we have observed the occurrence of abnormal spines on the two most posterior

caudal vertebrae with the number of spines sometimes doubled on each vertebra (Fig. 2)."

"When the vertebral counts in fish with normal spines were compared with those in fish with abnormal spines, the former group was 0.36-0.51 higher than the latter group. It is important, therefore, in using vertebrae as a meristic characteristic to record the incidence of fish with abnormal spines."

122. Department of Fisheries and Oceans Canada. 1999. Eulachon. DFO Science Stock Status report B6-06.

Keywords: British Columbia, distribution, geographic, fisheries, historical

123. Department of Fisheries and Oceans Canada. 2000. Pacific Region: 2000 management plan—eulachon.

Keywords: British Columbia, management

124. Department of Fisheries and Oceans Canada. 2003. Pacific Region integrated fisheries management plan: Eulachon—April 1, 2002 to March 31, 2003.

Keywords: British Columbia, management

125. Donaldson, I. 1953. Smelt or eulachon. 6 p.

Keywords: Columbia River, migration

Abstract: Typewritten manuscript from Oregon Fish. Co. describes smelt migration of 1953 at Bonneville Dam.

126. Drake, A., and Wilson, L. 1991. Eulachon, a fish to cure humanity. University of British Columbia Museum of Anthropology, Museum Note No. 32. Vancouver, B.C. 37 p.

Keywords: British Columbia, historical, subsistence

Abstract: This publication on the eulachon of British Columbia includes chapters on methods of harvesting, processing, trade and concerns for the future.

127. Drew, L., and Lepp, G. 1996. A feast fit for eagles. National Wildlife 34 (Jan):46-49.

Keywords: Alaska, Stikine River, predators (birds)

128. Drucker, P. 1951. The northern and central Nootkan tribes. Bureau of American Ethnology, Bulletin No. 144. Washington, D.C.

Keywords: historical

129. Drury, H. M. 1985. Nutrients in native foods of southeastern Alaska. Journal of Ethnobiology 5(2):87-100.

Keywords: Alaska, Southeast, fisheries (subsistence), proximate composition

130. Duffy, D. C. 1999. APEX project: Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska: *Exxon Valdez* Oil Spill Restoration Project annual report. Restoration Project 98163 A-T, Paumanok Solutions, 102 Aikahi Loop, Kailua, Hawaii 96734.

Keywords: Alaska, Gulf of Alaska, Prince William Sound, predators

131. Dutta, L. K. 1976. A review of suction dredge monitoring in the Lower Fraser River, 1971-1975. Proceedings of the World Dredging Conference, San Francisco, CA, 10 July 1976. 7:301-19.

Keywords: British Columbia, Fraser River, abundance, dredging, effects of, larvae, migration

Abstract: The Fraser River is used as a migratory route by numerous species of fish including all 5 species of Pacific salmon. An estimated 6.25 billion eulachon

larvae, and millions of salmon fry and juveniles traveled seaward through the lower Fraser River during 15 March to 31 May 1974. The lower 25 miles of the river is being used increasingly for navigation and sand-borrow purposes. Suction dredging activities during the downstream salmon fry migration period killed or injured a high proportion of the fish.

132. Eddy, S. 1957. How to know the freshwater fishes. First edition. Dubuque, IA: Wm. C. Brown Co. 258 p.

Keywords: taxonomy

133. Edwards, B. 2002. Commentary: Fishy harbingers of spring. Morning Edition (National Public Radio), sec. 27 May.

Keywords: Alaska, Chilkat River, Chilkoot River

Abstract: “10:00-11:00 AM. In Haines, Alaska, the days are getting longer, a sure sign that summer will soon be here. Commentator Heather Lende prefers spring, and for her, it’s the eulachon, a small fish, that best heralds spring.”

“HEATHER LENDE:

Eulachon are a herring-like smelt, longer and thinner than a sardine. They run up the Chilkat and Chilkoot rivers to spawn some time between March and May. They’re prized by my Tlingit Indian neighbors for many reasons.”

“For the first few hours of the run, spawned-out dead eulachon litter beaches. Soon, shorebirds descend in a feeding frenzy on the wide flats where the rivers meet the sea. Sea lions cruise the shoreline with their mouths wide open, beneath mountains that rise straight up from the beach. In the bay, humpback and killer whales surface. People also gather to watch the natural carnival, but it’s mostly

Tlingits that wade in with long dip nets, scooping up the eulachon and dumping them into buckets. Old fish camps are reopened along the riverbanks, with blue tarps for cover and maybe a shack or a camper to sleep in."

"Fresh eulachon are roasted over wood fires and eaten whole. Some are smoked and dried, but most are buried in lined pits and left to rot for about three weeks, then boiled in big pots until the oil can be skimmed off the top. When it cools, it's solid, like shortening."

"I have a friend who keeps his eulachon oil in a jar in the freezer. He scoops out a spoonful of the fishy fat every day. It's good for the heart, he says. He also likes the warm oil with seal meat or dried salmon, and stirred into bowls of berries. It's an acquired taste."

"Another native friend says he likes to help gather eulachon because it's a yearly reminder of the past and an affirmation of the Tlingit culture's future, but he won't eat them, boiled, roasted or smoked. They're so strong, he says, that just one bite is enough to make him grow fish scales."

"It won't officially be summer until solstice on June 21st. Then we'll have a bike race and dance. It's fun, but I prefer the movable feast of the eulachon, which is determined not by the predictable revolution of the Earth, but by the sudden overwhelming urge of a little fish to come home."

"EDWARDS: The comments of Heather Lende, a columnist for the Anchorage Daily News. She lives in Haines, Alaska."

"This is MORNING EDITION from NPR News. I'm Bob Edwards."

134. Edwards, G. T. 1978. Oolachen time in Bella Coola. The Beaver (Autumn):32-37.
Keywords: British Columbia, subsistence

135. Einarsen, A. S. 1925. Distribution of the smelts (Eulachon—*Thaleichthys pacificus*). Unpublished manuscript. Seattle: Washington Department of Fisheries.
Keywords: Washington, distribution, geographic

136. Einarsen, A. S. 1926. Herring, smelt and salmon, fall report. Unpublished manuscript. Seattle: Washington Department of Fisheries.
Keywords: Washington, historical

137. Einarsen, A. S. 1927. Effect of protective measures on the 1926 Puget Sound smelt run. Unpublished manuscript. Seattle: Washington Department of Fisheries.
Keywords: Washington, conservation, historical

138. Eldridge, M. B., and Bryan, C. F. 1972. Larval fish survey at Humboldt Bay. U.S. Department of Commerce Technical Report NMFS SSRF-665.
Keywords: California, Humboldt Bay, larvae

139. Emmett, R. L., Stone, S. L., Hinton, S. A., and Monaco, M. E. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Vol. II: Species life history summaries. Estuarine Living Marine Resources Program Report No. 8. Rockville, MD: National Oceanic and Atmospheric Administration, National Ocean Service, Strategic Environmental Assessments Division. 329 p.
Keywords: Pacific Ocean, abundance, distribution, geographic, life history

140. Emmett, R. L., and Brodeur, R. D. 2000. Recent changes in the pelagic nekton community off Oregon and Washington in relation to some physical oceanographic conditions, p. 11-20. *In* North Pacific Anadromous Fish

Commission Bulletin No. 2. Vancouver, B.C.

Keywords: Oregon, Washington, abundance, distribution, geographic

Abstract: “Since 1977, ocean survival of eulachon (*Thaleichthys pacificus*) declined.”

141. Emmons, G. T. 1991a. The history of Tlingit clans and tribes. Unpublished manuscript. New York: American Museum of Natural History.

Keywords: Alaska, Southeast, historical

142. Emmons, G. T. 1991b. The Tlingit Indians. Edited with additions by Frederica de Laguna. American Museum of Natural History Anthropological Paper No. 70. Seattle: University of Washington Press and the American Museum of Natural History.

Keywords: Alaska, Southeast

143. Envirocan Ltd. 1984. Environmental studies associated with the proposed Kemano Completion Hydroelectric Project. Vol. 7: Fish resources of the Kemano River system—Baseline information. Prepared for the Aluminum Company of Canada Ltd. 155 p.

Keywords: British Columbia, Kemano River

144. Eulachon Research Council. 1998. March 1998 meeting summary notes—Terrace, B.C. and Vancouver, B.C. Informal report jointly prepared by B.C. Forests, Department of Fisheries and Oceans Canada. 19 p.

Keywords: population status

Abstract: “Eulachons appear to be in a state of decline in most of British Columbia. The rapidity and extent of the decline in the Fraser River is alarming.

A drastic decline has also occurred in California and in the Columbia River."

"Monitoring, assessment, habitat work and research on eulachons will be significantly reduced in the coming year. Goal-setting and priorities for future research is absent."

"The cause(s) of the decline in eulachon stocks is unknown. Ocean climate may be the primary influence of the current decline. Other factors within human control may have contributed but regardless of their role in the decline, their potential to impede recovery warrants extreme caution."

"DFO [Department of Fisheries and Oceans Canada] has labeled the eulachon bycatch observed in the 1997 shrimp fishery as 'unacceptable' and has plans in place for bycatch reduction in 1998. Some Aboriginal fisheries are instituting traditional fishing practices to ensure adequate spawning. Unfortunately, there are no plans to deal with the impacts of dredging or upstream forest practices on eulachon habitat."

"There may be a functional ecological link between factors affecting sturgeon and eulachons in the Fraser River. Fraser River sturgeons may rely on eulachons as an important forage species and the current decline in sturgeon may be associated with the eulachon decline."

145. Eulachon Research Council. 2000. Notes summarizing meetings in Terrace, B.C. (May 4), New Westminster, and Bella Coola, B.C. (May 9). Informal joint report prepared jointly by B.C. Forests, Department of Fisheries and Oceans-Canada. 24 p.

Keywords: biology, bycatch, distribution, geographic, eggs, population status, run

timing, sex ratio, stock identification

Abstract: This report summarizes what is known about the distribution, biology, status, bycatch, stock identification, and harvest of eulachon. It provides a list of Web sites containing information on eulachon, and a list of individuals working on eulachon that includes addresses, email, and telephone numbers.

146. Evans, A. W. 1954. When the oolichons are in, school's out. Vancouver Sun. April 3.

Keywords: British Columbia, Kitimat, historical

Abstract: Note from Langer et al. (1977): "Observations of native fishery at Kitimat in 1954."

147. Evermann, B. W., and Goldsborough, E. L. 1906. The fishes of Alaska. U.S. Bureau of Fisheries Bulletin No. 26:219-360.

Keywords: distribution, geographic, general references on fish, taxonomy

148. EVS Consultants Ltd. (EVS). 1990. Studies assessing the potential impacts of the Kemano Completion Project on the Kemano River oolichan (*Thaleichthys pacificus*). Prepared for the Kitamaat Village Council, North Vancouver, B.C. 16 p.

Keywords: British Columbia, Kemano River

149. Fall, J. A., Foster, D. J., and Stanek, R. T. 1984. The use of fish and wildlife resources in Tyonek, Alaska. Technical Paper No. 105, Alaska Department of Fish and Game, Division of Subsistence. 219 p.

Keywords: Alaska, subsistence

150. Farara, D. 1996. The toxicity of pulp mill effluent on eulachon eggs and larvae in the Kitimat River. Consultants report prepared by Beak International for Eurocan Pulp Mills Ltd., Kitimat, B.C.

Keywords: British Columbia, Kitimat River, contaminants, water pollution effects

151. Fechhelm, R. G., Wilson, W. J., Griffiths, W. B., Stables, T. B., and Marino, D. A. 1999. Forage fish assessment in Cook Inlet oil and gas development areas, 1997-1998. Environmental Studies Program, U.S. Department of the Interior, Minerals Management Service, Alaska Outer Continental Shelf Region. 172 p.

Keywords: Alaska, Cook Inlet, abundance, age at spawning, food and feeding habits, length, proximate composition, sex ratio, weight

Abstract: "Forage fish surveys were conducted in lower Cook Inlet, Alaska, in 1997-1998 using hydroacoustics and net sampling. The principal species collected by beach seine and Isaacs-Kidd midwater trawl were Pacific herring, surf smelt, eulachon, Pacific sand lance, longfin smelt, walleye pollock, and tomcod. The trawl was used to verify species composition of schools detected by hydroacoustics, and fish collected were sampled for length, weight, sex, age, proximate body composition, and diet. Although the nearshore marine waters near Chisik Island provide habitat for forage fish, this area appears to be less favorable than other coastal areas of southern Alaska for production of forage fish."

152. Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Fisheries Research Board of Canada Bulletin No. 93. 58 p.

Keywords: British Columbia, Skeena River, predators (mammals)

Notes: cited in Pitcher, Food of the harbour seal

153. Fisk, M. 1913. A review of the fishes of the genus *Osmerus* of the California coast. Proceedings of the U.S. National Museum 46(2027):291-93.

Keywords: California, historical, length, taxonomy

Abstract: Note from Langer et al. (1977): "Identified as *Osmerus thaleichthys* Ayres. Gives detailed body measurements on 10 specimens from San Francisco area."

154. Franzel, J., and Nelson, K. A. 1981. Stikine River eulachon (*Thaleichthys pacificus*). Petersburg, AK: U.S. Department of Agriculture, Forest Service, Petersburg Ranger District.

Keywords: Alaska, Stikine River, age at spawning, fecundity, length, migration, run timing, sex ratio, spawning, weight

Abstract: "The peak of the eulachon run occurred in early April in 1979 and 1980, and appears to be correlated with water temperatures and spring breakup. The run duration was observed to last 3 to 4 weeks."

"The highest catch per unit effort occurred between Binkley Slough (Middle Arm) and Kakwan Point. It is felt that this area is the major spawning grounds for Stikine River smelt. Sampling effort was insufficient in the very lower part of the estuary, the North Arm, and the South Arm below Sergeif Island to comment about distribution. Sampling effort was also insufficient above Kakwan Point to precisely pinpoint upstream penetration, although based on limited upstream catch data and bird observations, it is felt that the limit is the Shakes Slough area."

"Smelt were not observed in any tributary streams below the United States-Canada border."

"Different types of fishing gear did not have a significant effect on the ratio of males to females captured. Sex ratios for 2 years of averaged gillnet data indicate a 17.5 : 1 ratio of males to females. Sinking gillnets with 1-1, 4- and 1-1, 2-inch stretch monofiliment [sic] mesh were the most effective gear."

"The mean fork lengths of 3-year-old smelt on the Stikine River were found to be significantly larger than Columbia River 3-year-old smelt."

"Fecundity rates of gravid female smelt varied between 18,157 and 43,620 eggs per female. A positive correlation was found between fork length and number of eggs."

"The majority of the smelt are 3 years old when returning to spawn."

155. Fritz, L. W., Wespestad, V. G., and Collie, J. S. 1993. Distribution and abundance trends of forage fishes in the Bering Sea and Gulf of Alaska. *In* Is it food?, p. 30-44. Addressing marine mammal and seabird declines: Workshop summary. Alaska Sea Grant Report No. 93-01. Fairbanks: University of Alaska.

Keywords: Alaska, Bering Sea, distribution, geographic

Abstract: "Eulachon also spawn in spring in rivers of the Alaska Peninsula, and possibly other rivers draining into the southeastern Bering Sea. Eulachon live to age 5 (and grow to 25 cm), but most die following first spawning at age 3. Eulachon are consistently found by groundfish fisheries and surveys between Unimak Island and the Pribilof Islands in the Bering Sea, and in Shelikof Strait in the Gulf of Alaska."

156. Futer, P., and Nassichuk, M. 1983. Metals in eulachons from the Nass River and crabs from Alice Arm, B.C. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1699. Vancouver, B.C.: Department of Fisheries and Oceans Canada, Pacific Region. 76 p.

Keywords: British Columbia, Nass River, bioaccumulation, contaminants

Abstract: "In 1981, Amax Molybdenum of Canada Ltd. began discharging tailings from its molybdenum mine at Kitsault, British Columbia into Alice Arm. Native Indians living in coastal areas of northern B.C. expressed concern with respect to the potential for metal contamination of certain food fish and invertebrates as a result of the tailings disposal. In response to this concern, the Department of Fisheries and Oceans carried out a sampling program in 1981 and 1982 to determine the metal content of Nass River eulachons (*Thaleichthys pacificus*) and small numbers of King crab (*Paralithodes camtschatica*) and Tanner crab (*Chionoecetes bairdi*) from Alice Arm. Levels of arsenic, cadmium, chromium, copper, manganese, mercury, molybdenum, nickel, lead, and zinc were measured in organisms sampled."

"This report presents results of the sampling program and compares them with metal data from organisms previously collected from coastal waters of British Columbia and other selected coastal locations throughout the world."

157. Garfield, V., and Wingate, P. S. 1966. The Tsimshian Indians and their arts. Seattle: University of Washington Press.

Keywords: historical, subsistence

158. Garrison, K. J., and Miller, B. S. 1980. Review of the early life history of Puget Sound fishes. FRI-UW-8216. Seattle: Fisheries Research Institute, University of Washington. 729 p.

Keywords: Washington, Puget Sound, life history

159. Gende, S. M., Womble, J. N., Willson, M. F., and Marston, B. H. 2001. Cooperative foraging by Steller sea lions, *Eumetopias jubatus*. The Canadian Field-Naturalist 115(2):355-56.

Keywords: Alaska, Berners Bay, predators (mammals)

Abstract: Steller Sea Lions were observed cooperatively foraging for Eulachon (*Thaleichthyes pacificus*) and possibly Herring (*Clupea pallasi*) in Berners Bay, southeast Alaska in spring, 1996-1999.

160. Gibson, J. R. 1992. Otter skins, Boston ships and China goods: The maritime fur trade of the Northwest Coast, 1785-1841. Montreal: McGill Queens University Press.

Keywords: historical

161. Gilbert, C. H. 1895. The ichthyological collections of the steamer Albatross during the years 1890 and 1891. Report of the U.S. Comm. Fish. No. 19 (Ap. 6):393-476.

Keywords: historical

Abstract: note from Langer et al. (1977): “Apparently eulachons taken as far north as Nushagak River and Bristol Bay.”

162. Gillespie, G. E., and Westrheim, S. J. 1997. Synopsis of information on marine fishes utilized as prey by marine and shoreline birds of the Queen Charlotte Islands. *In* The ecology, status, and conservation of marine and shoreline birds of

the Queen Charlotte Islands. Edited by K. Vermeer, and K. H. Morgan. Canadian Wildlife Service Occasional Paper No. 93.

Keywords: British Columbia, abundance

Abstract: Eulachon are probably the most abundant smelt in the Queen Charlotte Islands and are an important prey of marine birds.

163. Girard, C. F. 1859. Ichthyological notices. Proceedings of the Academy of Natural Sciences, Philadelphia. p. 223-225.

Keywords: historical

164. Girard, D. F. 1859. Fishes. *In* General report on the zoology of several Pacific railroad routes. U.S. Pacific Railroad Survey 10(4):325

Keywords: historical

Abstract: Note from Langer et al. (1977): "Apparently mentions eulachons (named *Thaleichthys stevensi*)."

165. Glenn, M. 1933. No daylight when the candlefish came. Vancouver Province (November 18): 9.

Keywords: British Columbia, Nass River, historical

Abstract: Note from Langer et al. (1977): "Telling of the Raven legend, which deals with eulachon fishing and the arrival of daylight to the Nass River."

166. Goldschmidt, W. R., and Haas, T. H. 1946. Possessory rights of the natives of southeastern Alaska. Washington, D.C.: Commissioner of Indian Affairs.

Keywords: Alaska, Southeast, historical

167. Gordon, D. K., and Levings, C. D. 1984. Seasonal changes of inshore fish populations on Sturgeon and Roberts Bank, Fraser River estuary, British

Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1240. 81 p.

Keywords: British Columbia, Fraser River

168. Gordon, M. 1996. Meeting of the BC Eulachon Research Council minutes, November 6.

Keywords: British Columbia

169. Gotshall, D. W., Allen, G. H., and Barnhart, R. A. 1980. An annotated checklist of fishes from Humboldt Bay, California. California Fish and Game 66:220-232.

Keywords: California, Humboldt Bay, distribution, geographic

170. Gotthardt, T. A. 2001. The foraging ecology of harbour seals (*Phoca vitulina richardsi*) in southcentral Prince William Sound, Alaska, 1994-1997. M.S. thesis. Anchorage: University of Alaska.

Keywords: Alaska, Prince William Sound, abundance, distribution, geographic

Abstract: "During 1994 and 1995 fall and summer surveys, eulachon were patchily distributed throughout PWS, in waters ranging from 40-180 m. Most eulachon schools were concentrated in the northeast. In fall 1994, eulachon made up 30% of fishes caught in 40-80 m in Port Gravina (Table 4) (Haldorson et al. 1995). During summer 1995, eulachon made up 73% of the catch in Galena Bay, where they were caught along with pollock in deep water (160-180 m) (Fig. 4, Table 3)."

"During fall 1995, small numbers (3-20) of eulachon were caught in northern, central, and southern PWS (Table 5). In the north they were caught in Landlocked Bay in 67-90 m of water, and made up 5% of the total catch (Haldorson et al.

1996). Eulachon represented 0.6-1.4% of the total catch near Applegate Rocks (central PWS) where fish were caught in 40-80 m [of] water. In southwestern PWS, eulachon were caught in waters ranging from 30-60 m deep [in?] the East arm of Whale Bay where they made up 4% of the catch and co-occurred with juvenile and adult pollock (90%) and herring (6%) (Fig. 4). Aerial surveys are unable to detect fish schools deep in the water column, which may explain the absence of eulachon from aerial data."

171. Gregory, R. 2000. Cranmer wins another American Indian film award. Raven's Eye. January 3(9):10.

Keywords: British Columbia, subsistence

Abstract: "Features the award received by the movie 'T'Lina: The Rendering of Wealth,' directed by Barb Cranmer in San Francisco, California."

172. Grinols, R. D. 1965. Check-list of the offshore marine fishes occurring in the northeastern Pacific Ocean, principally off the coast of British Columbia, Washington, and Oregon. M.S. thesis. Seattle: University of Washington.

Keywords: Pacific Ocean, distribution, geographic

Abstract: note from Langer et al. (1977): "Apparently gives geographic limits of distribution."

173. Gruchy, I. M., and McAllister, D. E. 1972. A bibliography of the smelt family, Osmeridae. Fisheries Research Board of Canada, Technical Report No. 368. 104 p.

