SUMMARY OF EULACHON RESEARCH IN THE COPPER RIVER DELTA, 1998-2002

REPORT TO THE ALASKA BOARD OF FISHERIES

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INTRODUCTION

Recent Commercial Use

Interest in a commercial fishery for eulachon *Thaleichthys pacificus* in the Copper River began in 1995 because of the steep decline in abundance of Columbia and Frasier River eulachon in the early 1990s. In 1996 four permits were issued for the freshwater harvest of eulachon with dip nets. One permit holder harvested a small amount to distribute to potential buyers. In 1997 two permits were issued for a purse seine fishery in marine waters with a quota of 55 metric tons (mt) or approximately 60 tons. No harvest occurred due to a record sockeye salmon run.

Four permits were issued in 1998 for the dip net harvest of eulachon in the fresh waters of the lower Copper River. The quota was again set at 55 mt, and the quota harvested in only 7 days. Subsequently, a daily quota of 3.6 mt was instituted for the remainder of the run and the total harvest was 78.3 mt. As many as four people fished with all the Copper River harvest occurring between 20 May and 2 June (14 days). The majority of the harvest occurred along a 33 m length of the western shore of the western-most channel of the Copper River at the Copper River Highway. This channel (Flag Point Channel) is also referred to as 27-Mile Channel. Fish were harvested from shore with 50 cm (~20 inch) diameter dip nets with 1.8 m (~ 6 ft) handles. All harvest occurred in daylight hours with between 1 and 8 h fished (average = 4 h).

The successes of the 1998 fishery lead to many requests for information about the permit process for 1999. Therefore, the department changed the fishery from an open-access Commissioners permit structure to a department test fishery. A single permit would be issued to the high bidder. This was a precautionary measure that allowed us to 1) control commercial effort while collecting data required for a better understanding of the biology of the Copper River eulachon, and 2) fund the required research efforts.

The test fishery process started with the 1999 fishery; however, no fish were harvested due to a small run in the Flag Point Channel of the Copper River. In 1999, the Board of Fisheries established the Prince William Sound Eulachon Smelt Management Plan (5 AAC 24.520). The management plan states that eulachon may only be harvested with dip nets in the freshwaters of the Copper River downstream of Miles Lake from 1 May through 15 June. It also specifies the maximum annual harvest allowed as 272 mt (300 tons).

The harvest quota for the 2000 test fishery was reduced to 182 mt due to the apparent low abundance of fish in 1999. The 2000 harvest of 59.2 mt occurred between 19 May and 28 May (10 days). As in 1998, harvest occurred along the west beach of the western-most channel of the Copper River.

Because the department had not completed a biomass estimate, the harvest quota for 2001 was lowered to 136.5 mt. The 2001 fishery harvested 71 mt from 19 May through 30 May (11 days). In 2001, the river discharge shifted more to the middle channel at Flag

Point Channel, along with the majority of the migrating eulachon. The test fishery permit holder moved to the middle channel on 26 May, about 6 days into the run.

In 2002 only one bid was received; however, the bid would not provide adequate funding for research and was not accepted. Columbia River eulachon harvest increased to about 327 mt in 2002 (G. Bargmann Washington Department of Fish and Wildlife, Seattle, Washington personal communication). This may limit the market for Copper River eulachon in the future. The Copper River commercial harvest has ranged from no fish in 1999 to 78.3 mt in 1998 (Table 1).

Table 1. Commercial eulachon harvests in the Copper River area, 1996-2002.

Year	Harvest Quota (mt)	Gear	Permits	Harvest (mt)
1996	None	Dip net	4	Small
1997	55	Purse Seine	2	None
1998	55	Dip net	4	78.3
1999	272	Dip net	Test Fishery	None
2000	182	Dip net	Test Fishery	59.2
2001	136	Dip net	Test Fishery	71.0
2002		No bid accepted		None

Cordova subsistence users have expressed concerns about the commercial fishery for eulachon in the Copper River. The Native Village of Eyak (NVE) filed a Special Action Request with the Federal Subsistence Board in 2001. NVE requested an emergency closure of all fresh waters of the Copper River to harvest of eulachon to all but federally-qualified subsistence fishers. The federal staff analysis by Buklis (2001) concluded that given the gear restriction and harvest level, the test fishery did not threaten subsistence uses in the Copper River.

Proposal 19 seeks to close commercial fishing for eulachon in waters currently closed to salmon fishing within the Copper River District under 5 AAC 24.350 (1). The proposal proponents, NVE, cite concerns about the sustainability of the harvest, availability of eulachon for subsistence, and effects of the commercial harvest on populations of marine mammals, birds, and fishes that prey on eulachon.

Summary of Eulachon Biology

In the family Osmeridae, eulachon are a small (< 250 mm) forage fish. Eulachon is the scientifically accepted common name; however, they have other common names, such as hooligan and candlefish in Alaska. They 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. There are probably other eulachon spawners in similar glacial, mainland systems that have yet to be documented. In Alaska eulachon spawn 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 (R. Berceli, ADF&G, Cordova, 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 > 1,000 documented salmon spawning systems and perhaps only six eulachon spawning systems (Copper River, Martin River, Alaganik Slough, Scott River, Ibeck Creek, and Eyak River.