Keywords: bibliography

Abstract: "This bibliography includes approximately 1800 titles from the year

1553 to 1971. Papers were added to the manuscript up to the cutoff date of 1 October 1972. While probably not complete, the bibliography does contain the majority of important papers on the group. Books or papers with only a line or two on smelts and catch statistics have not generally been included; these are the only categories of publication intentionally excluded."

174. Gunther, A. C. L. G. 1866. *Thaleichthys pacificus*. *In* Catalogue of the fishes of the British Museum, Vol. 6 (Physotomi), p. 166-171. London: British Museum of Natural History.

Keywords: British Columbia, taxonomy

Abstract: note from Langer et al. (1977): "Apparently describes first specimens taken from British Columbia waters."

175. Hakkinen, E. S. 1979. Haines: The first century. Alaska in perspective Vol. 3 No.2, Alaska Historical Commission.

Keywords: Alaska, Southeast, historical

176. Haldorson, L. 1989. Larval fish studies. *In* APPRISE Annual Report, SFOS APP88-200, p. 105-143. Fairbanks: University of Alaska, School of Fisheries and Ocean Sciences.

Keywords: Alaska, larvae

177. Haldorson, L., Pritchett, M., Paul, A. J., and Ziemann, D. 1993. Vertical distribution and migration of fish larvae in a Northeast Pacific Bay. Marine Ecology Progress Series 101:17-80.

Keywords: Alaska, larvae

178. Haldorson, L., Shirley, T., and Coyle, K. 1999. Forage fish studies in Prince William Sound, 1998. *In* APEX Project (Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska): *Exxon Valdez* Oil Spill Restoration Project annual report. Edited by D. C. Duffy. Restoration Project 98163 A-T.

Keywords: Alaska, Prince William Sound, distribution, geographic

179. Haldorson, L., Shirley, T., Coyle, K., and Thorne, R. 1995. Biomass and distribution of forage species in Prince William Sound. *In* APEX project (Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska): *Exxon Valdez* Oil Spill Restoration Project annual report.

Keywords: Alaska, Prince William Sound, biomass, distribution, geographic

180. Haldorson, L., Watts, J., and Sterritt, D. 1986. Larval fish production in Auke Bay, Alaska-1986. Component 9. *In* APPRISE: Association of Primary Production and Recruitment In a Subarctic Ecosystem, Vol. 1, p. 320-360. Edited by O. A. Mathisen, J. J. Goering, and P. K. Bienfang. APPRISE Technical Report, SFS-870, Vol. 1. Fairbanks: University of Alaska, School of Fisheries and Ocean Sciences.

Keywords: Alaska, Auke Bay, larvae

181. Haldorson, L., Watts, J., Sterritt, D., Pritchett, M., and McNutt, L. 1987. Larval fish production in Auke Bay, Alaska-1987. Component 4. *In* APPRISE: Association of Primary Production and Recruitment In a Subarctic Ecosystem, Vol. 1, p. 299-360. Edited by O. A. Mathisen, J. J. Goering, and P. K. Bienfang. APPRISE Technical Report, APP87-100. Fairbanks: University of Alaska, School of Fisheries and

Ocean Sciences.

Keywords: Alaska, Auke Bay, larvae

182. Haldorson, L., Pritchett, M., Sterritt, D., and Watts, J. 1992. Abundance patterns of marine fish larvae during spring in a southeastern Alaskan bay. Fishery Bulletin, U.S. 91:36-44.

Keywords: Alaska, Auke Bay, abundance, larvae

Abstract: "The osmerids in our study are most likely eulachon *Thaleichthys pacificus* and capelin *Mallotus villosus*. Eulachon is an anadromous species that spawns demersal, adhesive eggs in rivers. After hatching, the larvae are carried into nearby marine waters. The most likely source of eulachon larvae in Auke Bay is the Mendenhall River, a glacier-fed stream about 2 km east of Auke Bay. The fresh and turbid waters from the Mendenhall River form a surface lens that projects out into nearby Fritz Cove and often intrudes into the eastern edge of Auke Bay through a narrow passage northeast of Spuhn Island (Fig. 1). In 1987 we studied the depth distribution of fish larvae in Auke Bay and found that osmerids were always concentrated above the pycnocline and moved to the surface at night (unpubl. data). Most other species were found at or below the pycnocline and tended to move deeper at night. Therefore, interannual and seasonal variation in osmerid abundance may reflect variation in the amounts of river water reaching Auke Bay."

183. Halpin, M. M., and Seguin, M. 1990. Tsimshian peoples: Southern Tsimshian, Coast Tsimshian, Nishga, and Gitksan. *In* Handbook of North American Indians, Vol. 7: Northwest Coast. Edited by W. C. Sturtevant and W. Suttles. Washington, D.C.:

Smithsonian Institution.

Keywords: subsistence

184. Hammond, L. 1990. Tape transcription of Haines eulachon workshop, May 1, 1990. Juneau: Alaska Department of Fish and Game, Division of Subsistence.

Keywords: Alaska, subsistence

185. Harbo, R., Convey, L., Boutillier, J., and Hay, D. 2000. Pacific coast shrimp trawl fisheries: New management and assessment co-management programs. Journal of Shellfish Research 19(1):559.

Keywords: British Columbia, bycatch

Abstract: "At-sea observers on board commercial vessels, research cruises and plant sampling have been undertaken to determine the catch composition and develop preliminary estimates of by-catch, with an emphasis on eulachon and halibut."

186. Harger, D. 1954. Oregon's smelt run. Fisherman 22:14-16.

Keywords: Oregon

187. Harke, V. L., and Lucey, W. G. 2000. Seasonal abundance of Steller sea lions at Dry Bay, Alaska. Yakutat, AK: U.S. Department of Agriculture, Forest Service, Tongass National Forest, Yakutat Ranger District. 6 p.

Keywords: Alaska, Alsek River, predators (mammals), spawning

Abstract: "In the Yakutat area, Steller sea lions are known to congregate at Dry Bay each year. The animals haul-out at the mouth of the Alsek River, or sometimes they haul-out on gravel islands one or two miles upriver from the mouth. Steller sea lions may use Dry Bay as a seasonal feeding area, as they are

usually present when eulachon (*Thaleichthys pacificus*) are spawning from February to May."

"During the study period, eulachon were most abundant in late March and rapidly declined during the first two weeks of April."

"These observations indicate that perhaps 4% to 5% of the total Southeast Alaska population of sea lions may be present in the Yakutat area during the spring eulachon runs from February through May."

188. Harrington, L. 1953. On the trail of the candlefish. The Beaver: March.

Keywords: British Columbia; historical

189. Harrington, R. 1967. Eulachon and the grease trails of British Columbia. Canadian Geographic Journal (January):28-31.

Keywords: British Columbia; historical; grease

190. Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin No. 180. 739 p.

Keywords: general references on fish

191. Hart, J. L. 1943. Comparison of eulachon catch statistics for three years. Fisheries Research Board of Canada Pacific Program Report No. 56, p. 6.

Keywords: British Columbia, population status\

Abstract: note from Langer et al. (1977): "Catch, effort statistics presented for Fraser River, 1942 and 1943. No decline in eulachon availability was noted."

192. Hart, J. L., and McHugh, J. L. 1944. The smelts (Osmeridae) of British Columbia. Fisheries Research Board of Canada Bulletin No. 64. 27 p.

Keywords: British Columbia, abundance, age at spawning, distribution,

geographic, eggs, fecundity, fisheries (commercial), historical, larvae, length, morphology, predators (fish), predators (mammals), scales, sex ratio, sexual dimorphism, size, skeleton, spawning, subsistence

Abstract: An excellent source of information about the historical abundance and use of eulachon in British Columbia.

193. Harvey, J. T. 1987. Population dynamics, annual food consumption, movements, and dive behaviors of harbor seals, *Phoca vitulina richardsi*, in Oregon. Dissertation. Corvallis: Oregon State University. 189 p.

Keywords: Oregon, otoliths, predators (mammals)

Abstract: "The results of experiments with captive harbor seals indicated that only 25-34% of some fish species (e.g. *Engraulis mordax*, *Clupea harengus*, and *Thaleichthys pacificus*) was represented as otoliths in feces, whereas with other species it was 80%. Over 80% of the otoliths were excreted within 24 h of ingestion. Mean reduction in otolith length (X = 27.5%, SD = 10.3) was not significantly different among fish species."

194. Harvey, J. T., Loughlin, T. R., Perez, M. A., and Oxman, D. S. 2000. Relationship between fish size and otolith length for 63 species of fishes from the eastern North Pacific Ocean. U.S. Department of Commerce, NOAA Technical Report NMFS 150. 48 p.

Keywords: Pacific Ocean, otoliths

195. Hawthorne, H. B., Belshaw, C. S., and Jamieson, S. M. 1960. The Indians of British Columbia: A study of contemporary social adjustment. Toronto: University of

Toronto Press.

Keywords: British Columbia, subsistence

196. Hay, D., and Boutillier, J. 1999. Eulachon. Fisheries and Oceans Canada, Pacific Region. 5 p.

Keywords: Canada

197. Hay, D. E. 1996. Coastal pelagics—Herring and eulachon. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2108, Proceedings, Marine Ecosystem Monitoring Network—1995 March, Nanaimo, Canada. p. 33-36.

Keywords: British Columbia, Fraser River, Klinaklini River, Nass River, Washington, Columbia River, fisheries (commercial), spawning

Abstract: "The Eulachon is an anadromous smelt that usually does not catch the attention of many people. There is very little published information and most of the information presented here is from unpublished data or informal sources. However, this has recently changed."

"Eulachon runs decreased sharply in 1994 in 3 rivers: the Columbia, the Fraser and the Klinaklini at the head of Knight Inlet. The fishery for eulachons varies in size with the Columbia as the largest. In that river, catch statistics probably reflect abundance. The 1994 commercial catch of eulachons in the Columbia River was about 1-2% of the long term average catch. The 1995 eulachon catch was larger, but still only about 20% of the long term average. Fraser River eulachon catch statistics vary with market demand, so are not a guide to abundance. Nevertheless, the small commercial fishery was closed in 1994 because of concerns about the small catches."

"The synchronous decline in the runs in each of these three rivers could be coincidental, but perhaps there is a common cause. If there were similar declines in other rivers they have not yet been documented, although the fishery in the Nass River in northern B.C. did not seem affected. If there were a common explanation for the synchronous decline, we do not know where, when or how this could occur. The life history of eulachons varies with each river. Spawning times are mainly in February in the Columbia, late March and April in the Klinaklini and April to early May in the Fraser. The small, benthic eggs incubate in the rivers for 2-3 weeks prior to hatching when they are flushed into marine waters. Therefore, something affecting estuarine or ocean conditions seems reasonable as an explanation for synchronous declines in the three rivers. We know little of the marine life of eulachons; we are not even certain of their ages or whether they survive after spawning. Eulachons are now under intensive study in several rivers and we plan to bring much of the informal, unpublished information forward into accessible published reports. Those reports will include some time series data on catches in the Fraser River (1940s to present) and about 20 years of time series data on bycatches in offshore shrimp surveys."

198. Hay, D. E. 1998a. Bycatch in the shrimp trawl fishery: Eulachon Research Council meeting notes, 1998. Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

    Keywords: British Columbia, bycatch, distribution, geographic

199. Hay, D. E. 1998b. Historic changes in capelin and eulachon populations in the Strait of Georgia. *In* Back to the future: Reconstructing the Strait of Georgia ecosystem,

p. 42-44. Edited by D. Pauley, T. Pitcher, and D. Preikshot. University of British Columbia, Fisheries Centre Research Reports Vol. 6 No. 5. Vancouver

Keywords: British Columbia, Strait of Georgia, Columbia River, Fraser River, abundance, biology, distribution, geographic, historical, life history, predators (fish)

Abstract: "A brief review of the biology of two small pelagic species of the Strait of Georgia, capelin (*Mallotus villosus*) and eulachon (*Thaleichthys pacificus*) is given, with emphasis on distribution and historic change in abundance. The conclusion is drawn that the abundance of these two species one hundred years ago may not have been higher than today."

200. Hay, D. E. 1998c. Eulachon backgrounder (draft). Department of Fisheries and Oceans-Canada, Stock Assessment Branch. 4 p.

Keywords: British Columbia

201. Hay, D. E. 1999. Climate change and the decline of eulachons. Canadian Conference for Fisheries Research, January 1999, Edmonton, Alberta.

Keywords: British Columbia, population status

202. Hay, D. E., Boutillier, J., Joyce, M., and Langford, G. 1997. The eulachon (*Thaleichthys pacificus*) as an indicator species in the North Pacific. *In* Forage fishes in marine ecosystems, p. 509-530. Proceedings of the Wakefield Fisheries Symposium, Alaska Sea Grant College Program 97-01. Fairbanks: University of Alaska.

Keywords: Pacific Ocean, Columbia River, Fraser River, abundance, bycatch, distribution, geographic, historical, indicator species

Abstract: “Eulachons (*Thaleichthys pacificus*) were captured incidentally in annual shrimp trawl surveys conducted off the coast of southern British Columbia. We compiled these catch records and used spatial analysis to estimate eulachon densities. From this we derived an “offshore” index of abundance for nearly all years from 1973 to 1996. We compared the offshore index data with catch data from the Columbia and Fraser rivers. The offshore index is significantly correlated to eulachon catch records in the Columbia River but not with the Fraser River. In both rivers, however, there were sharp declines in 1994. This sharp decline was observed in the previous year (1993) in the offshore index. Declines in 1994 spawning runs also happened in some smaller rivers in British Columbia but no time series data are available. The offshore index time series appears to be influenced by the time trends in ocean climate, but in ways that we cannot explain. The offshore index varied positively with water temperature (sea surface temperature was used from Amphitrite Point, on the west coast of Vancouver Island). Fraser River varied negatively in relationship with temperature but there was no apparent relationship between Columbia River catches and temperature. There was, however, positive covariance between offshore index and Columbia River catches. Therefore, we found three relationships: (1) Fraser River catches were negatively related to temperature, (2) offshore eulachon abundance was positively related to temperature, and (3) the Columbia River catch was correlated with the offshore index. Although each relationship was statistically significant, we are less certain of the biological significance. The clearest results were the sharp declines in 1983 and 1993. The

1983 offshore decline preceded a sharp Columbia River catch decline by 1 year. The 1993 offshore decline preceded a widespread decline in most rivers, including the Columbia and Fraser, where eulachons are known to spawn—even though the timing of the spawning runs varies by 2-3 months. Synchronous (i.e., within a year) changes among different eulachon populations may reflect geographically widespread oceanographic changes (El Niño). In the rivers, there may be other, more localized, environmental changes affecting eulachons, particularly changes affecting spawning areas."

203. Hay, D. E. , Harbo, R., Boutillier, J., Wylie, E., Convey, L., and McCarter, P. B. 1999. Assessment of bycatch in the 1997 and 1998 shrimp trawl fisheries in British Columbia, with emphasis on eulachons. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat (PSARC), working paper 199:13, research document No. 99, 179. 45 p.

Keywords: British Columbia, bycatch

204. Hay, D. E., Harbo, R., Southey, C. E., Clarke, J. R., and McCarter, P. B. 1998. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch—with emphasis on eulachons. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, PSARC Working Paper 198: 8. 40 p.

Keywords: British Columbia, bycatch

205. Hay, D. E., Harbo, R., Southey, C. E., Clarke, J. R., Parker, G., and McCarter, P. B. 1998. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch with emphasis on eulachons. Department of Fisheries and

Oceans Canada, Canadian Stock Assessment Secretariat, Pacific Stock Advice Review Committee (PSARC) working paper, January 1998, research document 99, 26. 40 p.

Keywords: British Columbia, bycatch, distribution, geographic

206. Hay, D. E., Harbo, R., Southey, C. E., Clarke, J. R., Parker, G., and McCarter, P. B. 1999. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch with emphasis on eulachons. Nanaimo, B.C.: Department of Fisheries and Oceans Canada. 45 p.

Keywords: British Columbia, bycatch, distribution, geographic

207. Hay, D. E., Harbo, R., Southey, K., Clarke, J., Parker, G., and McCarter, P. 1999. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch—with emphasis on eulachons. Canada Department of Fisheries and Oceans, Canadian Stock Assessment Secretariat, Research Document 99, 26. Ottawa. 45 p.

Keywords: British Columbia, bycatch

208. Hay, D. E., Healey, M. C., Ware, D. M., and Wilimovsky, N. J. 1992. Distribution, abundance, and habitat of prey fish on the west coast of Vancouver Island. *In* The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island. Edited by K. Vermeer, R. W. Butler, and K. H. Morgan. Canadian Wildlife Service Occasional Paper No. 75.

Keywords: British Columbia, abundance, larvae, mixed-species schools

Abstract: Larvae enter the sea in late spring and reach the west coast of Vancouver Island by midsummer. They mature after 2 to 3 years at an average

length of about 20 cm. Eulachon were more abundant in the 1950s than after 1970. They sometimes occur in mixed-species schools, with young herring and anchovy.

209. Hay, D. E., and McCarter, P. B. 1999. Distribution of spawning eulachon stocks in the central coast of British Columbia as indicated by larval surveys. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 99, 177. Ottawa. 64 p.

    Keywords: British Columbia, distribution, geographic, larvae

210. Hay, D. E. and McCarter, P. B. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145. Ottawa. 92 p.

    Keywords: Canada, biology, bycatch, distribution, geographic, eggs, fisheries, fecundity, genetics, habitat, fisheries (commercial), historical, illustrations, larvae, otoliths, population status, run timing, spawning, straying, subsistence, taxonomy

    Abstract: “The anadromous eulachon (*Thaleichthys pacificus*) is a small species of smelt that spawns in the lower reaches of coastal rivers and streams from northern California to the southern Bering Sea. Nearly all eulachon spawning runs have declined from California to south-eastern Alaska in the last 20 years, especially since the mid-1990’s. The causes of the declines are uncertain, and this paper reviews and comments on the main suggestions and explanations. Climate change is implicated as a cause of a general decline, but other factors cannot be overlooked, including local habitat alterations and bycatch in commercial trawl fisheries. The decline of eulachons is a concern for many First Nations, for whom

the eulachon is of major cultural significance, especially as a source of an important traditional staple called ‘grease’. The status of eulachons also concerns fisheries managers and the commercial fishing industry because eulachons are common as bycatch in shrimp trawls in some areas. The decline of eulachons has prompted specific management actions to limit eulachon bycatch, and such actions may reduce potential shrimp catches in some areas. The available biological information on eulachons is fragmentary and previously has not been synthesized into a single document. This paper attempts to pool and summarize the available biological information on eulachons prior to commenting on their biological status. Genetic evidence, which is subject to confirmation, indicates that eulachons constitute a single ESU (evolutionary significant unit) throughout their entire range. Other biological data, including data on meristic analyses and river-specific spawning times indicate that there is substantial local stock structure. This may indicate that although different eulachon stocks are genetically coupled, presumably through straying or mixing, different rivers (or estuaries) probably represent demographically uncoupled stocks. Therefore we point out that probably it is precautionary to assume that stock structure is geographically fine, until shown otherwise. The significance of the genetic data to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is that classification applies at the level of the ESU, or a significant part of it. Available evidence suggests that [runs in] several rivers in the central coast of BC 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 for more than 20 years. Based on these observations, we suggest that the widespread decline in the southern part of the range warrants a COSEWIC classification of 'threatened' in Canadian waters. We further point out, however, that this status could change rapidly as the abundance of immature eulachons in southern offshore waters is substantially greater in 2000 than in the previous decade. If this offshore abundance is indicative of stronger spawning runs in future years, then the classification of 'threatened' may be too severe. On the other hand, the abundant offshore eulachons appear to be mainly from the 1999-year class, which probably will spawn in 2002, and may not contribute to stronger spawning runs in year 2001. We conclude with a plea for the development and implementation of policy for eulachon management, which will cover issues such as commercial fisheries for eulachons, forest industry interactions, dredging and habitat alteration in spawning areas, pollution of spawning rivers and bycatch in offshore trawl fisheries. In this regard, as a potential policy template, we include a short section of recommendations, modified to suit eulachons, from the recent draft of the DFO 'Wild Salmon Policy' paper."

211. Hay, D. E., McCarter, P. B., Joyce, M., and Pedersen, R. 1997. Fraser River eulachon biomass assessments and spawning distribution based on egg and larval surveys. Department of Fisheries and Oceans Canada, Canadian Stock

Assessment Secretariat, Pacific Stock Assessment Review Committee (PSARC) Working Paper G97-15. 60 p.

Keywords: British Columbia, Fraser River, biomass, eggs, larvae, spawning

212. Hay, D. 1995. The mysterious eulachon. The Westcoast Fisherman (March):47.

213. Herald, E. S. 1961. Living fishes of the world. Garden City, NY: Doubleday and Co., Inc. 304 p.

Keywords: general references on fish

214. Herald, E. S., and Simpson, D. A. 1955. Fluctuations in abundance of certain fish in South San Francisco Bay as indicated by sampling at a trash screen. California Fish and Game 41:271-78.

Keywords: California, abundance

215. Higgins, P. S., Birtwell, I. K., Atagi, B. T., Chilton, D., Gang, M., Kruzynski, G. M., Mahood, H., Piercey, G. E., Raymond, B. A., Rogers, I. H., and Spohn, S. 1987. Some characteristics of the eulachon (*Thaleichthys pacificus*) captured in the Fraser River estuary, B.C., April 1986. Department of Fisheries and Oceans Canada, Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1913. West Vancouver. 47 p.

Keywords: British Columbia, Fraser River, age at spawning, gonad development, length, length-weight relationship, liver development, morphology, otoliths, sex ratio, size, spawning

Abstract: “Morphometric characteristics of eulachons (*Thaleichthys pacificus*) captured in gill nets (2.50, 3.75 cm mesh size) and undergoing spawning migrations through the Fraser River estuary between April 8 and 29, 1986 were

examined. Site specific and sexually based differences in length-weight relationships, length frequency, gonad and liver development and age frequency were documented in relation to an investigation of organic contaminants in these fish."

"Variation in fish size was found to be dependent on the sex of the fish and unrelated to the site of capture. Male eulachons (mean fork length ± S.D.: 181 ± 13.82 mm, n = 325) were found to be larger than females (mean fork length ± S.D.: 161 ± 23.52 mm, n = 95). Notwithstanding gill net selectivity, length frequency analysis revealed that 60% of the fish were between 175-195 mm fork length, and males outnumbered females by a ratio of 3.4 to 1. Evidence of unimodal length distribution of males and a bimodal distribution of females were also observed."

"Based upon the burnt otolith techniques of age determination, it was deduced that age IV+, V+, VI+ and VII+ fish were represented in our catches, most fish were from age IV+ (40%) and V+ (45%) cohorts."

"Variation in gonadal and hepatic development, based on gonadal and hepatosomatic indices, was [more] significant between the sexes than between the capture sites. Female eulachons had greater development in both organ systems than did males as did males over immatures."

"Correlation analysis between morphometric characteristics and the distance of the capture site from the river mouth revealed further sexual differences. Male fork length, gonad and liver size increased with capture distance from the mouth.

While female liver size increased with distance from the river mouth, there was no similar correlation between fork length or gonad size."

216. Hinrichsen, R. A. 1998. The ghost run of the Cowlitz. Cowlitz Historical Quarterly 40(2):5-21.

Keywords: Washington, Cowlitz River, historical, run timing

Abstract: An historical account of fishing on the Cowlitz River and variation in run size over a 60-year period.

217. Hocutt, C. H., and Wiley, E. O., Editors. 1986. The zoogeography of North American freshwater fishes. A Wiley-Interscience Publication. New York: John Wiley and Sons. 866 p.

Keywords: distribution, geographic, zoogeography

218. Hooper, H. M. 1985. Nutrient analysis of twenty southeast Alaska native foods. Report No. 2, revised. Mt. Edgecumbe, AK.

Keywords: Alaska, Southeast, nutrient content, proximate composition

219. Horwood, D. 1990. Ancient grease. Alaska Magazine (August):42-47.

Keywords: historical, oil, predators (birds), predators (fish), predators (mammals), subsistence

Abstract (from FirstSearch): "Pacific Coast eulachon (fish) were a precious trade commodity centuries ago because of the oil produced from them. Travelers traded otter, marmot and sometimes even children, for fishing rights, shelter and eulachon oil."

220. Howe, A. L., Walker, R. J., Olnes, C., Heineman, G., and Bingham, A. E. 1999. Harvest and catch in Alaska sport fisheries during 1998. Alaska Department of

Fish and Game, Fishery Data Series No. 99-41. Anchorage. 128 p.

Keywords: Alaska, fisheries (sport)

221. Howell, M., and Uusitalo, N. M. 2001. Eulachon (*Thaleichthys pacificus*) studies related to lower Columbia River channel deepening operations. Report to be submitted to the U.S. Army Corps of Engineers, Portland, Oregon.

Keywords: Columbia River

222. Hubbs, C. L. 1925. A revision of the osmerid fishes of the North Pacific. Proceedings of the Biological Society of Washington No. 38. p. 49-56

Keywords: Pacific Ocean, taxonomy

Abstract: note from Langer et al. (1977): "Eulachons without teeth apparently regarded as separate species from those with teeth."

223. Huntington, H. P. 2000. Traditional knowledge of the ecology of belugas in Cook Inlet, Alaska. Marine Fisheries Review 62(3):134-40.

Keywords: Alaska, Beluga River, Placer River, Cook Inlet, predators (mammals)

Abstract: "By Tyonek and in the flats by Beluga River, belugas arrive in late April, following the whitefish and then the eulachon, *Thaleichthys pacificus* (also known as hooligan or candlefish), and Pacific salmon, *Oncorhynchus* sp. Belugas go up Beluga River, which is shallow with a rocky bottom, and there are reports of them going as far as Beluga Lake over 30 mi (50 km) upstream."

"Belugas will travel to the upper end of Turnagain Arm, after hooligan in May and silver salmon in fall. They will travel past the Seward Highway bridge over the Placer River."

"When feeding on hooligan, the belugas are often in a frenzy and will chase the

fish up dead-end channels where they are trapped and the belugas can gorge on them."

224. Imler, R. H., and Sarber, H. R. 1947. Harbor seals and sea lions in Alaska. U.S. Fish and Wildlife Service Special Scientific Report No. 28. 23 p.

Keywords: Alaska, Southeast Alaska, Copper River, predators (mammals)

Abstract: "Notes on harbor seal observations were recorded daily during the 5 weeks' study on the Copper River. On June 12, near the height of their pupping season, approximately 280 seals were observed around the mouth and in the lower three miles of King Salmon Slough. A large run of eulachon (*Thaleichthys pacificus*) was moving up this stream, which is a part of the Copper River, and the seals were feeding exclusively on these fish."

"Seals collected in the Copper River district were feeding almost entirely on eulachon (*Thaleichthys pacificus*). Of the 67 stomachs tabulated from that area 64 contained only eulachon, two contained salmon and one, cod."

"Eulachon (*Thaleichthys pacificus*) and salmon were prominent foods in 1945 but much less so in 1946, when the salmon run was very poor."

"On the Copper River Delta the harbor seals were feeding principally on eulachon (*Thaleichthys pacificus*) during May and June but they were also taking some salmon."

"In southeastern Alaska the most common food in seal stomachs was gadids (pollack and tom cod). Other items of frequent occurrence were shrimp, herring, flounder, eulachon and salmon."

Table of stomach contents of harbor seals from Southeast Alaska shows for

eulachon: (a) for 39 seals, 1945—by volume 19.7%, by frequency 21%; (b) for 60 seals, 1946—by volume 5%, by frequency 5%; (c) for 99 seals, 1945-46—by volume 10.9%, by frequency 11%.

225. Isabella, J. 1999. A turbulent industry: Fishing in British Columbia. The Journal of the Maritime Museum of British Columbia 45, Spring 1999.

Keywords: British Columbia, fisheries (commercial)

226. Ivanov, V. N. 1983. Biology of the Far Eastern anadromous fishes. In Russian. Vladivostok: Izd.Dal'nevost. Univ. 132 p.

Keywords: biology

Abstract: "Several papers are devoted to the biology of Pacific redfin, eulachon, goy and to the results of acclimatization of Pacific mullet in the Black Sea."

227. Iverson, S. J., Frost, K. J., and Lang, S. L. C. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: Factors contributing to, among, and within species variability. Marine Ecology Progress Series 241(4 Oct):161-81.

Keywords: Alaska, Prince William Sound, fat content, fatty acid composition

Abstract: "We determined the fat content and fatty acid composition of 26 species of fish and invertebrates (n = 1153) that are primary forage species of piscivorous seabirds and marine mammals in Prince William Sound (PWS), Alaska. Flatfish, shrimps and octopus had the lowest average fat contents (approximately 1.0%), although some cods, as well as juvenile walleye pollock *Theragra chalcogramma*, Pacific herring *Clupea harengus pallasi* and pink salmon *Oncorhynchus gorbuscha* also ranged as low as 0.5 to 0.7 % fat. The highest fat contents were

found in eulachon *Thaleichthys pacificus* (25%), adult herring (21%) and the squid *Berrytheuthis magister* (5 to 13%)."

228. Jacobs, M., Jr., and Jacobs, M., Sr. 1982. Southeast Alaska native foods. *In* Ravens Bones. Edited by Andrew Hope III. Sitka, AK: Sitka Community Association.

Keywords: Southeast Alaska, subsistence

229. Jeffries, S. 1984. Marine mammals of the Columbia River estuary. Olympia, WA: Washington State Department of Game. 95 p.

Keywords: Columbia River, predators (mammals)

Abstract: "Analyses of harbor seal feeding habits were based on 436 scats collected June 1980 to April 1982 in the Columbia River. Annual abundances of northern anchovy and eulachon were preyed upon in season by almost all harbor seals in the Columbia River."

230. Jennings, M. R. 1996. Past occurrence of eulachon, *Thaleichthys pacificus*, in streams tributary to Humboldt Bay, California. California Fish and Game 82(3):147-48.

Keywords: California, Humboldt Bay, distribution, geographic

Abstract: "The substantial decline of eulachon, *Thaleichthys pacificus*, in northern California over the past two decades has stimulated efforts to document past occurrences of this fish at the southern edge of its range (Moyle et al., 1995). The most southern spawning run of eulachon was in the Mad River, Humboldt County, California (Odemar 1964). South of this drainage, eulachon have occasionally been found during the winter in Humboldt Bay (Barnhart et al.

1992), but there are no reports of adults in tributary streams. I present evidence that, in the recent past, eulachon spawned in streams tributary to Humboldt Bay."

231. Johnstone, N. T., Albright, L. J., Northcote, T. G., Oloffs, P. C., and Tsumura, K. 1975. Chlorinated hydrocarbon residues in fishes of the Lower Fraser River. University of British Columbia, Westwater Research Center, Technical Report No. 9. 31 p.

Keywords: British Columbia, Fraser River, contaminants

232. Jones, B. C., and Geen, G. H. 1977. Food and feeding of spiny dogfish (*Squalus acanthias*) in British Columbia waters. Journal of the Fisheries Research Board of Canada 34:2067-78.

Keywords: British Columbia, predators (fish)

233. Jones, L. F. 1914. A study of the Thlingets of Alaska. New York: Fleming H. Revell Company.

Keywords: Alaska, subsistence

234. Jordan, D. S. 1925. Fishes. New York: Appleton. p. 129-130, 347-349.

Keywords: general references on fish

Abstract: note from Langer et al. (1977): "Considered eulachon (*Thaleichthys pacificus*) first in ranks of food-fish. Said to reach lengths of about a foot. Mention of predation by fish (including sturgeon) and sea-birds."

235. Jordan, D. S., and Evermann, D. W. [1896-1900?]a. The fishes of Middle and North America. Bulletin of the U.S. National Museum 47(3):2823.

Keywords: general references on fish

236. Jordan, D. S., and Evermann, D. W. [1896-1900?]b. The fishes of Middle and North America. Bulletin of the U.S. National Museum 47(1):521.

Keywords: taxonomy

Abstract: note from Langer et al. (1977): "Names eulachons as *Thaleichthys pacificus* (Richardson), notes length of 12 inches. Early brief, general description also records new species *Osmerus albatrossis* from Kodiak Island, Alaska that is actually eulachon."

237. Jordan, D. S., and Gilbert, C. H. 1881. List of the fishes of the Pacific coast of the United States, with a table showing the distribution of the species. Proceedings of the National Museum, Vol. 3. p. 452-458

Keywords: geographic distribution, taxonomy

238. Jordan, D. S., and Evermann, B. W. 1923. American food and game fishes: a popular account of all species found in America north of the equator, with keys for ready identification, life histories and methods of capture. New York: Doubleday, Page and Co. p. 225-231

Keywords: life history, taxonomy

239. Jordan, D. S., and Gilbert, C. H. 1899. The fishes of Bering Sea. *In* Fur seals and fur seal islands of the North Pacific Ocean, Part 3. Edited by D.S. Jordan . 433-n.g.

Keywords: Alaska, Bering Sea, geographic distribution

240. Jordan, D. S., and Starks, E. C. 1895. The fishes of Puget Sound. Proceedings California Academy of Science(s) 2, Ser. 5 [reprint in Contrib. Bio. Hopkins Seaside Lab. 3:1-71]. p. 785-855

Keywords: Washington, Puget Sound, geographic distribution

241. Kajimura, H., Fiscus, C. H., and Stroud, R. K. 1980. Food of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington: With appendices on size and food of Dall's porpoise from Alaskan waters. Edited by K. G. Konstantinov. U.S. Department of Commerce, NOAA Technical Memorandum. Seattle: National Marine Fisheries Service, Northwest and Alaska Fisheries Center. 33 p.

Keywords: predators (mammals)

Abstract: "Listed as prey of the *P. dalli* for the first time are: *Thaleichthys pacificus*; *Cololabis saira*; *Theragra chalcogramma*; *Ammodytes hexapterus*; pleuronectids; and the squid, *Octopoteuthis* sp., *Berryteuthis magister* and *G. borealis*."

242. Keller, K. 1998. Eulachon on the Fraser. Canadian Geographic 108 (Feb, Mar):54-56.

Keywords: British Columbia, Fraser River, fisheries (commercial), fisheries (subsistence), historical

Abstract: An account of commercial fishing for eulachon in the Fraser River in 1987.

243. Kelson, J. 1996. Kitamaat River 1995 oolichan (*Thaleicthys pacificus*) study. Report prepared by the Kitamaat Village Council for Forest Renewal B.C.

Keywords: British Columbia, Kitamaat River

244. Kimsey, J. B., and Fisk, L. O. 1960. Keys to the freshwater and anadromous fishes of California. California Fish and Game 4:453-79.

Keywords: California, taxonomy

245. Kincaid, T. 1919. An annotated list of Puget Sound fishes. Olympia: State of Washington Department of Fisheries. Frank M. Lamborn, public printer.

Keywords: Washington, Puget Sound, geographic distribution, historical

246. King, R., Sr. 1990. Tape transcription of Haines eulachon workshop, May 1, 1990. Juneau: Alaska Department of Fish and Game, Division of Subsistence.

Keywords: Southeast Alaska

247. Klyukanov, V. A. 1970. Classification of smelts (Osmeridae) with respect to peculiarities of skeleton structure in the genus *Thaleichthys*. Zoologicheski Zhurnal 49:399-417.

Keywords: skeleton, taxonomy

Abstract: Until recently, smelts were divided into two subfamilies, Osmerinae (*Osmerus*, *Allosmerus*, *Spirinchus*, *Thaleichthys*) and Hypomesinae (*Hypomesus*, *Mallotus*). A comparative osteological study of all genera has established that the skeleton of *Thaleichthys* is distinctive from the rest of the family, especially the pronounced development of chondrocranium and a peculiar junction of the gill cover with the visceral skeleton. *Thaleichthys* is the most primitive of osmerid genera and should be treated as a separate subfamily Thaleichthyinae.

248. Klyukanov, V. A. 1976. The evolution and distribution of the smelts of the family Osmeridae. Acts of the 2nd European Ichthyological Congress Organized With the National Museum of Natural History. Paris, UNESCO. 8-15 September 1976

40(3-4):641.

Keywords: Pacific Ocean, geographic distribution, evolution, taxonomy

Abstract: “There are more species of smelts in the Pacific ocean than in the Atlantic. There are three endemic genera in the Pacific (*Thaleichthys*, *Spirinchus* and *Allosmerus*) and the primitive nature of the first two genera confirms the Pacific origin of smelts. *Thaleichthys* has the greatest number of primitive characters. The endemic genera are confined to the coasts of North America, except for the amphipacific *Spirinchus*. The break in the continuous range of *Spirinchus* and its differentiation into species apparently took place in the Pleistocene. The Pacific species of *Osmerus* and the most advanced members of the Hypomesinae, *Mallotus* and *Hypomesus* migrated into the Polar basin at the end of the Pliocene, became widely distributed and representatives of *Osmerus* and *Mallotus* reached the Atlantic. Progressive cooling of the seas and the encroachment of the glaciers encouraged them to move along the European and North American coasts. Their continued isolation from the Pacific forms led to the development of the species and subspecies *O. eperlanus*, *O. mordax mordax* and *Mallotus villosus villosus*. In the postglacial period *O. eperlanus* became widely distributed throughout Europe and *O. m. mordax*, in North America, formed anadromous, lake-river and lake forms. The Pacific smelt *O. m. dentex* Steindachner, reached the White Sea again with postglacial period where it now occurs with *O. eperlanus*. During this period the Pacific capelin had the chance to extend its range into the Arctic Seas, but the lowered salinity prevented both it, and the Atlantic form, from spreading. In the Pleistocene, the continuous North

Pacific coastline separated into two parts. As a result the genus *Hypomesus* speciated into eastern and western forms *H. japonicus* and *H. pretiosus*. These species were ancestral to *H. nipponensis* and *H. transpacificus* which occupy the niches free from the more northerly *H. olidus*. The latter species apparently separated from the ancestral form in the Pliocene and had time to colonise widely in the polar basin before glacial cooling. In the Littorina period it migrated into the Arctic seas and the fall of temperature in the Holocene stopped their further movement."

249. Kopas, C. R. 1950-1951. Delate klush muck-a-muck. Northwest Digest 6, 7: 4-5, 32.

Keywords: subsistence

Abstract: Note from Langer et al. (1977): "Popular account of native eulachon fishery—Bella Coola."

250. Kopas, L. 1974. Eulachon the savior fish. Wildlife Review 7(2).

Keywords: subsistence

Abstract: Note from Langer et al. (1977): "Popular account of the eulachon fishery."

251. Kopas, L. 1980. Oil of oolichan. Beautiful British Columbia (Winter):35-38.

Keywords: British Columbia, oil, subsistence

252. Koppel, T. 1997. Forests of the sea. Canadian Geographic 117(2):68.

Keywords: oil, subsistence

Abstract: "The Haida, Salish and other coastal native peoples made ample use of kelp. Bull kelp stipes were stretched and twisted into strong fishing lines and the

hollow bulbs and thicker ends of the stipes were dried and used as bottles to store the highly prized oil from the smelt-like eulachon fish."

253. Koppel, T. 1998, 99. Catching the saviour fish. Beaver: Exploring Canada's History. December, January 78(6):20-25.

Keywords: British Columbia, historical, subsistence

Abstract: "Focuses on the eulachon fish that flourishes along Nass River valley in the northwestern British Columbia. Qualities of the fish; Abundance of the fish in the Nass River during spring; Information on the social life and condition of the Nisga'a Indians."

254. Krause, A. [1885] 1970. The Tlingit Indians: Results of a trip to the northwest coast of America and the Bering Straits. Translated by Erna Gunther. Seattle: University of Washington Press.

Keywords: historical, subsistence

255. Krzynowek, J. M. J. 1987. Proximate composition, energy, fatty acid, sodium, and cholesterol content of finfish, shellfish, and their products. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Report No. NMFS 55. Seattle. 53 p.

Keywords: moisture content, protein, proximate composition

256. Kubik, S. W., and Trent, T. W. [no date]. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna and Central Cook Inlet drainages. Alaska Department of Fish and Game, Division of Sport Fish Annual Report, Study G, Vol. 15.

Keywords: Alaska, Twentymile River, age at spawning, fisheries (sport), sex

ratio, spawning

Abstract: “Eulachon (*Thaleichtys pacificus*), spawning in Twentymile River, were 3 and 4 yr of age and had a 2:1 male to female ratio. An estimated 72,950 eulachon were harvested by recreational fishermen in 1973.”

257. Kuhnlein, H. V., Chan, A. C., Thompson, and J. N., Nakai, S. 1982a. Ooligan grease: A nutritious fat used by native people of coastal British Columbia. Journal of Ethnobiology 2(2):154-61.

Keywords: British Columbia, fatty acid composition, grease, nutrient content, vitamins

Abstract: “Marine fat, derived from several sources, was formerly used to great extent by Northwest Coast Indians as a flavor enhancer of many foods as well as for medicinal and ceremonial purposes. The most prominent source of food fat used by British Columbia native people has been from the ooligan (*Thaleichthys pacificus* Richardson, Osmeridae) a small fish which is harvested in bulk in early spring, allowed to ripen in large bins, and then rendered to give a pungent, golden, thick oil called “ooligan grease”. Samples from five preparations of this fat were made in 1981 from the Nuxalk Community of Bella Coola, B.C. and several nutrient analyses were done. Fatty acids, expressed as mean and range of percent methyl esters were: saturated at 32.2 (30-33), monounsaturated at 64.5 (63-66), and polyunsaturated at 0.9 (0.8-1.1). The principle fatty acid was oleic acid. In addition, there are small amounts of Kjeldahl N (16-19 ug/g), Ca (27-206 ug/g), and P (70-100 ug/g). Analyses with high pressure liquid chromatography yielded the following mean and range values for three fat soluble vitamins: vitamin A—

20 ug/g (18-29); vitamin E—220 ug/g (148-279); vitamin K—10 ug/g (4-13). It is concluded that ooligan grease is a nutrient-rich food fat that is currently consumed much less frequently than it was formerly."

258. Kuhnlein, H. V., Turner, N. J., and Kluckner, P. D. 1982b. Nutritional significance of two important "root" foods (Springbank clover and Pacific silverweed) used by native people on the coast of British Columbia. Ecology of Food and Nutrition 12:18-95.

Keywords: oil, subsistence

259. Kuhnlein, H. V., Yeboah, F., Sedgemore, M., Sedgemore, S., and Chan, H. M. 1996. Nutritional qualities of ooligan grease: A traditional food fat of British Columbia first nations. Journal of Food Composition and Analysis. 9(1):18-31.

Keywords: British Columbia, Bella Coola, Kitimaat, Nass River, Kingcome Inlet, Knight Inlet, contaminants, ethnic foods, fat content, fatty acid composition, grease, moisture content, nutrient content, proximate composition, vitamins

Abstract: "Food composition including moisture, total fat, cholesterol, vitamin A, calcium, iron, zinc, fatty acids, and four heavy metals were measured in the traditional fish fat, ooligan grease and in ooligan fish (*Thaleichthys pacificus*), collected from five First Nations communities (Nass River, Kitimaat, Bella Coola, Kingcome Inlet, and Knights Inlet) in the coastal area of British Columbia, Canada. There were few differences in nutrient composition of ooligan grease collected from different sites. Ooligan fish and extracted grease had mean fat contents of 18.0% and 98.0%, respectively. Cholesterol in ooligan grease was 197 ± 76 mg, 100 g. Ooligan grease was a rich source of vitamin A (2000 ± 1200 RE,

100 g wet weight) and omega-3 fatty acids (19 ± 4.4 g, 100 g), but had less vitamin A compared to raw fish (3200 RE, 100 g). However, there was a 10-fold increase of omega-3 fatty acid in grease compared to ooligan fish fat, which may be attributed to microbial conversion of other fatty acids to docosahexaenoic acid during ooligan grease preparation. Ooligan fish, usually consumed whole, are a good source of calcium (300 ± 74 mg, 100 g), iron (1.8 ± 0.4 mg, 100 g), and zinc (1.6 ± 0.4 mg, 100 g). Mean heavy metal concentrations in ooligan grease were 140 ± 12 micrograms, 100 g arsenic, 1.8 ± 0.5 micrograms, 100 g cadmium, 0.3 ± 0.1 micrograms, 100 g mercury, and 2.0 ± 2.6 micrograms, 100 g lead. These concentrations are below guidelines established by Health Canada and Agriculture Canada."

260. Kuhnlein, H. V. 2000. The joys and pains of sampling and analysis of traditional food of indigenous peoples. Journal of Food Composition and Analysis 13(4):649-58.

Keywords: British Columbia, grease, nutrient content

Abstract: "At the opposite end of the spectrum of obtaining sufficient sample size is the case of sampling ooligan grease and the fish from which it is made. *Thaleichthys pacificus* is a small smelt-like fish harvested in early spring by many British Columbia First Nations for use as a flesh food as well as for making the traditional fat. As a result of ecological concerns for the health of the fish habitat, several First Nations requested investigation into the nutrient and organochlorine contents of ooligan grease. Nineteen community preparations of ooligan grease were sampled and analysed (Kuhnlein et al. 1996; Chan et al. 1996)."

"The fish are netted as a community effort, and approximately 2 t of fish are placed into a large wooden box constructed close to the river. The box is covered and the fish are left to 'ripen' at ambient spring temperatures for 10 days to 2 weeks, after which the grease is prepared. Preparation involves placing the ripened fish into a simmering water bath; the oil rises to the top of the water and is skimmed off. The recovered oil is then strained, reheated and strained again; it is then bottled and stored in a cool place or in a freezer. Each family preparation is different, depending on the conditions of ripening, the stage to which the fish develop before cooking, and the final stages of reheating and bottling. Each ripening box containing about 2 t of fish will yield from 15 to 20 gallons of finished ooligan grease."

"Ooligan grease is a cherished food of First Nations. It has been said that appreciation of its flavour identifies 'Indian-ness' in the individual. The finished product is used as a food condiment with many other traditional food items, such as dried fish, berries, roe, etc.; it is also recognized as a traditional medicine and as a useful preservation agent. As a food, ooligan grease has some outstanding nutrient qualities (Table 5). While it is about 100% fat, it is comprised primarily of monounsaturated fatty acids (37%). The raw fish are an excellent source of retinol (25,000 RE 100 g) and the finished, processed oil is still an outstanding source (1200 RE 100 g). The contents of total omega-3 fats in the finished oil in contrast to the raw fish demonstrate that there is some enhancement during the preparation process, probably during the microbiologically induced ripening stage."

"This example of sampling a traditional food product demonstrates that it is possible to thoroughly sample a food. Nineteen preparations of ooligan grease represent approximately 38 t of fish and in excess of 285 gallons of finished grease. The interest and collaboration of the First Nations communities and research assistants contributed greatly to make this project a sampling success."

261. Laake, J. L., Browne, P., DeLong, R. L., and Huber, H. R. 2002. Pinniped diet composition: A comparison of estimation models. Fishery Bulletin 100(3):434-47.

Keywords: Washington, Columbia River, otoliths, predators (mammals)

Abstract: The authors talk about smelt, and in the Lower Columbia these are likely to be mostly eulachon.

262. Langer, O. E., Shepherd, B. G., and Vroom, P. R. 1977. Biology of the Nass River eulachon (*Thaleichthys pacificus*). Department of Fisheries and Environment Canada, Fisheries and Marine Service, Technical Report Series No. PAC, T-77-10. 56 p.

Keywords: British Columbia , Nass River, age at spawning, bibliography, eggs, fisheries (commercial), fisheries (subsistence), length, log handling effects, migration, sex ratio, spawning

Abstract: "The upriver migratory and spawning activities of the Nass River eulachon (*Thaleichthys pacificus*) runs from 1969 to 1971 were examined in connection with possible detrimental effects from log driving. Echo-sounding, gillnetting, and dipnetting techniques were used to determine annual and seasonal variations in timing and distribution of adults and eggs. Catches of adults were sampled to determine sexual characteristics, sex ratios, age, and length. Results

were compared with those available for other runs, and three possible impacts of the log drive on the Nass run were identified. An annotated eulachon bibliography has been appended to this report."

263. Larkin, P. A., and Ricker, W. E. 1964. Canada's Pacific marine fisheries: Past performance and future prospects. *In* Inventory of the natural resources of British Columbia. B.C. Natural Resources p. 249

Keywords: British Columbia , fisheries (commercial), population status

Abstract: Note from Langer et al. (1977): "Suggest Fraser River run to be under-exploited, but vulnerable to pollution by expanding industrialization"

264. Larson, K. W., and Moehl, C. E. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. *In* Effects of dredging on anadromous Pacific Coast fishes. Workshop proceedings, September 8-9, 1988. Edited by C. A. Simestad. Seattle: University of Washington Sea Grant Program.

Keywords: Columbia River, dredging, effects of dredging

Abstract: "Studies were conducted at the mouth of the Columbia River, USA, to determine the number and types of estuarine organisms entrained by hopper dredging. As part of the study, information was obtained on the number and types of fish species entrained. Fourteen species or species groups of fish were collected during the four [year] study. Eulachon (*Thaleichthys pacificus*) was the only anadromous species entrained. No juvenile or adult salmonids were collected. Numbers of individuals entrained were low for all species except Pacific sand lance (*Ammodytes hexapterus*), which were collected in moderate numbers throughout the study. None of the species collected showed any seasonality

except Pacific sand lance, which were slightly more abundant in the late summer. These results indicated that anadromous species were not entrained in any numbers by hopper dredging at the mouth of the Columbia River."

265. Lawrence, S. 1977. Eulachon salvation. Raincoast Chronicles (5):18-19.

Keywords: British Columbia, subsistence

Abstract: note from Langer et al. (1977): "Popular account of various methods used in earlier native eulachon fishing on British Columbia coast"

266. Levings, C. D. 1980. Vertical distribution and abundance of epibenthos and macrozooplankton in the lower Fraser River estuary. Edited by M. B. Collins, F. T. Banner, P. A. Tyler, S. J. Wakefield, and A. E. James. Canadian Data Report, Fisheries and Aquatic Sciences No. 241. 63 p.

Keywords: British Columbia, geographic distribution, larvae

Abstract: "Samples were obtained from Feb-Sept 1978 using a drift sampling technique and a large volume submersible pump. Simultaneous salinity and temperature measurements were obtained. 80 taxa were recorded at 4 sites, namely North Arm, Steveston Island (South Arm) Sea Reach, Canoe Pass, and Roberts Bank. When the salt wedge was present at the Steveston Island station, typical marine organisms such as chaetognaths, salps, and calanoid copepods were found in the bottom and middle of the water column. Copepod abundance ranged from approximately 0.1 to 10 m^3 when salinity levels were <15 ‰, but when salinity was >22 ‰, catches ranged up to 400 m^3. A preliminary analysis of the data showed that most of the abundant taxa were at either surface or bottom samples, except for larval eulachon (*Thaleichthys pacificus*) which were

distributed through the water column. At Roberts Bank, only 4 of the abundant taxa were heterogeneously distributed in the water column. At this location megalopa stages of *Cancer magister* were abundant (up to 13 m^3 in pump samples in July and August). A listing of temperature and salinity data is also provided."

267. Lewis, A. 1998. Skeena River eulachon study, 1997. Report prepared by Triton Environmental Consultants Ltd. (Terrace, B.C.) and the Tsimshian Tribal Commission (Prince Rupert, B.C.) for Forest Renewal B.C.

    Keywords: British Columbia, Skeena River

268. Lewis, A. 2001. Eulachon: Status, threats and research needs. Eulachon Conservation Society Bulletin 1 (February).

    Keywords: British Columbia, population status

269. Lewis, A. F. J., McGurk, M. D., and Galesloot, M. G. 2002. Alcan's Kemano River eulachon (*Thaleichthys pacificus*) monitoring program 1988-1998. Consultant's report prepared by Ecofish Research Ltd. for Alcan Primary Metal Ltd., Kitimat, B.C. 136 p.

    Keywords: British Columbia, Kemano River, Wahoo River, age at spawning, distribution within river, eggs, fecundity, fisheries (subsistence), habitat, hydrology, larvae, length, life history, migration, mortality, ovary weight, population status, run timing, salinity, sex ratio, sexual dimorphism, spawning, water temperature, weight

    Abstract: "Alcan Primary Metal British Columbia (formerly BC Operations, Alcan Smelters and Chemicals Ltd.) has investigated eulachon (*Thaleichthys pacificus*) in the Kemano River since 1988. This report provides detailed results

of scientific studies from 1988 to 1998. The goal of the Kemano River eulachon monitoring program was to establish baseline population and biology data, and to assess trends in eulachon abundance, biology, behaviour, and habitat use. These characteristics, in combination, provide data from which to assess eulachon stock status. The monitoring program was designed based on a preliminary understanding of Kemano River eulachon biology gained during 1980 (Envirocon 1984), and the program was revised continuously based on experience."

"Ten years of age data (1988 to 1990, and 1992 to 1998) based on otolith readings were compiled for eulachon from the Kemano River estuary. From these data, the mean age of eulachon was 4.0 years, ranging from 2 to 7 years of age, with a modal age of 4 years. No spawning checks were identified on the otoliths. For both sexes in every year, ages 3, 4 and 5 were the dominant age classes, with ages 2 and 6 accounting for no more than 14% and, in some years, none of the population."

"Eulachon varied in size between sexes, and among years and ages. Based on length and weight measurements taken from 7,061 specimens of all conditions, eulachon in the Kemano River estuary had a mean fork length of 182 mm. From a sample of 2,543 unspawned eulachon, mean weight was calculated as 45.6 g. Male eulachon weighed an average of 3.3 g more than female eulachon and were 2 mm longer."

"Fecundity averaged 27,047 eggs per female based on measurements of 516 females over 5 years of study. Within years, fecundity was normally distributed and displayed a near ten-fold range from 6,774 to 57,260 eggs (Figure 28)."

"The arrival of adult eulachon to the Kemano River estuary was remarkably consistent between years. From 1988 to 1997, eulachon arrived between March 18 and March 25. On average, eulachon arrived on March 22 but were as late as March 27. The beginning of the eulachon run was dramatic. Aggregations of gulls, eagles, seals and sea lions in Gardner Canal signalled the arrival of eulachon, and these predators followed the eulachon into Kemano Bay and the Kemano River estuary."

"Sex ratio was biased in favour of males. Sex ratio weighted by abundance was estimated at 1.56 : 1. For samples collected in-river in research beach seines, sex ratio averaged 25 males per female."

"A Scuba survey and sampling by suction sampler showed that eulachon eggs were distributed throughout the Kemano mainstem, Kemano sidechannel, and Wahoo River. At all these locations, thin layers of eggs covered the river bottom. Eggs were found adhering to individual pieces of gravel and cobble, as well as wedged between these particles. Eggs were also found lying on the sand, anchored to one or more grains of sand, as well as buried in the sand."

"In 1990, the standard lengths of 96 eulachon larvae were measured from four sites on five dates. Lengths fell within a relatively narrow range of 4 to 6 mm. In 1990, the migration began on or near May 9 and was estimated to peak on May 20. Migration continued for at least 20 days after this date, for a total estimated migration period of 40 days. The duration of egg incubation was 50 days."

"Egg-to-larvae survival was calculated by dividing larval abundance by egg abundance. In 1990, egg survival was 2.9% in the Kemano River, 0.7% in the

Wahoo River, and 2.9% combined. In 1997, egg-to-larvae survival was 4.8% in the Kemano River, 0.21% in the Wahoo River, and 1.5% combined."

"The fishery for Kemano River eulachon began at least hundreds and perhaps thousands of years ago. Only members of the Haisla Nation and their guests fish for the eulachon in this river. No commercial fishery for eulachon exists within B.C. Based on numbers given verbally (hailed) by the eulachon fishers daily, the fishery has taken between 32.5 and 146.5 tonnes of eulachon annually since 1988."

"The apparent decline in Kemano eulachon abundance creates a potential conservation concern. However, the status of the population is difficult to assess because our data span only eleven years. The observed decline could be typical of eulachon populations and not indicative of a longer trend. To put our observations into a broader perspective, we compared eulachon abundance in the Kemano River to the abundance of other populations."

"Kemano River eulachon population dynamics were compared to those populations with data for the same time period (1988-1998). Similar trends in abundance of Kemano, offshore and Columbia populations were observed. This may be evidence that marine fishing mortality or broad-acting environmental factors drive eulachon abundance. Whether this is part of a longer trend of decline will require additional monitoring."

270. Lewis, A. F. J., and O'Connor, P. J. 2002. Bella Coola eulachon study 2001. Consultant's report prepared by Ecofish Research Ltd. for Nuxalt Fisheries Commission, Bella Coola, B.C.

Keywords: British Columbia, Bella Coola, Paisla Creek, age at spawning, eggs, fecundity, fisheries (subsistence), larvae, life history, run timing, spawning, subsistence

Abstract: The Bella Coola River supports a little-studied spawning population of eulachon that has sustained a fishery by the Nuxalk Nation. Adult eulachon were sampled by gill-netting from 25 March to18 April, 2001, but only 43 adults were captured in the 52 gillnet sets in the Bella Coola and Paisla Creek. A total of 1570 eulachon eggs were collected during 476 plankton-net tows; of these, 676 eggs were dead and 894 were alive. Only 18 larval eulachon were captured in 2001 – 9 of them in March, earlier than reported for some other rivers. Most larvae migrated during the second half of April, an estimated four weeks after adults spawned. Despite the very small samples, the total number of eggs (10,283,000) and larvae (311,000) transported downstream was estimated by multiplying average weekly density by average weekly river flow, and summing the weekly estimates. The total adult population was back calculated from eulachon egg and larval abundance, assuming standard fecundity and sex ratio, as 0.030 tonnes of eulachon. Clearly, the Bella Coola run in 2001 was small, lower than that from some other rivers. Because of the trend of declining catches, together with low returns throughout Nuxalk territory, the run should be classified as Code 2 (intense protective action of uncertain duration), consistent with the status assessed by Hay and McCarter (2000).

271. Lincoln, J. H., Foster, R. F. 1943. Report on investigation of pollution in the lower Columbia River. Washington State Pollution Commission and Oregon State

Sanitary Authority. 143 p.

Keywords: Washington, Columbia River, water pollution effects

Abstract: note from Langer et al. (1977): "Stated that adult male smelt did not appear to suffer any ill effects from effluents discharged near Longview, WA."

272. Lindsey, C. C. 1957. Possible effects of water diversions on fish distribution in British Columbia. Journal of Fisheries Research Board of Canada 14:651-68.

Keywords: British Columbia, distribution, geographic, hydrology

273. Lindsey, C. C., and McPhail, J. D. 1986. Zoogeography of fishes of the Yukon and Mackenzie basins. *In* The zoogeography of North American freshwater fishes. Edited by C.H. Hocutt and E.O. Wiley. New York: John Wiley and Sons. p. 639-674.

Keywords: distribution, geographic

274. Lord, J. K. 1866. The naturalist in Vancouver Island and British Columbia, Vol. 1. London: Richard Bentley.

Keywords: British Columbia, oil, subsistence

Abstract: note from Langer et al. (1977): "Apparently contains details of native catch and process methods"

275. Lucey, B. 2001. Seasonal abundance of Steller sea lions at Dry Bay, Alaska. Yakutat, AK: U.S. Department of Agriculture, Forest Service, Tongass National Forest, Yakutat Ranger District.

Keywords: Alaska, Akwe River, Tawah Creek, predators (mammals), run timing, spawning

Abstract: “Sea lion abundance appears to coincide with the presence of eulachon in the Yakutat area. In 2001 sea lion peak abundance on the Akwe River, coincided with the eulachon run that occurred in early February. The first eulachon on the forelands were observed in Tawah Creek, a tributary of the Situk Ahrnklin Estuary, on January 20 by Mike Freeman a local ADF&G [Alaska Department of Fish and Game] employee. Sea lions and eulachon were first observed on a swan survey at the Akwe River on February 5. During the study period, eulachon were most abundant in late March and rapidly declined during the first two weeks of April.”

276. MacNair, P. L. 1971. Descriptive notes on the Kwakiutl manufacture of eulachon oil. Syesis 4:169-77.

Keywords: British Columbia, Knight Inlet, fisheries (subsistence), historical, oil

Abstract: “Details of the Kwakiutl rendering of eulachon oil have never been fully described in the literature. A detailed account is presented here, along with an inventory of the implements used and notes on recent innovations in the fishery, e.g., the substitution of a seine net for the traditional conical net.”

277. Macy, P. T., Wall, J. M., Lampsakis, N. D., and Mason, J. E. 1978. Resources of nonsalmonid pelagic fishes of the Gulf of Alaska and eastern Bering Sea. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Final Report. Outer Continental Shelf Environmental Assessment Program (OCSEAP), Task A-7, RU 64, 354. Part I. 355 p.

Keywords: Alaska, Bering Sea, Gulf of Alaska, distribution, geographic

278. Magdanz, J. [1988] 1993. Harvest and exchange of eulachon from the Chilkat and Chilkoot Rivers, Alaska. *In* The sharing, distribution, and exchange of wild resources in Alaska: A compendium of materials presented to the Alaska Board of Fisheries. Edited by R. J. Wolfe, and J. Magdanz. Juneau: Alaska Department of Fish and Game, Division of Subsistence. 15 p.

Keywords: Alaska, Chilkat River, Chilkoot River, historical, oil, subsistence

Abstract: "Trade in wild, renewable resources has a long history in Alaska. One such product which has been traditionally traded in southeast Alaska is the oil of the eulachon (*Thaleichthys pacificus*). In the 1980s, the most productive and well-known of Alaska's eulachon fisheries occurred each May on the Chilkat River just upstream from Haines. The Chilkat area is one of the few in Alaska where eulachon are numerous and dependable, and where families have maintained traditional skills in harvesting eulachon and processing its oil. Traditionally, their product has been in demand by Tlingit throughout southeast Alaska and in the southern Yukon. That demand has been filled through a variety of exchange mechanisms with a long history, including cash exchange. This report describes the Chilkat area, the local eulachon fishery there, and the nature and extent of traditional and contemporary exchanges of eulachon oil."

279. Margolis, L., and Arthur, J. R. 1979. Synopsis of the parasites of fishes of Canada. Bulletin of the Fisheries Research Board of Canada No. 199.

Keywords: parasites

280. Marston, B. H., Willson, M. F., and Gende, S. M. 2002. Predator aggregations during eulachon *Thaleichthys pacificus* spawning runs. Marine Ecology Progress

Series 231:229-36.

Keywords: Alaska, Berners Bay, predators (birds), predators (fish), predators (mammals), run timing

Abstract: “Predators congregated in large numbers during the 1996 and 1997 spring spawning runs of eulachon *Thaleichthys pacificus* Richardson (Osmeridae) in the lower reaches of the rivers entering Berners Bay, southeastern Alaska. Predator abundance rose rapidly at the beginning of the runs and was significantly correlated with an index of eulachon abundance within years. Gulls (Laridae) were the most abundant predators, with a daily average peak of 40,000 during the 1996 run, at a density of 3000 km^{-2}. A daily average peak of over 250 Steller sea lions *Eumetopias jubatus* and harbor seals *Phoca vitulina* fed on eulachon early in the run in both years. Daily average counts of bald eagles *Haliaeetus leucocephalus* approached 600 on the lower reaches of the rivers, and many others foraged upstream. Eulachon are unusually high in lipid content, and many of the prodigious spawning runs in Alaska and British Columbia occur in spring, when predator energy demands are high. We suggest that spring spawning runs of eulachon and other forage fishes are an ecological cornerstone for regional coastal ecosystems, supporting large numbers of wildlife species.”

“Thirty-four species of bird consumers were observed to forage on eulachon, including 12 gulls and terns (Laridae), 10 ducks (Anatidae), 4 shorebirds (Scolopacidae), a kingfisher (Alcedinidae), 3 raptors (Falconidae), and 4 passerines (2 Corvidae, Motacillidae, Emberizidae). Gulls were the primary avian predators. Mew gulls *Larus canus* dominated the flocks early in the run, and

larger gulls later (herring gull *L. argentatus*; glaucous-winged gull *L. glaucescens*; Thayer's gull *L. thayeri*) (Fig. 3A). Mew gulls often foraged farther upstream than the larger gulls. Bonaparte's gulls *L. philadelphia* were rare in 1997 and were seen only occasionally in 1996. Thayer's gulls dominated the flocks toward the end of May, numbering at least 6000. Additionally, the relative abundance of juvenile gulls increased as the run progressed (Fig. 3B). The principal mammalian predators were Steller sea lions *Eumetopias jubatus* and harbor seals *Phoca vitulina*; humpback whales *Megaptera novaeangliae* were occasionally encountered. The abundance of marine mammal predators was high early in the run, as the fish entered the river. Seals did not appear in high abundance until sea lion numbers dropped markedly. In contrast, bald eagles (see Fig 4) and corvids (>100 individuals) were particularly abundant and active later in the run, when many dead eulachon accumulated on the shores. Two species of salmonid fish (*Oncorhynchus kisutch* and *Salvelinus malma*) also fed on eulachon eggs or larvae in 1996 (M. Wipfli pers. comm.). In addition, large numbers of grebes *Podiceps* sp. (>100), scoters *Melanitta* sp. (15,000), mergansers *Mergus* sp. (700), and marbled murrelets *Brachyrhamphus marmoratus* (290) were seen in 1995. Other animals occasionally observed in the spawning area probably also feed on eulachon, including bears *Ursus* sp., wolves *Canis lupus*, mink *Mustela vison*, river otters *Lontra canadensis* and loons *Gavia* sp."

281. Matarese, A. C., Kendall, A. W., Jr., Blood, D. J., and Vinterr, B. J. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. U.S. Department of Commerce, National Oceanographic and Atmospheric

Administration Technical Report NMFS 80.

Keywords: larvae

282. Matsuoka, M., Iwai, T. 1983. Adipose fin cartilage found in some teleostean fishes. Japanese Journal of Ichthyology 29(1):37-46.

Keywords: adipose fin, morphology

Abstract: "Adipose fins of 33 species belonging to the Salmoniformes, Cypriniformes, Siluriformes and Myctophiformes were studied. Cartilaginous structure was found in the base of the adipose fin in 14 species of the Salangidae, Osmeridae, Plecoglossidae, Myctophidae and Neoscopelidae. In the Osmeridae, the cartilaginous structure can be divided in two types: a rather large slender cartilage observed in *Spirinchus*, and a small pear-shaped cartilaginous structure observed in *Thaleichthys*, *Osmerus* and *Hypomesus*. The former is similar to that of the Salangidae. The latter is similar to the cartilage of the Plecoglossidae in shape and location. In the Myctophidae and Neoscopelidae, cartilage and chondroid tissue are ventrally inserted in the underlying muscle layer, and different from the cartilaginous structure found in the three families of the Salmoniformes in morphological characters."

283. Maxfield, J. 1995. Hats off to Raven. Arts and Activities 118(4):35.

Keywords: subsistence

Abstract: "When Raven examined the box on the shore at the edge of the sea, he discovered that it had many doors of various sizes. He opened the smallest one first and out came all the tiny smelts, the littlest of fishes. They swam out into the

ocean, happy to be free. The next door opened released the herrings and the "oolachans" [candlefish], who followed the smelts into the sea."

284. McAllister, D. E. 1960. List of the marine fishes of Canada. National Museum of Canada Bulletin No. 168. p. 1-76.

Keywords: Canada, distribution, geographic

285. McAllister, D. E. 1963. A revision of the smelt family, Osmeridae. National Museum of Canada, Biological Series 71, Bulletin No. 191. p. 1-53

Keywords: taxonomy

286. McAllister, D. E. 1965. Type specimens of fishes in the National Museum of Canada. With brief historical notes. National Museum of Canada Natural History Paper No. 31. p. 1-12

Keywords: taxonomy

287. McAllister, D. E. 1966. Numerical taxonomy and the smelt family, Osmeridae. Canadian Field-Naturalist 80(4):227-38.

Keywords: taxonomy

288. McCabe, G. T., Jr., Emmett, R. L., and Hinton, S. A. 1993. Feeding ecology of juvenile white sturgeon (*Acipenser transmontanus*) in the lower Columbia River. Northwest Science 67(3):170-180.

Keywords: Columbia River, eggs, predators (fish)

Abstract: Eulachon eggs comprised an important spring food of juvenile white sturgeon in the Columbia River.

289. McCarter, P., and Hay, D. 2001. Eulachon embryonic egg and larval outdrift sampling manual for ocean and river surveys. PSARC working paper, Department

of Fisheries and Oceans Canada.

Keywords: eggs, larvae

290. McCarter, P. B., and Hay, D. E. 1999. Distribution of spawning eulachon stocks in the central coast of British Columbia as indicated by larval surveys. Canada Department of Fisheries and Oceans, Canadian Stock Assessment Secretariat, PSARC P99-8, Research document 99, 177. Ottawa. 64 p.

Keywords: British Columbia, distribution, geographic

291. McClane, A. J. 1965. McClane's standard fishing encyclopedia and international fishing guide. New York, Chicago, San Francisco: Holt, Rinehart and Winston. 1057 p.

Keywords: general references on fish

292. McClellan, C. 1975. My old people say: An ethnographic survey of southern Yukon Territory, Part 2. National Museums of Canada, Publications in Ethnology 6(2). Ottawa.

Keywords: Yukon Territory, subsistence

293. McDonald, T. E., and Margolis, L. 1995. Synopsis of the parasites of fishes of Canada. Supplement (1978-1993). Canadian Special Publication of Fisheries and Aquatic Sciences No. 122.

Keywords: parasites

294. McGregor, M. 1981. Native medicine in Southeast Alaska: Tsimshian, Tlingit, Haida. Alaska Med. 23(6):65-69.

Keywords: Alaska, Southeast, subsistence

295. McHugh, J. L. 1939. The eulachon. Fisheries Research Board of Canada, Progress Reports of the Pacific Biological Station No. 40. 17-22

Keywords: British Columbia, Fraser River, length, life history, population status, sex ratio, sexual dimorphism, spawning

Abstract: note from Langer et al. (1977): "Describes Fraser River life history (length, age, spawning, sexual condition, sex ratio and sexual differences). Notes a possible decline in eulachon abundance."

296. McHugh, J. L. 1940. Where does the eulachon spawn? Fisheries Research Board of Canada, Progress Reports of the Pacific Biological Station No. 44. p. 18-19.

Keywords: British Columbia, Fraser River, eggs, larvae, spawning

Abstract: note from Langer et al. (1977): "Describes egg and larval distributions in the Fraser River between New Westminster and mouth of the Fraser. Also describes egg attachment to sand grains and the differences between eulachon and Pacific herring larvae."

297. McHugh, J. L. 1941a. Eulachon catch statistics. Fisheries Research Board of Canada, Progress Reports of Pacific Biological Station No. 49. p. 18-19

Keywords: British Columbia, population status

Abstract: note from Langer et al. (1977): "Catch, effort statistics presented for Fraser River in 1941"

298. McHugh, J. L. 1941b. Report on eulachon investigation. Canada Department of Fisheries. National Archives, Burnaby, RG23, Vol. 1826, file 769-11-29, part J.

Keywords: British Columbia, historical

299. McIlwriath, T. F. 1948. The Bella Coola Indians, Vol. 2. Toronto: University of Toronto Press.

Keywords: British Columbia, subsistence

300. McIsaac, D., and Bohn, B. 1988. Columbia River fish runs and fisheries, 1960-1987. Olympia: Washington Department of Fisheries, and Oregon Department of Fish and Wildlife. 83 p.

Keywords: Columbia River, fisheries, population status

301. McLean, J. E., Hay, D. E., and Taylor, E. B. 1999. Marine population structure in an anadromous fish: Life history influences patterns of mitochondrial DNA variation in the eulachon, *Thaleichthys pacificus*. Molecular Ecology 8(12):S143-S158.

Keywords: DNA, population structure, postglacial dispersal

Abstract: "Due to the apparent decline in size of a number of populations, eulachon, *Thaleichthys pacificus*, have recently become the focus of a conservation movement in the northeast Pacific. Little is known of the marine life-history phase of this anadromous fish, and although it has been suggested that eulachon spawning in different rivers may form distinct populations, nothing is known of their population structure. Molecular genetic data were used to investigate population structure and possible management schemes. Mitochondrial DNA genotypes, determined through restriction fragment length polymorphisms (RFLP) analysis, were resolved in fish from several rivers throughout the geographical range of eulachon. Our data support the idea that extant eulachon populations result from postglacial dispersal from a single Wisconsinan glacial refuge. Further, while three of the 37 haplotypes recovered

account for approximately 79% of the samples, many private haplotypes were observed, suggesting possible regional population structure. While a great deal of genetic variation was observed (37 haplotypes in 315 samples), an ANOVA showed that >97% of the total variation was detected within populations. As yet, it is unclear whether genetically distinct populations of eulachon exist, or if these fish may be treated as one or a few large populations. Results were tested against predictions made from hypotheses concerning the origin and persistence of subdivided populations in marine species, and seem to be more consistent with the Member-Vagrant hypothesis than isolation by distance. Eulachon present an interesting situation that illustrates the difficulties involved in defining management units in organisms with high levels of gene flow."

302. McLean, J. E., and Taylor, E. B. 2001. Resolution of population structure in a species with high gene flow: Microsatellite variation in the eulachon (Osmeridae: *Thaleichthys pacificus*). Marine Biology 139(3):411-20.

Keywords: DNA, genetics

Abstract: "Five microsatellite loci were used to examine genetic variation within and among putative populations of the eulachon, *Thaleichthys pacificus* (Pisces: Osmeridae), over the entire range of the species. A previous mitochondrial DNA study, while revealing a high degree of genetic variation within the species, did not resolve the level of population sub-division expected for this anadromous fish."

303. McNair, P. L. 1971. Descriptive notes on the Kwakiutl manufacture of eulachon oil. Syesis 4:169-77.

Keywords: British Columbia, oil, subsistence

304. McPhail, J. D., and Lindsey, C. C. 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Research Board of Canada Bulletin No. 173. 381 p.

Keywords: distribution, geographic

305. McPhail, J. D., and Lindsey, C. C. 1986. Zoogeography of the freshwater fishes of Cascadia (the Columbia system and rivers north of the Stikine). *In* The zoogeography of North American freshwater fishes, p. 615-637. Edited by C.H. Hocutt and E.O. Wiley. New York: John Wiley and Sons.

Keywords: distribution, geographic, zoogeography

306. Mecklenburg, C. W., Mecklenburg, T. A., and Thorsteinson, L. K. 2002. Fishes of Alaska. American Fisheries Society.

Keywords: Alaska, distribution, geographic, taxonomy

307. Meek, A. 1916. The migrations of fish. London: Edward Arnold. 427 p.

Keywords: migration

308. Menke, K. 1997. The hooligan harvest—a springtime tradition in Haines, Alaska. Native Peoples 10 (Spring):40-46.

Keywords: Alaska, Chilkat River, Chilkoot River, subsistence

Abstract: An account of the eulachon harvest by the Tlingit of Haines and Klukwan.

309. Merrick, R. L., Chumbley, K. M., and Byrd, G. V. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: A potential

relationship. Canadian Journal of Fisheries and Aquatic Sciences 54:1342-48.

Keywords: Alaska, predators (mammals)

310. Mikkelson, P., Paasivirta, J., Rogers, I. H., and Ikonomou, M. 1996. Studies on eulachon tainting problem: Analyses of tainting and toxic aromatic pollutants. *In* Environmental fate and effects of pulp and paper mill effluents. Edited by M. R. Servos, K. R. Munkittrick, J. H. Carey, and G. J. Van Der Kraak. Delray Beach, FL: St. Lucie Press. p. 327-333.

Keywords: British Columbia, Kemano River, Kitimat River, contaminants, grease

Abstract: "Eulachon were taken from the Kitimat River downstream of the discharge of a nonbleaching kraft mill, and reference fish from the Kemano River were exposed in tanks to concentrations of mill effluent. Eulachon grease was rendered from exposed and unexposed fish by a traditional method. Gas chromatographic, mass spectrometric analyses were performed on homogenates of whole fish and on eulachon grease to measure the levels of chloroanisoles (PCAs) as well as coplanar and mono-ortho-PCBs, dioxins (PCDDs) furans (PCDFs), polyaromatic hydrocarbons (PAHs) and some sulfur aromatics. The concentrations of PCDDs, PCDFs and PAHs (excluding dibenzothiophene and its methyl derivatives) were at low background levels without statistically significant differences between exposed and unexposed fish samples. The levels of the sulfur aromatic dibenzothiophene and its mono- and di-methyl derivatives (DBT+C1DBT+C2DBT) were 181 ng g^{-1} fw in exposed and 18 ng g^{-1} fw in unexposed fish grease samples. These substances are persistent and lipophilic components of crude oil. They also occur in oil-based defoamers used in pulp

mills and, consequently, in pulp mill biosludge. Their significance as pollutants in exposed eulachons needs to be evaluated. 3,5-Dichloroanisole and 2,4,5-trichloroanisole were detectable (4-70 ng g^{-1} lw) in all tainted and nondetectable (<2 ng g^{-1}) in all nontainted oil samples. Levels of these PCAs in tainted eulachon grease were similar to levels of PCAs and PCVs (polychloroveratroles) in bad-tasting fish from a watercourse receiving pulp mill wastes. The source of the PCAs in the eulachons is unknown but cannot derive from bleaching."

311. Miller, D. J. 1960. A field guide to some common ocean sport fishes of California. Revised edition, part 1. California Department of Fish and Game. p. 36-39.
Keywords: California, distribution, geographic
Abstract: note from Langer et al. (1977): "Reports southern limit of eulachons as Mad River"

312. Miller, M. G., and Moffit, S. 1999. Assessment of Copper River eulachon (*Thaleichthys pacificus*) commercial harvest: Project operational plan. Alaska Department of Fish and Game, Division of Commercial Fisheries. 14 p.
Keywords: Alaska, Copper River, eggs, fisheries (commercial), historical
Abstract: "In the spring of 1998 a commercial dip net fishery for eulachon (*Thaleichthys pacificus*) occurred in the Copper River and Alaganic Slough near Cordova. This was the first directed commercial fishery for eulachon in the Copper River area. Interest in this fishery started with the failure of eulachon runs in the Columbia and Fraser Rivers beginning in 1994 (Hay 1995). Commercial markets for eulachon include fresh market sales, and feed for zoos, aquariums, and fur farms."

"Eulachon have been used by Aboriginal peoples along the Pacific coast for food and oil for at least several centuries (Hart 1973). Payne et al. (1997) reported that prespawning eulachon, or candlefish, have a high oil content (>16%) and low moisture content (<71%). These characteristics, along with a high seasonal abundance, allowed coastal Aboriginal peoples to render large quantities of oil for use as food and as a trade item (Macnair 1971; Stewart 1975)."

"There are subsistence, personal use, and sport fisheries for eulachon from Southeast Alaska to the Alaska Peninsula. The subsistence harvest in Alaska appears to be fairly small (J. Fall, Alaska Department of Fish and Game, Anchorage, personal communication). The people of Klukwan near Haines may be the only Alaskans still harvesting eulachon for oil (Mills 1982). The sport harvest in Alaska averaged >210,000 smelt (eulachon and capelin, *Mallotus villosus*) for the years 1977-1997 (Mills 1991; Howe et al. 1998). About half (average = 54%) of this harvest occurred in the Twentymile River or the immediately adjacent salt water of Turnagain Arm. The subsistence and sport harvests appear to be insignificant in most spawning systems in years of average abundance."

"Commercial fisheries for eulachon started as early as 1877 in the Nass River (Scott and Crossman 1970) and 1894 in the Columbia River (Smith and Saalfeld, 1955). For most of this century the commercial fisheries south of Alaska have been limited to the Columbia and Fraser Rivers (Hay 1995). The only long term commercial fishery in Alaska is a small harvest from the Unuk and Chickamin Rivers near Ketchikan (P. Doherty, Alaska Department of Fish and Game,

Ketchikan, personal communication). Even after a century of commercial harvests, knowledge of the life history of eulachon is limited (McPhail and Lindsey 1970; Hart 1973; Scott and Crossman 1973)."

"Eulachon are also an important food source for many other birds and mammals. Spawning runs of eulachon are feed [sic] upon by gulls, bald eagles, harbor seals, fur seals, harbor porpoises, dogfish sharks, halibut, coho salmon, chinook salmon, brown bears, and wolves. Eulachon larvae are prey for sockeye salmon, and returning sockeye salmon will eat spawning eulachon."

"Eulachon are anadromous and seasonally abundant in a limited number of river systems over their range. Most documented eulachon spawning rivers are large, mainland, glacial systems. Eulachon probably spawn in other glacial, mainland systems that are as yet undocumented. In Alaska they occur in at least 35 different river systems including the Stikine, Taku, Chilkoot, Chilkat, Copper, Kenai, Twentymile, Susitna, Bear, Sandy, and Meshik. The only documented spawning river on a large island in Alaska is on Unimak Island at the western extent of eulachon range (ADF&G [Alaska Department of Fish and Game], personal communication). This is probably the only island in Alaska with a glacial river of the type similar to mainland systems used for spawning. Eulachon use fewer systems than salmon over the same range. In the Prince William Sound and Copper River area there are >1000 documented salmon spawning systems and perhaps only four eulachon spawning systems (Copper River, Martin River, Alaganic Slough, and Ibeck Slough)."

"In Alaska, eulachon enter river systems from March through early July; starting

earliest in Southeast Alaska and getting progressively later as you move north and west to the Alaska Peninsula. Entrance timing may be related to water temperature as most studies have documented run entry between 2 and 10 degrees C (Smith and Saalfeld 1955, Franzel and Nelson 1981, Barrett et al. 1984). However, Vincent-Lang and Queral (1984) noted no relationship between water temperature and migration timing in the Susitna River."

"Spawning usually occurs in glacially occluded waters over sand and coarse gravel (Morrow 1980). Eulachon are broadcast spawners whose eggs adhere to the bottom substrate (McHugh 1940). The eggs hatch after 30 to 40 days at 4.4 to 7.2 [degrees] C (Hart 1973). The larvae are flushed into the marine environment, and very little is known of their life history until they return to spawn (Barraclough 1964). Age at maturity is usually reported as three years (Smith and Saalfeld 1955, Trent 1973, Barrett et al. 1984); however, Hart and McHugh (1944) reported most of the Fraser River spawners as just completing their second year. Most fish probably die after spawning, but there is some evidence for repeat spawning (Barraclough 1964)."

313. Mills, D. D. 1982. Historical and contemporary fishing for salmon and eulachon at Klukwan: An interim report. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper No. 69. Juneau. 28 p.

Keywords: Alaska, Chilkat River, Klukwan, historical, oil, subsistence

Abstract: "Beginning in the spring, Klukwan residents established camps between 4 and 9 miles upstream from the mouth of the Chilkat River for taking eulachon (Figure 2). Annually between mid- and late May, eulachon (*Thaleichthys*

pacificus) travel upstream from the ocean in substantial numbers. Large dip nets on the end of a pole were drawn through the water or held in the current by an individual standing on the shore or in a small boat near the shoreline. When the eulachon run reached its peak, good fishing would last one or occasionally as long as two weeks. Large quantities of fish were taken both for preserving whole and for rendering oil, which was highly valued. A three man canoe filled with eulachon would yield between five and six gallons of oil. Numerous canoe loads were harvested by each fisherman (Stewart 1977). Generally men conducted the fishing activities but the entire family was involved in preparation and processing activities."

"Rendering eulachon oil was usually a group project, sometimes involving a number of families and considerable time and effort. A large pit was dug in the ground, filled with eulachon, and covered with wood. The eulachon were then left to "ripen" in the pit for ten days to three weeks, depending on the ambient temperature. After ripening, the fish were put into large wooden boxes or barrels full of water, and boiled and stirred for several hours until the oil was released from the fish and the solids sank to the bottom. After standing, the oil rose to the top and was skimmed and sealed in a container. The eulachon oil, often called grease, was eaten with most foods and used for preserving berries, roots, and herbs. It was consumed in large quantities at feasts (Oberg 1973)."

314. Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58.

Anchorage.

Keywords: Alaska, fisheries (sport)

315. Minckley, W. L., Hendrickson, D. A., and Bond, C. E. 1986. Geography of western North American freshwater fishes: Description and relationship to intracontinental tectonism. *In* The zoogeography of North American freshwater fishes, p. 519-613. Edited by C.H. Hocutt and E.O. Wiley. New York: John Wiley and Sons.

Keywords: distribution, geographic

316. Mitchell, D., Leland, D. 1988 . Archaeology and the study of Northwest Coast economies. *In* Research in Economic Anthropology, Supplement #3, p. 304. JAI Press, Inc.

Keywords: historical, subsistence

317. Moffitt, S., Marston, B., and Miller, M. 2002. Summary of eulachon research in the Copper River delta, 1998-2002. Regional Information Report No. 2A02-34. Anchorage: Alaska Department of Fish and Game.

Keywords: Alaska, Copper River Delta, age, body size, larvae, length, run timing, sex ratio, spawning

Abstract: Age of spawners ranged from 2 to 6 years, with age-4 or age-5 fish dominating in different years. Both male and female standard lengths and weights varied annually, and males tended to be larger than females. The sex ratio was about equal at the beginning of the run, but males predominated later. Sex ratio and age distribution sometimes differed among streams on the delta. Run timing also varied among streams on the delta, but in the Copper River the main run occurred in May.

318. Monaco, M. E., Emmett, R. L., Hinton, S. A., and Nelson, D. M. 1990. Distribution and abundance of fishes and invertebrates in west coast estuaries. Vol. 1: Data summaries. ELMR Report No. 4. Rockville, MD: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Strategic Assessment Branch. 240 p.

Keywords: abundance, distribution, geographic

319. Moore, H. F. 1917. The eulachon: A rich and delicious little fish. U.S. Department of Commerce, Bureau of Fisheries, Economic Circular No. 33. Washington, D.C.: U.S. Government Printing Office.

Keywords: historical, recipes

Abstract: This paper presents 19 recipes for preparing eulachon, along with methods of handling and cleaning them.

320. Moring, J. R. 1996. Fish discoveries by the Lewis and Clark expedition and Red River expeditions. Fisheries 21(7).

Keywords: historical

321. Morrow, J. E. 1980. The freshwater fishes of Alaska. Anchorage: Alaska Northwest Publishing Company. 248 p.

Keywords: Alaska, distribution, geographic, taxonomy

322. Morstad, S. 1998. Eulachon—1998 season summary. Alaska Department of Fish and Game. 16 p.

Keywords: Alaska

323. Morton, A. 2000. Occurrence, photo-identification and prey of Pacific white-sided dolphins (*Lagenorhyncus obliquidens*) in the Broughton Archipelago, Canada,

1984-1998. Marine Mammal Science 16(1):80-93.

Keywords: British Columbia, Broughton Archipelago, predators (mammals)

Abstract: "This study summarizes occurrence of Pacific white-sided dolphins (*Lagenorhyncus obliquidens*) in the Broughton Archipelago on the west coast of Canada, from October 1984 through December 1998. Prey species were collected from 25 encounters with feeding dolphins. Predation on eulachon (*Thaleichthys pacificus*) is suspected."

324. Moulton, L. L. 1997. Early marine residence, growth, and feeding by juvenile salmon in northern Cook Inlet, Alaska. Alaska Fisheries Research Bulletin 4(2):154-77.

Keywords: Alaska, Cook Inlet, predators (fish)

325. Moyer, E. 1956. How about a tasty dish of *Thaleichthys pacificus*? Vancouver Province (February 11):3.

Keywords: subsistence, recipes

326. Moyle, P. B. 1976. Inland fishes of California. Berkeley: University of California Press. 405 p.

Keywords: California, distribution, geographic

327. Moyle, P. B., Yoshiyama, R. M., Williams, J. E., and Wikramanayake, E. D. 1995. Fish species of special concern in California (second edition). Sacramento, CA: California Department of Fish and Game. 72 p.

Keywords: California, population status

328. Mueter, F. J., and Norcross, B. L. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of

Alaska. Fishery Bulletin 100:559-81.

Keywords: Gulf of Alaska, distribution

Abstract: Trawl samples showed that the frequency of occurrence and catch per unit effort (of eulachon) varied among regions of the gulf and among depths.

329. Narver, D. W. 1962. Chignik red salmon studies. Research in Fisheries, Fisheries Research Institute, University of Washington Contribution No. 139. p. 12-13.

Keywords: Alaska, distribution, geographic

330. National Marine Fisheries Service. 1970. Fur seal investigations, 1968. U.S. Fish and Wildlife Service Specal Scientific Report in Fisheries No. 617. 125 p.

Keywords: predators (mammals)

Abstract: note from Gruchy and McAllister 1972: "Fish eaten by fur seals include *T. pacificus*."

331. Nelson, R. 2002. Groundfish assessment: Annual eastern Bering Sea bottom trawl survey. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Resource Assessment and Conservation Engineering (RACE) Division.

Keywords: Alaska, Bering Sea, distribution, geographic

332. Niblack, A. P. [1890] 1970. The coast Indians of southern Alaska and northern British Columbia. Washington: U.S. Government Printing Office. New York: Johnson Reprint Company.

Keywords: historical, subsistence

333. Nisga'a Tribal Council. 1990. Nisga'a eulachon fishery 1990. Unpublished report prepared by Nisga'a fisheries crew and Nortec Consulting. 24 p.

Keywords: fisheries (subsistence)

334. Northcote, T. G. 1974. Biology of the lower Fraser River: A review. University of British Columbia, Westwater Research Center, Technical Report No. 3. Vancouver. 94 p.

Keywords: British Columbia, Fraser River, biology, population status

Abstract: Note from Langer et al. (1977): "Reviews eulachon utilization of Fraser River; updates catch statistics to 1972; and notes low mercury levels (0.02-0.04 ppm) in eulachons."

335. Obee, B. 2000a. Plentiful 'sea bears' rarely seen. Beautiful British Columbia 42(1):38.

Keywords: predators (mammals)

Abstract: "The fur seal is most abundant in B.C. from January to June, when it hunts for herring, salmon, walleye, pollock, squid, eulachon, and rockfish, fattening up for its long journey to northern breeding rookeries in Alaska, Japan, and Russia."

336. Obee, B. 2000b. Undersea rainforests. Beautiful British Columbia 42(2):16.

Keywords: British Columbia, oil, subsistence

Abstract: "They stored eulachon oil in flasks made from the gas-filled floats that hold the kelp fronds at the surface. Fresh roe laid on the fronds by herring was an important seasonal food."

337. Oberg, K. 1973. The social economy of the Tlingit Indians. Seattle: University of Washington Press.

Keywords: subsistence

338. Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. California Fish and Game 50(4):305-7.

Keywords: California, Humboldt Bay, Klamath River, Redwood Creek, Mad River, distribution, geographic

Abstract: "The eulachon (family Osmeridae), also known as candlefish, is anadromous and spawns from March to mid-May in streams from the Klamath River, in northern California, to the Nushagak River, Alaska (McAllister, 1963). Local residents have reported this species in Redwood Creek, Humboldt County, 15 miles south of Klamath River. Miller (1960) reported *T. pacificus* from the Mad River, Humboldt County, some 35 miles south of Klamath River, but did not mention spawning runs in the river. During the spring of 1963, runs of *T. pacificus* in Klamath River, Redwood Creek, and Mad River reported by local residents, were confirmed by personnel of the California Department of Fish and Game. These runs were large enough for a commercial fishery to develop, and nearly 56,000 pounds were reported sold. An additional unknown amount was taken by sport fishermen. The bulk of the catch was made during April."

339. Okada, S., and Kobayashi, K. 1968. Coloured illustrations of pelagic and bottom fishes in the Bering Sea. In Japanese with English captions for figures and tables.

Keywords: illustrations

340. Olesiuk, P. F. 1993. Annual prey consumption by harbor seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia. Fishery Bulletin 91:491-515.

Keywords: British Columbia, energy density, predators (mammals)

Abstract: Smelt, mainly eulachon, occurred in 0.4% of the harbor seals in the Strait of Georgia. The seals consumed an estimated 40 tons of smelt per year. The energetic density of eulachon was 5.90.

341. Olesiuk, P. F., Bigg, M. A., Ellis, G. M., Crockford, S. J., and Wigen, R. J. 1990. An assessment of the feeding habits of harbour seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia, based on scat analysis. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1730. Nanaimo, B.C.: Department of Fisheries and Oceans Canada, Pacific Biological Station. 135 p.

Keywords: British Columbia, Strait of Georgia, predators (mammals)

342. Olson, R. L. 1967. Social structure and social life of the Tlingit in Alaska. University of California Publications. Anthropological Records Vol. 26. Berkeley and Los Angeles: University of California Press.

Keywords: Alaska, Southeast, subsistence

343. Olson, W. M., and Hubbard, L. T., Jr. 1984. Fishing: The key to Tlingit culture. *In* The fishing culture of the world: Studies in ethnology, cultural ecology and folklore, Vol. 2, p. 917-938. Edited by B. Gunda. Budapest: Akademiai Kiado.

Keywords: Alaska, subsistence

Abstract: "An account is given of the environment and subsistence of the Tlingit Indians in Southeast Alaska, describing the major fish species that form the subsistence base of Tlingit culture: salmonids, Pacific herring (*Clupea harengus*

pallasi), eulachon (*Thaleichthys pacificus*) and Pacific halibut (*Hippoglossus stenolepis*)."

344. Oregon Department of Fish and Wildlife, and Washington State Department of Fisheries. 1993. Status report—Columbia River fish runs and fisheries, 1938-1992. Joint publication. 257 p.

Keywords: Columbia River, fisheries (commercial), population status

345. Orr, U. 1984. Eulachon sampling on the lower Nass River in relation to log handling. Unpublished data report. Prince Rupert, B.C. or Vancouver, B.C.: Department of Fisheries and Oceans Canada. 25 p.

Keywords: British Columbia , Nass River, log handling effects, population status

346. Outram, D. N., and Haegele, C. 1972. Food of Pacific hake (*Merluccius productus*) on an offshore bank southwest of Vancouver Island, British Columbia. Journal of the Fisheries Research Board of Canada 29(12):1792-95.

Keywords: British Columbia, predators (fish)

Abstract: "In 1196 adult Pacific hake (*Meriuccius productus*) stomachs from off the British Columbia coast euphausiids occurred in 94%; Pacific sandlance (*Ammodytes hexapterus*) in 26%; Pacific herring (*Clupea harengus pallasii*) and eulachon (*Thaleichthys pacificus*) each 5%; and lanternfish, young rockfish, northern anchovy (*Engraulis mordax*) and pandalid shrimp each in 3% or less. Fish, particularly herring, were of greater importance in the diet of larger hake. The extent of stomach fullness and the stage of digestion of stomach contents were similar for all sizes of hake taken in daylight tows. The presence of fresh to near-fresh organisms in only 9% of the stomachs, coupled with large numbers

(52%) of empty to near-empty stomachs, indicated low feeding activity during daylight hours."

347. Paasivirta, J., and others. 1987. Chlorinated anisoles and veratroles in fish. Model compounds. Instrumental and sensory determinations. Chemosphere 16:1231-41.

Keywords: contaminants

348. Parente, W. D., and Snyder, G. R. 1970. A pictorial record of the hatching and early development of the eulachon (*Thaleichthys pacificus*). Northwest Science 44(1):50-57.

Keywords: Washington, Cowlitz River, age at spawning, eggs, embryology, fecundity, illustrations, spawning

Abstract: "Ripe eulachon were obtained from the Cowlitz River; eggs were fertilized in 250-ml beakers and then placed in covered incubation trays. . . Temperature of the water used for incubation and hatching ranged from 6.5° to 9.0°C."

"The embryo follows a typical teleostean development. Three hr after fertilization, the blastodisc can be seen as a transparent yellow cap on the yolk. At 30 hr cleavage is under way, at 60 hr invagination is in process, and at 120 hr the head, eyes, and auditory capsules are formed. A weak heartbeat can be detected behind the nape of the embryo by about 300 hr. At this time the eyes have darkened and the lenses are present. By 400 hr the heartbeat is strong, and the yolk has been reduced to about one-half the original size. After 500 hr, the embryo becomes active and hatching begins. All eggs under observation hatched within five days."

349. Payne, S. A., Johnson, B. A., and Otto, R. S. 1997. Proximate composition of some northeastern Pacific forage species. *In* Forage fishes in marine ecosystems. Proceedings of the Wakefield Fisheries Symposium, Alaska Sea Grant College Program 97-01. Fairbanks: University of Alaska. p. 721-724.

Keywords: Alaska, Bering Sea, Gulf of Alaska, caloric content, lipid content, proximate composition

Abstract: "Baseline proximate composition values are valuable for understanding the relative importance of forage species as prey in the northeastern Pacific. Samples of 14 Bering Sea and Gulf of Alaska forage species were collected opportunistically from August 1991 through June 1995 and were analyzed for protein, oil (total lipid), ash, and moisture content. Total lipids were extracted by the method of Reppond et al. (1995). Proximate values were obtained from whole organisms as would be consumed by predators. The only species with enough samples for hypothesis testing were eulachon (*Thaleichthys pacificus*), capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*) and Pacific sandfish (*Trichodon trichodon*). Juveniles of walleye pollock (*Theragra chalcogramma*), Atka mackerel (*Pleurogrammus monopterygius*), and Pacific herring (*Clupea pallasi*) are also included to provide proximate information for smaller prey than those taken in commercial fisheries. Other species included are pricklebacks (*Lumpenus* sp.), lanternfish (Myctophidae), squid (Gonatidae), surf smelt (*Hypomesus pretiosus*), rainbow smelt (*Osmerus mordax*), deepsea smelt (Bathylagidae), and juvenile prowfish (*Zaprora silenus*)."

"Species from the Gulf of Alaska and Bering Sea are ranked together according to

proximate composition to illustrate potential similarities. Eulachon was the highest in oil (16.8-21.4%) and lowest in moisture (64.6-70.8%) content. A single spawned-out eulachon was 8.7% oil and 77.3% moisture. Capelin oil ranged from 2.1% to 14.0%; capelin rank similarly in oil and moisture to Pacific sandfish, Pacific sand lance, and pricklebacks. Squid and juveniles of walleye pollock, Atka mackerel, Pacific herring, and prowfish were low in oil (<1.8%) and high in moisture (>80.3%) content. Surf smelt, rainbow smelt, pricklebacks, Atka mackerel, Pacific sand lance, and Pacific sandfish ranked high in median protein content (>15.4%). Median ash content for all species ranged from 0.6% to 3.3%." "Total wet mass caloric content (kcal, g = protein × 5.65 + oil × 9.50) was calculated for additional comparisons and is presented as it relates to moisture. Eulachon and capelin were higher in caloric content than most forage species from the northeastern Pacific and those whole fish included in Sidwell (1981). Pacific sand lance, Pacific sandfish, and pricklebacks appear virtually identical. Single observations of lanternfish and deepsea smelt contained higher caloric content than capelin. Squid and juveniles of walleye pollock, prowfish, and Pacific herring had high moisture content and low caloric values."

350. Payne, S. A., Johnson, B. A., and Otto, R. S. 1999. Proximate composition of some north-eastern Pacific forage fish species. Fisheries Oceanography 8(3):159-77.

Keywords: Alaska, Bering Sea, Gulf of Alaska, caloric content, proximate composition

Abstract: "To understand the relative dietary value of forage fish as prey in the Bering Sea and Gulf of Alaska, whole organisms of 13 species were analysed for

proximate composition (protein, oil, ash and moisture content). Eulachon (*Thaleichthys pacificus*) were high in oil (total lipid) (16.8% to 21.4%) and low in moisture (64.6% to 70.8%). Oil in capelin (*Mallotus villosus*) ranged from 2.1% to 14.0%. Juveniles of walleye pollock (*Theragra chalcogramma*), Atka mackerel (*Pleurogrammus monopterygius*), Pacific herring (*Clupea pallasii*), and prowfish (*Zaprora silenus*) had low oil contents (<1.8%) and high moisture contents (>80.3%). Rankings of median proximate values illustrate the similarities. Surf smelt (*Hypomesus pretiosus*), rainbow smelt (*Osmerus mordax*), pricklebacks (*Lumpenus* sp.), Atka mackerel (*Pleurogrammus monopterygius*), Pacific sand lance (*Ammodytes hexapterus*) and Pacific sandfish (*Trichodon trichodon*) ranked high in median protein content (>15.4%). Median ash content for all species ranged from 0.6% to 3.3%. Total wet mass caloric content (kcal g^{-1}) was calculated for the four main species and a linear model was developed for caloric content as a function of moisture. The linear models (caloric content = $b_0 + b_1 \times$ moisture) were Pacific sand lance and Pacific sandfish ($b_0 = 7.82$, $b_1 = -0.09$); eulachon ($b_0 = 7.97$, $b_1 = 0.08$); and capelin ($b_0 = 9.70$, $b_1 = -0.11$)."

351. Pedersen, R. V. K., Orr, U. N., and Hay, D. E. 1995. Distribution and preliminary stock assessment (1993) of the eulachon, *Thaleichthys pacificus*, in the lower Kitimat River, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2330. Prince Rupert, BC: Department of Fisheries and Oceans Canada, North Coast Division, Habitat and Enhancement Branch, Pacific Biological Station. 23 p.

Keywords: British Columbia, Kitimat River, age at spawning, biomass, eggs,

fecundity, larvae, length, length-weight relationship, migration, run timing, sex ratio, spawning

Abstract: “Samples of spawning eulachons *Thaleichthys pacificus* were collected in March 1993, during the annual eulachon spawning period in the Kitimat River, British Columbia. Weekly samples of emerging larvae and unhatched eggs were sampled with a plankton net, at several sites along the river, during April, May and June, 1993. A flowmeter on the net al.lowed estimation of egg and larval densities in numbers per m^3. These densities, when analysed with data on total daily river volumes, provided a basis to estimate the total production of eggs and larvae from the river during the main spawning period. The total production of eggs and larvae was estimated at about 5.7 × 109. The estimated relative fecundity (about 252 eggs/g for males and females combined), and estimated mean weight, allowed us to estimate the total spawning biomass at about 22.6 tonnes or about 514,000 individuals. We emphasized that this estimate is an approximation, and we discussed sources of error in this estimation. Comparison of larval production at different sites in the river was used to identify the main spawning sites. Analyses of water temperatures enabled a calculation of the thermal units required for incubation. The results of this study provide a basis for better evaluation of the impacts of industrial wastes from industry and urbanization around the river. We made recommendations for future improvements of the methods used in this study and suggested new information requirements.”

352. Pendray, T. 1993. Skeena River eulachon larvae sampling 1993. Unpublished draft report. Department of Fisheries and Oceans Canada, Prince Rupert, B.C.
Keywords: British Columbia, Skeena River, larvae

353. People of ‘Ksan. 1980. Gathering what the great nature provided: Food traditions of the Gitksan. Seattle: University of Washington Press.
Keywords: subsistence

354. Perez, M. A. 1994. Calorimetry measurements of energy value of some Alaskan fishes and squids. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum No. NMFS-AFSC-32. Seattle: Alaska Fisheries Science Center. 32 p.
Keywords: caloric content

355. Pete, M. C. 1984. Subsistence use of herring in the Nelson Island region of Alaska. Technical Paper No. 113. Juneau: Alaska Department of Fish and Game, Division of Subsistence.
Keywords: Alaska, subsistence

356. Petroff, I. 1882. Report on the population, industries, and resources of Alaska: Tenth Census. Washington, D.C.: U.S. Department of the Interior, Census Office.
Keywords: Alaska, historical

357. Piatt, J. F., Kettle, A. B., and Abookire, A. A. 1999. Temporal and geographic fish communities of lower Cook Inlet, Alaska. Fisheries Bulletin 97(4):962-77.
Keywords: Alaska, Cook Inlet, distribution, geographic

358. Pirozhnikov, P. L. 1947. New data on the fishes of Laptex Fea [in Russian]. Dokl. Akad. Nauk SSSR 56. 441-443

Keywords: taxonomy

Experiment—does that apply to this study? *Thaleichthys* taxonomic notes; cited in Gruchy and McAllister

359. Pitcher, K. W. 1977. Population productivity and food habits of harbor seals in the Prince William Sound-Copper River Delta area, Alaska. Final report to U.S. Marine Mammal Commission, Report No. MMC-75, 03. 36 p.

Keywords: Alaska, Prince William Sound, Copper River, predators (mammals)

360. Pitcher, K. W. 1980. Food of the harbor seal, *Phoca vitulina Richardsi*, in the Gulf of Alaska. Fishery Bulletin 78(2):544-49.

Keywords: Alaska, Gulf of Alaska, predators (mammals)

Abstract: "The five top-ranked prey of harbor seals in the Gulf of Alaska were walleye pollock, octopus, capelin, eulachon, and Pacific herring." Table shows eulachon ranked #4; modified Index of Relative Importance—57; occurrences—4.9%; volume—11.6%.

361. Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fishery Bulletin, U.S. 79(3):467-72.

Keywords: Alaska, Gulf of Alaska, predators (mammals)

362. Porter, R. P. 1893. Report on population and resources of Alaska at the eleventh census: 1890. Washington, D.C.: U.S. Department of the Interior, Census Office.

Keywords: Alaska, historical

363. Price, R. E. 1990. The great father in Alaska: The case of the Tlingit and Haida salmon fishery. Douglas, AK: First Street Press.

Keywords: Alaska, Southeast, historical, fisheries (subsistence)

364. Prince Rupert Forest Region. 1998. Eulachon: A significant fish for First Nations communities. Forest Sciences, Prince Rupert Forest Region, Extension Note No. 32. Smithers, B.C..

Keywords: British Columbia, biology, fisheries (subsistence), habitat , life history, run timing, sexual dimorphism, spawning

Abstract: "This extension note provides background on eulachon biology, discusses recent population declines, and provides information for forestry people planning or undertaking work in eulachon watersheds."

365. Pruter, A. T. 1966. Commercial fisheries of the Columbia River and adjacent ocean waters. U.S. Fish and Wildlife Service, Fish. Ind. Res. 3(3):17-68.

Keywords: Columbia River, fisheries (commercial)

366. Redwood, T. 1880. Eulachon oil. Proceedings of the National Museum No. 3. p. 262-263.

Keywords: historical, oil, subsistence

367. Reeves, K. 2001. Harvest along the Chilkoot. Alaskan Southeaster (June):45-46.

Keywords: Alaska, Chilkat River, Chilkoot River, fisheries (subsistence), historical, oil, subsistence

Abstract: "Known also as candlefish, because of the oiliness of the flesh, and to the Tlingits as saak, this member of the smelt family has been an important staple to the Natives of the Chilkat Valley since beyond memory. It can be smoked,

dried, frozen or eaten fresh, but is gathered primarily for the prized oil, rendered in an extensive process and used as a dip for a variety of foods."

368. Rexstad, E. A., and Pikitch, E. K. 1986. Stomach contents and food consumption estimates of Pacific hake, *Merluccius productus*. Fishery Bulletin 84(4):947-56.

Keywords: predators (fish)

369. Richardson, J. 1836. Fauna boreali-Americana; or the zoology of the northern parts of British America. Part Third, The Fish. London: Richard Bentley. p. 226.

Keywords: Columbia River, historical

Abstract: Note from Langer et al. (1977): "Apparently describes type specimen from Columbia River locality (named *Salmo* (*Mallotus*) *Pacificus*)."

370. Ricker, W. E., Manzer, D. F., and Neave, E. A. 1954. The Fraser River eulachon fishery, 1941-1953. Fisheries Research Board of Canada, Manuscript Report No. 583. 35 p.

Keywords: British Columbia, Fraser River, abundance, age at spawning, fisheries (commercial), run timing

Abstract: "The catch of Fraser River eulachon has tended to increase over the years 1939-54, the largest take being 750,000 lb in 1952. Catch per unit effort has fluctuated, but shows no consistent trend up or down (Fig. 1). About half of the variation in catch is the result of changes in amount of fishing done, the remainder being ascribable to variation in abundance (or possibly catchability) of the stock. The decrease in the size of the stock caused by fishing was not large enough to be reflected in the seasonal indices available, or in comparisons of effort and catch per unit effort between years. Rate of exploitation has probably not exceeded 30

percent."

"The age of maturing eulachons has not yet been satisfactorily settled, but the great majority appear to fall within the range II to IV years. If maturity is predominantly at either age II or age III or some combination of these, the larger stocks (as indicated by catch per unit effort) have produced the smaller progeny generations, on the whole (Fig. 2-4)."

"Following the Fraser River flood of 1948, the catch and availability of eulachon was low two years later. This could be significant only if the fish mature mostly at age II."

"There is an indication that the time of arrival of the fish varies with river temperature near the end of March, but this depends almost wholly upon one year, 1941, in which temperature was 3 degrees Fahrenheit warmer than usual and the run was 5 days earlier than average."

371. Riemer, S. D., and Brown, R. F. 1997. Prey of pinnipeds at selected sites in Oregon identified by scat (fecal) analysis, 1983-1996. Oregon Department of Fish and Wildlife, Wildlife Diversity Program Technical Report No. 97-6-02. 34 p.

Keywords: Oregon, Columbia River, predators (mammals)

Abstract: "Table 11. Prey species identified from Pacific harbor seal scat (fecal) samples (n = 51) collected in spring (February, March) 1992-1993 at the Columbia River, (Desdemona Sands) Oregon

Prey Species	% Frequency of Occurrence
Eulachon	84.3

Pacific Lamprey	19.6
Starry Flounder	11.8
Fish unid.	7.8
Pacific Staghorn Sculpin	7.8
Pacific Herring	5.9
Smelt	5.9
Whitebait Smelt	3.9
Longfin Smelt	2.0
Pacific Sand Lance	2.0
Pacific Tomcod	2.0
Pacific Whiting	2.0”

372. Robinson, D. G., Barraclough, W. E., and Fulton, J. D. 1968a. Data record: Number, size composition, weight and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, May 1-4, 1967. Fisheries Research Board of Canada Manuscript Report Ser. No. 964.

Keywords: British Columbia, Strait of Georgia, food and feeding habits, larvae

Abstract: Note from Langer et al. (1977): “Total of 148 eulachons caught near Fraser River; feeding on copepods, cirripeds, and trematodes.”

373. Robinson, D. G., Barraclough, W. E., and Fulton, J. D. 1968b. Data record: Number, size composition, weight and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, June 5-9, 1967. Fisheries Research Board of Canada Manuscript Report Ser. No. 972.

Keywords: British Columbia, Strait of Georgia, food and feeding habits, larvae, predators (fish)

Abstract: Note from Langer et al. (1977): "Approximately 2 × 105 eulachons (most with yolk sac) caught; larger fish contained copepods, cirripeds, trematodes, nematodes, cladocerans, and amphipod. Predators of eulachon included Pacific herring, steelhead trout, chum and sockeye salmon, surf smelt, kelp greenling, and Pacific sandlance."

374. Rogers, B. J., Wangerin, M. E., Garrison, K. J., and Rogers, D. E. 1980. Epipelagic meroplankton, juvenile fish, and forage fish: Distribution and relative abundance in coastal waters near Yakutat. Interim report to Outer Continental Shelf Environmental Assessment Program (OCSEAP). Seattle: Fisheries Research Institute, College of Fisheries, University of Washington. 106 p.

Keywords: Alaska, Yakutat, abundance, distribution, geographic

Abstract: "Eulachon were not targeted for this study; however, since they are a potentially important species to the ecology of the Yakutat area, we have included this section in the report."

"Large numbers of adult eulachon spawn in the Yakutat study area during March to early June (A. Brogall, pers. comm.). Eulachon are anadromous, sometimes traveling tens of miles upstream to spawn. The eggs are spawned over gravel and sand and become attached to the sediment by an outer adhesive membrane. The larvae are carried out to sea as soon as they hatch and little is known about their marine life."

"Eulachon are not presently exploited commercially in Alaska, although they are

an important forage fish (Macy et al. 1978). We expect to see larval eulachon at nearshore stations during spring and, or summer. However, it will be difficult to distinguish among species of smelt when the larvae are small (i.e., prior to the dvelopment of fin rays)."

375. Rogers, I. H., Birtwell, I. K., and Kruzynski, G. M. 1990. The Pacific eulachon (*Thaleichthys pacificus*) as a pollution indicator organism in the Fraser River estuary, Vancouver, British Columbia. Science of the Total Environment 97-98:713-27.

Keywords: British Columbia, Fraser River, age at spawning, bioaccumulation, contaminants, lipid content, migration, run timing, sex ratio

Abstract: "Eulachons return to the Fraser River each spring and migrate through the estuary to spawn in freshwater. During this migration they may be subjected to varying water quality conditions due to the discharge of domestic and industrial wastes and land drainage."

"Fish were captured at five estuarine stations in April 1986 and again at three stations in April, May 1988. The locations were from Steveston, at the river mouth, to Port Mann bridge, 31.0 km upstream, just above saltwater influence. Water samples, whole fish, gonads and pooled livers of both sexes were analyzed separately for selected organochlorine contaminants."

"Water and tissue samples contained chlorophenols from wood preservation operations and chloroguaiacols from pulp bleaching. Whole fish also contained DDE and DDD, 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 (TeCG), 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. Marked differences occurred in the concentration of contaminants in eulachon livers (for example, levels of 50.8 ± 42.2 ng g^{-1} 3,4,5-TCG at Steveston, and 446.4 ± 222.5 ng g^{-1} at Port Mann)."

"The relatively high lipid content of eulachons suggests them to be potential integrators of low-level contaminants in the Fraser River system. This, and their anadromous life history, recommend them as suitable annual monitors of selected organic compounds."

376. Rohner, R. P. 1967. The people of the Gilford: A contemporary Kwakiutl village. National Museum of Canada Bulletin No. 225, Anthropological Series No. 83. Ottawa.

Keywords: British Columbia, subsistence

377. Rohr, A. C., Hall, E. R., and Hall, K. J. 1996. Use of semipermeable membrane devices for monitoring pulp mill effluents: A preliminary assessment. Water Quality Research Journal of Canada 31(1):85-100.

Keywords: pulp mill effluents, water pollution effects

Abstract: "The application of semipermeable membrane devices (SPMDs) to the monitoring of pulp mill effluents is described. SPMDs were shown to be effective in sequestering candidate fish tainting compounds, thereby indicating their

potential for application to aquatic off-flavour problems such as tainting of eulachon."

378. Ronholt, L. L., Shippen, H. H., and Brown, E. S. 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass 1948-1976 (A historical review). Northwest and Alaska Fisheries Center Processed Report, Vol. 2. 570 p.

Keywords: Alaska, Gulf of Alaska, distribution, geographic, historical

379. Rostland, E. 1952. Freshwater fish and fishing in native North America. University California Publications in Geography No. 9. 313 p.

Keywords: subsistence

380. Rugh, D. J., Shelden, K. E. W., and Mahoney, B. A. 2000. Distribution of belugas in Cook Inlet during June, July 1993-2000. Marine Fisheries Review 62(3):6.

Keywords: Alaska, Cook Inlet, predators (mammals)

Abstract: "Access to food (Factor 3) may be the overriding element in beluga distribution in June and July (Moore et al., 2000), as described by Natives in Cook Inlet (Huntington, 2000). The consistency of whale concentrations at river mouths can best be explained as an efficient way for the whales to feed. These coastal concentrations apparently last from April until November (Huntington, 2000) and are very likely associated with the migration of anadromous fish, particularly eulachon, *Thaleichthys pacificus*, and Pacific salmon, *Oncorhynchus* sp. (Moulton, 1997; Huntington, 2000; Moore et al., 2000). However, it is unknown why belugas concentrate at only a few of the many rivers in Cook Inlet

and why they are not found at other rivers where presumably fish runs are adequate for their needs."

381. Sackett, R. 1979. The Chilkat Tlingit: A general overview. Occasional Paper No. 23, Anthropology and Historic Preservation, Cooperative Park Studies Unit. Fairbanks: University of Alaska.

Keywords: historical, subsistence

382. Samis, S. C. 1977. Sampling eulachon eggs in the Fraser River using a submersible pump. Water Quality Division Habitat Protection Directorate, Department of Fisheries and the Environment Canada, Pacific Region, Technical Report No. PAC, T-77-18. 10 p.

Keywords: British Columbia, Fraser River, Pitt River, eggs, spawning

Abstract: "Eulachon (*Thaleichthys pacificus*) spawning sites on the Fraser River are reported to be concentrated between Chilliwack and Mission (Hart and McHugh, 1944). An increased number of municipal sewage discharges to the Fraser River, plus the continuing encroachment of industry on the lower Fraser River waterfront, are factors expected to adversely affect existing eulachon stocks."

"To gain information on the extent of present eulachon spawning zones, a method of egg recovery was developed which would allow spot sampling of eulachon eggs in areas of moderate water velocities. A submersible electric pump was used to sample water, bottom sediments, intact fish eggs, and other benthic material to a water depth of 8 metres. The sampling method was effective in determining the presence or absence of eulachon eggs at selected sites; however, modifications in

sampler design will be required before the technique can be applied in a quantitative manner."

383. Scammon, C. M. 1974. The marine mammals of the northwestern coast of North America. San Francisco: Carmany.

Keywords: predators (mammals)

Abstract: Note from Langer et al. (1977): "Apparent reference to Nass eulachon run and attendant concentrations of seals, porpoises, killer whales, and sea lions"

384. Schultz, L. P. 1936. Keys to the fishes of Washington, Oregon, and closely adjoining regions. University of Washington Publications in Biology 2(4):103-338.

Keywords: taxonomy

385. Schultz, L. P. 1958. Keys to the fishes of Washington, Oregon and closely adjoining regions. Seattle: University of Washington Press. 140 p.

Keywords: taxonomy

386. Schultz, L. P., and DeLacy, A. C. 1935. Fishes of the American northwest. Journal of the Pan-Pacific Research Institute 10(4):365-80.

Keywords: general references on fish

387. Scott, J. M. 1973. Resource allocation in four syntopic species of marine diving birds. Ph.D. thesis. Oregon State University. Corvallis, OR.

Keywords: Oregon, predators (birds)

388. Scott, W. B. 1958. A checklist of the freshwater fishes of Canada and Alaska. Royal Ontario Museum, Division of Zoology and Palaeontology.

Keywords: general references on fish

389. Scott, W. B., and Crossman, E. J. 1967. Provisional checklist of Canadian freshwater fishes. Information Leaflet, Department of Ichthyology and Herpetology, Royal Ontario Museum. 39 p.

Keywords: general references on fish

390. Scott, W. B., and Crossman, E. J. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin No. 184:320-325.

Keywords: distribution, geographic, historical, life history, morphology, nomenclature

Abstract: pages on eulachon include:

"Nomenclature:

Salmo (*Mallotus*) *pacificus*—Richardson 1836:226 (type locality Columbia River)

Thaleichthys stevensi—Girard 1859:325

Osmerus pacificus—Swan 1881:258

Osmerus albatrossis—Jordan and Gilbert (1898) in Jordan and Evermann 1896-1900:2823

Thaleichthys pacificus (Richardson)—Jordan and Evermann 1896-1900:2823

Lestidium (*Bathysudis*) *parri*—Chapman 1939:522"

"Common names Eulachon: There are at least a dozen different attempts at the phonetics of the Chinook spoken name for this species. These range from hooligan to uthlecan to yshuh through the obvious variables of oolichan and ulichan. Candlefish, oilfish, small fish, salvation fish, and fathom fish are others. French common name: eulakane."

"Etymology:

Thaleichthys—oily fish; *pacificus*—of the Pacific."

391. Scudder, C. W. 1878. The ulikon or candle-fish of Alaska. Scientific American 39:266.

Keywords: Alaska, historical

392. Seaman, G. A., Lowry, L. F., and Frost, K. J. 1982. Foods of belukha whales (*Delphinapterus leucas*) in western Alaska. Cetology 44:1-19.

Keywords: predators (mammals)

393. Shepherd, B. G., and Vroom, P. R. 1977. Biology of the Nass River eulachon. Department of Fisheries and the Environment Canada, Pacific Region, Technical Report PAC, T-77-10. 55 p.

Keywords: British Columbia, Nass River, age at spawning, biology, length, run timing, sex ratio, sexual dimorphism, spawning

394. Shotridge, L. 1917. My northland revisited. The Museum Journal 8(2).

Keywords: historical

395. Sidwell, V. D. 1981. Chemical and nutritional composition of finfishes, whales, crustaceans, mollusks, and their products. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum No. NMFS F/SEC-11. 432 p.

Keywords: proximate composition

396. Silverstein, M. 1990. Chinookans of the Lower Columbia. *In* Handbook of North American Indians, Vol. 7: Northwest coast. Edited by W. C. Sturtevant and W.

Suttles. Washington, D.C.: Smithsonian Institution.

Keywords: historical, subsistence

397. Sinclair, E., Loughlin, T., and Pearcy, W. 1994. Prey selection by northern fur seals (*Callorhinus ursinus*) in the eastern Bering Sea. Fishery Bulletin, U.S. 92:144-56.

Keywords: Alaska, Bering Sea, predators (mammals)

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

Keywords: Oregon, Washington, Columbia River, Cowlitz River, Grays River, Lewis River, Sandy River, abundance, age at spawning, eggs, fecundity, fisheries (commercial), fisheries (sport), food and feeding habits, hatchery, historical, larvae, length, life history, migration, run timing, sex ratio, spawning, water pollution effects, water temperature

Abstract: "1. Smelt landings from the Columbia River and its tributaries have in recent years been second only to those of chinook salmon. Since the inception of the fishery the presence of smelt in the Columbia has been an annual affair, but runs in the tributaries have been sporadic in occurrence."

"2. Smelt are taken by gill nets and dip nets in the Columbia River and dip nets in its tributaries. The former gear ceases operation when fish are sufficiently available to the dip net fishery of the tributaries to supply the markets. In recent years diver gill nets have been introduced which allow a fishery during all stages of the tide in the Columbia River."

"3. Commercial and sport gear are known to disturb the developing eggs

deposited on the river bottom."

"4. The total annual commercial landings always exceed 1,000,000 pounds. At present the catch is limited to market demands by an association of smelt fishermen who catch only enough fish to fill successive orders. The catches have shown no decline but have fluctuated violently as the market has varied."

"5. Limited studies indicate that the young go to sea immediately and feed little, if at all, in fresh water. Little is known of their ocean habits, except that they feed on plankton."

"6. Smelt originating from the Columbia River probably return as adults to that watershed to spawn but do not necessarily return to the tributary from which they were hatched. Though racial characteristics have been only briefly investigated, the erratic tributary runs lend credence to the hypothesis that the entire smelt population is composed of one homogenous unit."

"7. A water temperature of approximately 40 degrees F is necessary to insure up-stream migration of smelt in the Columbia River to and beyond the mouth of the Cowlitz River."

"8. Experiments indicate that smelt exhibit an aversion to certain effluents from three different industrial sources located in the Longview, Washington, area."

"9. Readings of several hundred smelt otoliths indicate that Columbia River smelt spawn and die predominantly at three years of age and that four-year fish comprise a substantial portion of the run in some years."

"10. Male fish are at least three times as abundant as females throughout the run. Spawning occurs at night principally over fine gravel or coarse sand to which the

eggs attach. In 40-degree to 50-degree water, eggs hatch in approximately 30 to 40 days."

399. Snyder, G. R. 1970. Thermal pollution of Columbia River might threaten smelt. Commercial Fisheries 32(12):58-64.

Keywords: Columbia River, water temperature

400. Spalding, D. J. 1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbia coast. Fisheries Research Board of Canada Bulletin No. 146. 52 p.

Keywords: British Columbia, predators (mammals)

401. Spangler, E. A. K. 2002. The ecology of eulachon (*Thaleichthys pacificus*) in Twentymile River, Alaska. M.S. Thesis. Fairbanks: University of Alaska.

Keywords: Alaska, Twentymile River, age at spawning, fecundity, habitat, larvae, length, life history, migration, predators (birds), predators (fish), predators (mammals), radio telemetry, run timing, sex ratio, size, spawning , teeth, water temperature, weight

Abstract: Chapter 1—Life history of eulachon (*Thaleichthys pacificus*) in the Twentymile River, southcentral Alaska. "Eulachon entered the Twentymile River, a tributary of Turnagain Arm in southcentral Alaska, from 4 May to 21 June 2000 and from 17 April to 9 June 2001. Comparisons of size frequency distributions between gill nets and dip nets confirmed that gill nets were size selective. The frequency of males from dip net samples exceeded females, by a factor of 6.7:1.0 in 2000 and 2.1:1.0 in 2001. Male eulachon were larger and older than females in both years. The presence of teeth, which are assumed to be resorbed as a Ca

source during the late stages of sexual maturation, differed between sexes. More female eulachon had teeth than males. Fecundity ranged from 8,532 eggs to 67,507 eggs per female. Fecundity was related to age, length and weight. Compared to other river systems on the Pacific Coast, the duration of the eulachon run in Twentymile River is the longest recorded. We attribute this to differences in sampling methods and environmental conditions. Generally, fish from northern latitudes were larger and younger than fish from rivers further south. We postulate that the greater oceanic productivity of the northern regions accounts for these differences."

Chapter 2 - Environmental factors associated with the adult migration and downstream larval drift of eulachon (*Thaleichthys pacificus*) in a glacial river.

"The importance of eulachon (*Thaleichthys pacificus*) and recent changes in their apparent abundance in the Pacific Northwest has necessitated the development of population monitoring programs. In previous work, both the migration of adult eulachon and downstream drift of larvae have been used to aid in the monitoring of local populations. However, questions remain on how key environmental variables are associated with the migration of adult and downstream drift of larval eulachon, especially in Alaska where little work has been conducted. We investigated the migration of adults and downstream drift of larval eulachon in Twentymile River and compared them with the following environmental factors: water temperature, tide height, water discharge, light intensity, and density of bald eagles (*Haliaeetus leucocephalus*). Adult fish were detected from 4 May to 21 June 2000 and 17 April to 9 June 2001. The variables with the strongest

relationships with adult catch per unit effort included water temperature, tide height, light intensity, river discharge, and the density of bald eagles. Larval eulachon were captured with bongo nets from 8 May to 28 August 2001. The strongest relationships between larval productivity and environmental variables included water temperature, river discharge, and light intensity."

Chapter 3 - Migratory behavior of radio tagged adult eulachon (*Thaleichthys pacificus*). "Eulachon are an anadromous forage fish that inhabit temperate regions of North America. Little is understood of their migratory behavior in freshwater. We tested the feasibility of using redio telemetry for tracking adult eulachon and successfully applied this technique to learn more about their spawning migration. Radio tracking was conducted daily from 15 May to 22 June 2000 and 19 April to 20 June 2001 in Twentymile River, a tributary of Turnagain Arm, Cook Inlet. Of the 23 fish tagged in 2000 we successfully tracked 95.7 percent, with one tag remaining stationary. Of the 108 fish tagged in 2001, 86.2 percent were successfully tracked and 15 tags remaining stationary. The maximum upstream distance for males was 9,470 m in 2000 and 8,097 m in 2001. The maximum upstream distance for females was 6,855 m in 2000 and 7,761 m in 2001. Larval sampling was conducted to test whether we detected the upper limits of migration and spawning with radio telemetry. Although total numbers were low, larvae were observed upstream of the locations fish were observed with radio telemetry. There were four main clusters of observations identified as possible spawning sites in 2000 and five clusters in 2001. Four of the spawning sites were

in similar locations in both years varying by less than 330 m. Radio telemetry is a useful tool for studying the migration behavior of adult eulachon in freshwater."

402. Speckman, S. G., and Piatt, J. F. 2000. Historic and current use of Lower Cook Inlet, Alaska, by belugas, *Delphinapterus leucas*. Marine Fisheries Review 62(3):22-26.

Keywords: Alaska, Cook Inlet, abundance, distribution, geographic, predators (mammals)

Abstract: "Another common prey species, eulachon, *Thaleichthys pacificus*, is of uncertain status. Sport fishing harvests of eulachon have declined dramatically during the past 20 years in upper Cook Inlet, possibly indicating declines in eulachon stocks, decreased fishing effort, or both, but lack of data on species-specific fishing effort precludes interpretation of the catch data (Stratton and Cyr 1997, Howe et al. 1999, Howe 2000). Anecdotal observations indicate declines in numbers in the northern part of the inlet (Kitto 2000). Eulachon populations in lower Cook Inlet have not been assessed, and no information is available to suggest major changes (Fox 2000)."

403. Stacey, D. 1998a. An historic overview of the Kwawkewlth, Knight, and Kingcome Inlet oolachon fishery. Unpublished report on the historical eulachon fisheries of British Columbia. Prepared for the Canada Department of Fisheries and Oceans. 13 p.

Keywords: British Columbia, Knight Inlet, Kingcome Inlet, historical, fisheries (subsistence)

404. Stacey, D. 1998b. Meeting of the B. C. Eulachon Research Council—Minutes, March 12.

Keywords: British Columbia, Knight Inlet, Klinaklini River, oil, population status

405. Stacey, D. 1995. Eulachon: An historical overview. Unpublished manuscript by Common Resources Fishery Research. 75 p.

Keywords: British Columbia , distribution, geographic, fisheries (subsistence), historical, run timing

406. Stansby, M. E. 1976. Chemical characteristics of fish caught in the northeast Pacific Ocean. Marine Fisheries Review 38(9):1-11.

Keywords: Columbia River, proximate composition

407. Starks, E. C. 1911. Results of an ichthyological survey about the San Juan Islands, Washington. Annals of the Carnegie Museum 7(2):162-213.

Keywords: Washington, distribution, geographic, historical

408. Stewart, F. L. 1975. The seasonal availability of fish species used by the coast Tsimshians of northern British Columbia. Syesis 8:375-88.

Keywords: British Columbia, distribution, geographic, subsistence

409. Stewart, H. 1977. Indian fishing: Early methods on the northwest coast. Seattle: University of Washington Press.

Keywords: subsistence

410. Stoddart, C. W. 1899. Over the Rocky Mountains to Alaska. St. Louis: Herder.

Keywords: historical, predators (fish), predators (mammals)

Abstract: note from Langer et al. (1977): “Apparent reference to halibut, cod, porpoise, and finback as predators of eulachons”

411. Stratton, B., and Cyr, P. 1997. Annual management report for the Anchorage area, 1995. Alaska Department of Fish and Game, Fishery Management Report No. 97-01. Anchorage. 98 p.

Keywords: Alaska, Cook Inlet, management

412. Sturdevant, M. V. 1999. Forage fish diet overlap, 1994-1996. *Exxon Valdez* Oil Spill (EVOS) Restoration Project final report 97163C, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory. 103 p.

Keywords: Alaska, Prince William Sound, competition, food and feeding habits, size

Abstract: "The Forage Fish Diet Overlap component of the Alaska Predator ecosystem Experiment (APEX) investigated the trophic interactions of forage fish prey of seabird populations which were impacted during the *Exxon Valdez* oil spill. The authors analyzed more than 5000 specimens of 14 forage species, and zooplankton and epibenthic prey samples from Prince William Sound (PWS), 1994-96. The species examined were mainly young-of-the-year (YOY) and age-1 walleye pollock (*Theragra chalcogramma*), Pacific herring (*Clupea pallasi*), Pacific sandlance (*Ammodytes hexapterus*), pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), Pacific cod (*Gadus macrocephalus*), Pacific tomcod (*Microgadus proximus*), prowfish (*Zaprora silenus*), northern smoothtongue (*Leuroglossus schmidti*), eulachon (*Thaleichthys pacificus*), capelin (*Mallotus villosus*), threespine stickleback (*Gasterosteus aculeatus*), and Pacific sandfish (*Trichodon trichodon*)."

"The authors compared seasonal size, diet composition and diet overlap between

species from May-November, 1994; described the diets, prey fields and prey selection of juvenile pollock and herring in summer and autumn, 1995 and of juvenile pollock and herring in summer and autumn, 1995 and of juvenile herring, sandlance and pink salmon in summer, 1996; examined for prey shifts and feeding declines when the 1995-96 fish occurred in multi-species aggregations (sympatrically) compared to when they occurred in single species aggregations (allopatrically) to test for competition; and compared diet composition interannually for several species in July of the three years."

413. Sturdevant, M. V., Willette, T. M., Jewett, S., and Deberec, E. 1999. Diet composition, diet overlap, and size of 14 species of forage fish collected monthly in PWS, Alaska, 1994-95. Chapter 1. *In* Forage Fish Diet Overlap, 1994-96. M. V. Sturdevant. *Exxon Valdez* Oil Spill Restoration Project final report 98163C. p. 12-36

Keywords: Alaska, Prince William Sound, food and feeding habits

Abstract: The majority (55-80%) of small samples of eulachon (total n = 30) captured in October and November, 1994 and 1995, in Prince William Sound, Alaska, had empty stomachs. Those with prey in their stomachs had eaten euphausiids and unidentified malacostracans.

414. Sturtevant, W. C., and Suttles, W. 1990. Handbook of North American Indians, Vol. 7: Northwest coast. Washington, D.C.: Smithsonian Institution.

Keywords: historical, subsistence

415. Suttles, W. 1951. Economic life of the Coast Salish of Haro and Rosario Straits. Ph.D thesis. Seattle: University of Washington.

Keywords: British Columbia, historical, subsistence

416. Suttles, W. 1987. Coping with abundance: Subsistence on the Northwest Coast. *In* Coast Salish Essays. Seattle: University of Washington Press. p. 51

Keywords: historical, subsistence

417. Suttles, W. 1990. Environment. *In* Handbook of North American Indians, Vol 7: Northwest Coast. Edited by W. C. Sturtevant and W. Suttles. Washington, D.C.: Smithsonian Institution.

Keywords: historical, subsistence

418. Svetovidov, A. N., Dorofeeva, E. A., Klyukanov, V. A., and Shaposhnikova, G. K. 1975. Morphological principles of classification of Salmonoidei. Zoological Zhurnal 54(4):559-74.

Keywords: morphology, skeleton, taxonomy

Abstract: Comparative studies of common morphological features the suborder Salmonoidei showed that 3 families can be recognized: Osmeridae, Salmonidae and Plecoglossidae. These common features are fully represented in the genus *Thaleichthys* of the family Osmeridae, which was divided into subfamilies Thaleichthyinae, Osmerinae and Hypomesinae.

419. Swain, L. G., and Walton, D. G. 1989. Report on the 1988 fish monitoring program. Fraser River estuary monitoring. Victoria: Province of British Columbia. 147 p.

Keywords: British Columbia, Fraser River, population status

420. Swan, J. G. 1881. The eulachon or candle-fish of the northwest coast. Proceedings of the U.S. National Museum Vol. 3, p. 257-264. Smithsonian Miscellaneous Collection 1882, 22, article 1. Washington, D.C.: Smithsonian Institution Press.

Keywords: British Columbia, Nass River, historical

Abstract: An historical account of the eulachon run in the Nass River with reference to the Native fishery.

421. Swanton, J. R. 1909. Tlingit myths and texts. Smithsonian Institution Bureau of American Ethnology Bulletin No. 39. Washington, D.C.: U. S. Government Printing Office.

Keywords: historical, subsistence

422. Taranetz, A. Y. 1933. New data on the ichthyology of the Bering Sea. Vestn. D.V. Filiata Acad. Nauk SSR 1(3):67-78.

Keywords: Alaska, Bering Sea, length

Abstract: note from Langer et al. (1977): "Apparently reports eulachon maximum length as 9 in. (229 cm)."

423. Taylor, F. H. C., and Barner, L. W. 1974. A herring survey of Juan de Fuca Strait in 1971. Report on A.P. Knight cruises APK 71-3, -4, -5, -6 and -7 (July 22-December 12). Fisheries and Marine Service Technical Report No. 503. Nanaimo: Canada Department of the Environment.

Keywords: British Columbia, Juan de Fuca Strait, distribution, geographic, movements

Abstract: "This report covers 5 cruises from July to Dec 1971 to determine if it is possible to estimate for management purposes the abundance of adult and juvenile

herring passing through Juan de Fuca Strait. Evidence was found of immigration of adults and emigration of juveniles. Assessment of abundance was not considered feasible because of the presence of a layer of mixed spp in deep water and the existence of only a narrow shelf of shallow water. The mixed layer was composed of eulachon, hake, whiting, dogfish, and euphausids. Some information on the movement of dogfish, hake, and eulachon was also obtained."

424. Taylor, F. H. C., and Kieser, R. 1980. Hydroacoustic and fishing surveys for walleye pollock in Dixon Entrance and nearby areas, July 5-23, 1978. Canadian Maunscript Report of Fisheries and Aquatic Sciences No. 1572. Nanaimo, BC. 77 p.

Keywords: British Columbia, abundance

Abstract: "The hydroacoustic estimate of midwater fish in Dixon Entrance was 15,000 t. Of this, 10,000 t were considered pollock, 2,800 t rockfish, 1,000 t herring, and 500 t eulachon."

425. Townsend, L. D. 1938. Sampling Columbia River smelt. Washington State Department of Fisheries.

Keywords: Columbia River, population status

426. Trent, T. W. 1973. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna and Central Cook Inlet drainages. Alaska Department of Fish and Game Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14:53-73.

Keywords: Alaska, Susitna River, fisheries (sport)

427. Trent, T. W. 1974. Inventory and cataloging of sport fish and sport fish waters of the Lower Susitna and Central Cook Inlet drainages. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-6, 15:161-172.

Keywords: Alaska, Susitna River, fisheries (sport)

428. Triton Environmental Consultants. 1990. Life history of the eulachon (*Thaleichthys pacificus*) of the Kemano and Wahoo rivers, British Columbia: Results of 1989 investigations. Draft report prepared for the Aluminum Company of Canada Ltd. Triton References: 2039, WP 3677. 51 p.

Keywords: British Columbia, Kemano River, Wahoo River, life history

429. Triton Environmental Consultants. 1991. Freshwater life history of the eulachon (*Thaleichthys pacificus*) of the Kemano and Wahoo rivers, British Columbia. Vol. 1: Results of the 1990 investigations. Draft report prepared for the Aluminum Company of Canada Ltd. Triton References: 2055, WP 4014. 94 p.

Keywords: British Columbia, Kemano River, Wahoo River, life history

430. Turner, N. J. 1975. Food plants of British Columbia Indians. Part I. Coastal Peoples. British Columbia Provincial Museum.

Keywords: British Columbia, oil

Abstract: This handbook discussses how the coastal peoples prepared some berries by mixing them with eulachon oil and freshly fallen snow and whipping them to a froth to make a kind of “ice cream.”

431. Tutty, B. D., and Morrison, J. A. 1976. Dredge monitoring capture data and entrainment estimates during the 1976 juvenile salmonid migration in the lower

Fraser River. Technical Paper Ser PAC, T-76-21. Habitat Protection Directorate, Pacific Region, Environment Canada.

Keywords: British Columbia, Fraser River

432. Veijanen, A., Villberg, K., and Paasivirta, J. 1994. Studies on eulachon tainting problem. II. Integrated sensory and instrumental analysis. Presented at the Second International Conference on Environmental Fate and Effects of Bleached Pulp Mill Effluents, November 6-10, 1994, Vancouver, B.C., Canada.

Keywords: contaminants

433. Vincent-Lang, D. S., and Queral, I. 1984. Eulachon spawning in the lower Susitna River. Chapter 5. *In* Aquatic habitat and instream flow investigations, May-October 1983. Edited by C. C. Estes, and D. S. Vincent-Lang. Susitna Hydro Aquatic Studies, Report No. 3, Vol. 5. APA document No. 1934. Anchorage: Alaska Department of Fish and Game. p. 1-32 and appendices.

Keywords: Alaska, Susitna River, habitat, migration, run timing, spawning, temperature

Abstract: "Eulachon [*Thaleichthys pacificus* (Richardson)] are an anadromous member of the smelt family. Studies to determine naturally occurring hydraulic and temperature relationships to eulachon immigration and spawning were initiated by the Alaska Department of Fish and Game (ADF&G) in 1982 and continued into 1983. These surveys indicated that eulachon are probably the most abundant species of fish in the Susitna River. Based on 1982 and 1983 catch data, eulachon begin their upstream spawning migration during early to mid-May. Two distinct spawning runs of eulachon enter the Susitna River with no apparent

definite correlation with either mainstem discharge or temperature. Spawning was found to occur over a broad range of hydraulic and substrate conditions along the margins of mainstem habitats from the mouth of the Susitna River (RM 0) upstream to RM 50.3. Based on a representative number of spawning sites selected for further evaluation, it appears that similar physical habitat conditions will be present under both decreased and increased mainstem discharge conditions."

434. Walker, S. 2001. 2000 eulachon summary—public version. Memorandum January 19, 2001, Alaska Department of Fish and Game, Commercial Fisheries Division. Ketchikan, AK.

Keywords: Alaska, Stikine River, Unuk River, fisheries (commercial), historical, subsistence

Abstract: This memo presents the commercial harvest records (1969-2000) of eulachon for the Unuk and Stikine Rivers in Southeast Alaska.

435. Ware, D. M., and McFarlane, G. A. 1989. Fisheries production domains in the northeast Pacific Ocean. *In* Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Edited by R. J. Beamish, and G. A. McFarlane. Canadian Special Publications in Fisheries and Aquatic Sciences No. 108:359-379

Keywords: Pacific Ocean, population status

436. Warner, I. M., and Shafford, P. 1979. Forage fish spawning surveys—southern Bering Sea. Alaska Marine Environmental Asssessment Project completion report, Research Unit No. 19 (extension), May 1977-September 1977. Kodiak,

AK: Alaska Department of Fish and Game. 64 p.

Keywords: Alaska, Bering Sea, abundance, age at spawning, distribution, geographic, fecundity, length, run timing, sexual dimorphism, weight

Abstract: “Small catches of eulachon between June 5 and June 29 at Meshik-Port Heiden resulted in a mean length of 224 mm and mean weight 94 gms (Figure 26). Age determinations from otoliths showed a mean age of 3.1 years (Figure 27). Mean male-female body length differences were slight, with males being 223 mm in body length and females 227 mm. Fecundity samples from six specimens yielded a mean fecundity of 41.9 thousand ova, the range being from 34,000 to 57,000.”

“The authors believe these fish are significantly more important as a forage fish than our catch results indicate. Indeed in some years they might conceivably be the most numerous forage fish species in the southeastern Bering Sea. Several accounts by local natives indicate that Bear River, Sandy River and the Meshik River had or have large runs of eulachon. It is important to note that even during years of low abundance, this species of forage fish has a documented high potential which strongly indicates a significant level as food fish.”

437. Washington Department of Fish and Wildlife, and Oregon Department of Fish and Wildlife. 2001. Washington and Oregon eulachon management plan. Olympia: Washington Department of Fish and Wildlife. 32 p.

Keywords: Oregon, Washington, Bear River, Columbia River, Cowlitz River, Elochoman River, Grays River, Kalama River, Lewis River, Naselle River, Nemah River, Nooksack River, Quinault River, Queets River, Sandy River,

Skamokawa River, Wynoochee River, age at spawning, distribution, geographic , eggs, fecundity, fisheries (commercial), fisheries (sport), fisheries (subsistence), food and feeding habits, habitat , larvae, juveniles, life history, management, otoliths, predators (birds), predators (mammals), run timing, size, spawning

Abstract: "Eulachon, or Columbia River smelt (*Thaleichthys pacificus*) are a small, schooling, anadromous fish that inhabit the Northeast Pacific. The main run in Washington and Oregon returns to the Columbia River and its tributatries. The eulachon resource has been in recent decline and is the subject of increasing management and research activity. In particular, the decline prompted the fishery management agencies, the Washington Department of Fish and Wildlife (WDFW) and the Oregon Department of Fish and Wildlife (ODFW) to reassess their management framework for eulachon, as management had historically not been responsive to interannual changes in abundance or distribution. The purpose of this document is to provide abundance-based guidance for the eulachon management and research activities conducted by the WDFW and ODFW."

438. Weinberg, M. E., Wilkins, M. E., Lauth, R. R., and Raymore, P. A. 1994. The 1989 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and age length composition. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum NMFS-AFSC-33. 168 p.

Keywords: bycatch, distribution, geographic

439. Weitzman, S. H. 1967. The origin of the stomiatoid fishes with comments on the classification of salmoniform fishes. Copeia 3:507-40.

Keywords: taxonomy

440. Westrheim, S. J., and Harling, W. R. 1983. Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (*Gadus macrocephalus*), rock sole (*Lepidopsetta bilineata*), and Petrale sole (*Eopsetta jordani*) landed in British Columbia, 1950-1980. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1681. 38 p.

Keywords: British Columbia, predators (fish)

441. Wildwood, (no initial). 1940. The home of the eulachon. Vancouver Province (July 31):4.

Keywords: general references on fish

442. Wilimovsky, N. J. 1954. List of the fishes of Alaska. Stanford Ichthyological Bulletin 4(5):279-94.

Keywords: Alaska, distribution, geographic

443. Wilke, F. 1957. Food of sea otters and harbor seals at Amchitka Island. Journal of Wildlife Management 21:241-42.

Keywords: Alaska, predators (mammals)

444. Willoughby, C. 1889. Indians of the Quenaielt Agency, Washington Territory. Annual Report of the Smithsonian Institution, year ending June 30, 1886. Part 1. p. 267-273.

Keywords: historical, subsistence

445. Willson, M. F., Gende, S. M., and Marston, B. H. 1998. Fishes and the forest. Bioscience 48(6):455-62.

Keywords: Alaska, Southeast, Berners Bay, predators

Abstract: "At one location in Southeast Alaska, we have recorded over 30 species of birds and mammals feasting on eulachon during their spawning run; gulls, sea ducks, eagles, seals, and sea lions are most numerous, but the list also includes shorebirds and passerines (Marston et al. 2002)..

"For example, many thousands of Thayer's gulls (*Larus thayeri*) feed intensively on eulachon in Southeast Alaska in May, as they migrate to breeding grounds in the Canadian Arctic. Migrating red-breasted mergansers (*Mergus serrator*) throng the river mouths, feasting on eulachon as they move into fresh water."

446. Willson, M. F., and Marston, B. H. 2002. Fishing success of gulls at a southeast Alaska smelt run. Journal of Field Ornithology 73(1):91-96.

Keywords: Alaska, Berners Bay, predators (birds)

Abstract: "We observed foraging behavior and success of gulls (*Larus* sp.) at spawning runs of eulachon (*Thaleichthyes pacificu*s Osmeridae) in Berners Bay, Alaska, in spring 1996-1998. Adults foraged more effectively (≤56% of dives were successful) than immatures (≤56%) when diving for fish, but there was little difference in the effectiveness of piracy (≤23% success for all gull species and age classes). The hypothesis that larger birds would be better pirates and less likely to lose prey to pirates was not well supported, although smaller species seldom attacked larger ones. Age classes less successful at foraging were more likely to act as pirates, but this relationship did not hold among species or

between years. The frequency of piracy attempts was positively correlated with the availability of fish captured by other birds."

447. Wolfe, R. J. 1987. The super-household: Specialization in subsistence economies. Paper presented at the 14th annual meeting of the Alaska Anthropological Association, March 12-13. Anchorage.

Keywords: Alaska, Southeast, subsistence

448. Wolfe, R. J., and Magdanz, J. 1993. Case example of distribution and exchange: eulachon (hooligan) oil. Introduction to Section 1. *In* The sharing, distribution, and exchange of wild resources in Alaska: A compendium of materials presented to the Alaska Board of Fisheries. Juneau: Alaska Department of Fish and Game, Division of Subsistence.

Keywords: Alaska, Chilkat River, historical, subsistence

Abstract: "The annual harvest of eulachon for oil in southeast apparently has not made significant biological impacts on eulachon fish population levels, although extensive biological research on Alaska eulachon has not been done."

449. Womble, J. N. 2003. Seasonal distribution of Steller sea lions (*Eumotopias jubatus*) in relation to high-quality ephemeral prey species in southeastern Alaska. M.S. thesis. Fairbanks: University of Alaska.

Keywords: Alaska, predators (mammals)

Abstract: "Energetic demands are high for sea lions during spring when females are pregnant and lactating and males are preparing for extended fasting during the breeding season. Therefore, I predicted that the distribution of sea lions in spring would be influenced by the distribution of spring-spawning aggregations of high-

energy Pacific herring (*Clupea pallasii*) and eulachon (*Thaleichthys pacificus*) in southeastern Alaska. Monthly aerial surveys at 23 Steller sea lions haulouts revealed that haulout use was seasonally dynamic. Some sea lion haulouts were only occupied during spring. Other haulouts exhibited pronounced increases in the number of sea lions during certain seasons. Sea lion haulouts with peak numbers of sea lions in spring were significantly closer to forage fish aggregations than haulouts with peak numbers of sea lions at other times of year. From March through May 2002, I used aerial surveys to monitor the number of Steller sea lions at spring spawning aggregations of Pacific herring and eulachon. The maximal numbers of sea lions observed were 949 at a eulachon-spawning site and 252 at a herring-spawning site. Seasonal pulses of high-energy food resources may be critical to the reproductive success of individual Steller sea lions."

450. Wright, S. 1999. Eulachon petition: Endangered Species Act. Federal Register 64(228): 10 p.

Keywords: endangered species

451. Wynne, K. 1990. Marine mammal interactions with the salmon drift gillnet fishery on the Copper River Delta, Alaska 1988-1989. Alaska Sea Grant College Program Technical Report No. 90-05. 36 p.

Keywords: Alaska, Copper River, predators (mammals)

Abstract: Identifiable eulachon remains found in stomachs of three harbor seal carcasses washed up on beaches.

452. Wynne, K., Norcross, B., Hills, S., and Buck, L. 2000. Availability and use of prey at Steller sea lion haulouts in the Kodiak area. Fairbanks: University of Alaska.

Keywords: predators (mammals)

453. Young, J. S. 1984. Identification of larval smelt (Osteichthyes: Salmoniformes: Osmeridae) from northern California. M.S. thesis. Arcata, CA: Humboldt State University.

Keywords: identification, larvae

454. Yuasa, M. 2001. Cowlitz smelt fairly jumping in nets. The Seattle Times. Weekend Outlook Section (March 8):D8.

Keywords: Washington, Cowlitz River, abundance, larvae, taxonomy

Abstract: “It’s what many had been waiting years for: tons of shimmering silver smelt crowding the Lower Cowlitz River. It all started last week, when commercial and state Fish and Wildlife netters began tracking huge numbers of smelt, also known as a hooligan or eulachon, in the Lower Columbia River below Longview.”

WEB SITES

1. Alaska Department of Fish and Game, Juneau, AK. “Eulachon: Wildlife Notebook Series.” Web page. Available at http://www.adfg.state.ak.us/pubs/notebook/fish/eulachon.php.
2. Anonymous. no date. Ethnobotany and Eulachon. Washington State Department of Transportation, Environmental Affairs Office. Web page. Available at http://www.wsdot.wa.gov/Environment/CulRes/ethnobotony.htm.
3. Anonymous. no date. “Tsimshian Society and Culture.” Available at http://www.civilization.ca/aborig/tsimsian/socintre.html. Searching for “eulachon” lists several Web pages within Web site.
4. Brown, Evelyn D., and Okey, Thomas A. no date. “Planktivorous ‘Forage Fishes’: Eulachon.” Available at http://www.fisheries.ubc.ca/Projects/PWSound/AlaskaEco/PWSPOSTS/PWSREP29.HTM.
5. Department of Fisheries and Oceans Canada. 2000. “Pelagics & Minor Finfish - Pacific Region, Overview of the Eulachon Fishery. Available at http://www.pac.dfo-mpo.gc.ca/ops/fm/herring/eulachon/default_e.htm.
6. Eulachon on the Northcoast. 2000. Web page. Available at http://www.princerupert.com/nature/Eulachon_Apr_2000.htm.
7. Forage Fish Research. 2006. Web page. Available at http://www.afsc.noaa.gov/species/Forage_fish.htm.

8. Forseth, A. 1995-2002. “B.C. Adventure Home Page—Alexander Mackenzie Heritage Trail.” Web page. Available at http://www.bcadventure.com/adventure/explore/cariboo/trails/almack.htm.

9. Lipid Variations in spawning Eulachon. 2004. Poster (PDF file). Available at www.afsc.noaa.gov/Stellers/ppt_2003/Site_Specific_SSL_Studies/SE_Alaska/Schaufler%20poster.pdf.

10. Northwest Aquatic Information Network. “Anadromous fish life history profiles: Smelt.” Web page. Available at http://www.streamnet.org/pub-ed/ff/Lifehistory/smelt_fact.html.

11. Pacific States Marine Fisheries Commission, Gladstone, OR. “Eulachon (smelt).” Web page. Available at http://www.psmfc.org/habitat/edu_smelt_fact.html.

12. U.S. Geological Survey, Alaska Biological Science Center. 2002. “Seabirds, forage fish, and marine ecosystems in Alaska.” Available at http://www.absc.usgs.gov/research/seabird_foragefish/.

13. Waterbury, Barbara. 2002. “Indian Fishing.” Web page. Available at http://www.alaskafishingontheweb.com/tlingit_fishing.

KEYWORD INDEX (by reference number)

ADDENDUM TO BIBLIOGRAPHY (2003-2006 PUBLICATIONS)

1. Beacham, T. D, Hay, D. E., and Le, K. D. 2005. Population structure and stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt, in the Pacific Northwest. Marine Biotechnology 7(4):363-372.
2. Buchheister, A, and Wilson, M. T. 2005. Shrinkage correction and length conversion equations for *Theragra chalcogramma*, *Mallotus villosus* and *Thaleichthys pacificus*. Journal of Fish Biology 67(2):541-548.
3. Clarke, A. D. 2005. Elemental signatures in bone to determine life history characteristics in fish. M.S. Thesis. University of Northern British Columbia. 122 p.
4. Department of Fisheries and Oceans Canada, Nanaimo, BC. 2003. Eulachon embryonic egg and larval outdrift sampling manual for ocean river surveys. Canadian Technical Report Fishereies and Aquatic Sciences 2451. 36 p.
5. Gauthier, S, and Horne, J. K. 2004. Acoustic characteristics of forage fish species in the Gulf of Alaska and Bering Sea based on Kirchhoff-approximation models. Canadian Journal of Fisheries and Aquatic Sciences 61(10).
6. Gauthier, S, and Horne, J. K. 2004. Potential acoustic discrimination within boreal fish assemblages. ICES Journal of Marine Science 61(5):836-845.
7. Hamilton, J. B., Curtis, G. L., Snedaker, S. M., and White, D. K. 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams—a synthesis of the historical evidence. Fisheries 30(4):10-20.

8. Hay, D. E., and Beacham, T. D. In press. Stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt in the eastern Pacific. ICES Journal of Marine Sciences.

9. Hedrick, R. P., Batts, W. N., Yun, S., Traxler, G. S., Kaufman, J., and Winton, J. R. 2003. Host and geographic range extensions of the North American strain of viral hemorrhagic septicemia virus. Diseases of Aquatic Organisms 55(3):211-220.

10. Kaukinen, K. H., Supernault, K. J., and Miller, K. M. 2004. Development of microsatellite loci in eulachon (*Thaleichthys pacificus*). Molecular Ecology Notes 4(4):632-634.

11. Sigler, M. F, Womble, J. N., and Vollenweider, J. J. 2004. Availability to Steller sea lions (*Eumetopias jubatus*) of a seasonal prey resource: a prespawning aggregation of eulachon (*Thaleichthys pacificus*) Canadian Journal of Fisheries and Aquatic Sciences 61(8): 1475-1484.

12. Stables, T. B., Perrin, C. J., and Rosenau, M. L. 2005. Acoustic and trawl surveys to locate eulachon aggregations in the lower Fraser River, British Columbia. North American Journal of Fisheries Management 25(2):675-688.

13. Womble, J .N., Willson, M. F., Sigler, M. F., Kelly, B. P., and VanBlaricom, G. R. 2005. Distribution of Steller sea lions *Eumetopias jubatus* in relation to spring-spawning fish in Southeast Alaska. Marine Ecology Progress Series 294:271-282.