The marine distribution of eulachon includes almost all the west coast of North America from Monterey Bay, California through the eastern Bering Sea (Anderson 1976; Allen and Smith 1988). The limited distribution of eulachon in the Bering Sea suggests that they survived the most recent glaciation in a southern refuge along the Pacific coast, and expanded their range subsequent to the receding of the ice sheet (McPhail and Lindsey 1970). Recent work on eulachon genetics is consistent with expansion from a southern refuge area postglaciation (McLean et al. 1999).

In Alaska, eulachon enter river systems from January through early July; starting earliest in Southeast Alaska and generally getting progressively later as you move north and west to the north side of the Alaska Peninsula. Entrance timing may be related to water temperature because 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 C (Hart 1973), and the small larvae (3-6 mm; Barraclough 1964) are quickly carried into the marine environment. For example, larvae in the Copper River downstream of Miles Lake (river km 35) would be flushed into the marine environment within 24 hours at current velocities = 0.5 m/sec. Little is known of eulachon life history after the larvae enter the marine environment until they return to spawn.

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 Fraser River spawners as just completing their second year. Most fish die after spawning, but there is some evidence for repeat spawning (Barraclough 1964).

Eulachon are an important food source for many birds and mammals (Marston et al. 2002; Willson and Marston 2002). Spawning runs of eulachon are preyed upon by several bird species, including seabirds (Laridae), raptors (Falconidae), waterfowl (Anatidae), and Corvids (Corvidae). Additionally, several marine mammal species including harbor seals *Phoca vitulin*, stellar sea lions *Eumetopias jubatus*, humpback whales *Megaptera novaeangliae* also feed on spawning eulachon. Dogfish sharks *Squalus suckleyi*, halibut *Hippoglossus stenolepus*, coho salmon Onchorhynchus *kisutch*, chinook salmon *O. tshawytscha*, and numerous other predators may also feed on eulachon adults. Eulachon eggs and larvae are preyed upon by adult Dolly Varden

Salvelinus malma, as well as coho salmon parr (M. Wippfli, U.S. Forest Service, Juneau, personal communication). Also returning adult sockeye salmon *O. nerka* in the Copper River delta have been found with adult eulachon in their stomachs (J. A. Bernatowicz, Washington Department of Fish and Wildlife, Yakima, personal communication).

Historical Harvests

There are subsistence, personal use, and sport fisheries for eulachon from Southeast Alaska to the Alaska Peninsula. 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 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 or "grease" for use as food and as a trade item (Macnair 1971; Steward 1975). The people of Klukwan near Haines may be the only Alaskans still harvesting large quantities of eulachon to render for oil (Mills 1982).

In the Prince William Sound area, almost all the subsistence use of eulachon has been by residents of Cordova (Scott 2001). The Board of Fisheries has determined that smelt (including eulachon) in the Prince William Sound area are customarily and traditionally harvested for subsistence use (5 ACC 01.616). However, no determination was made of the amount reasonably necessary for subsistence uses. Subsistence harvest by Cordova residents was estimated for 6 years between 1984 and 1997. Harvest of smelt (eulachon and unidentified smelt) ranged from 0.8 mt in 1993 to 4.3 mt in 1997. The harvest of eulachon by NVE tribal members ranged from 15 to 57 liters per household in 1999-2001; however, one household was excluded because their harvest was much larger than the others (Joyce et al. 2002). Using the conversion of 1 liter ~ 0.4 kg, the use per household has ranged from ~ 6.0-22.8 kg. Of the 98 households surveyed that use eulachon in Cordova, Joyce et al. (2002) reported that the two major uses were food by 68 households, and bait by 11 households. Overall in Alaska, the subsistence harvest of eulachon appears to be fairly small (Jim Fall, Alaska Department of Fish and Game, Anchorage, personal communication).

The sport harvest in Alaska averaged >210,000 smelt (eulachon and capelin *Mallotus villosus*) from 1977-1997 (Mills 1991; Howe et al. 1998). Approximately half (average = 54%) of the harvest occurred in the Twentymile River or the salt water immediately adjacent to Turnagain Arm. The Alaskan sport harvest appears 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 of Canada (Scott and Crossman 1973) 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 et al. 1997). Columbia River harvests between 1960 and 1997 ranged from 1,520 mt in 1992 to only 18 mt in 1993 (Hay et al. 1997). The average harvest, 1960-1992, was 805 mt with the minimum harvest of 206 mt occurring in 1984, four years after Mt. St. Helens erupted (Hay et al. 1997). The Fraser River harvests are substantially smaller with a 1960-1992 mean of 50 mt (Hay et al.

1997).

The only long-term commercial fisheries in Alaska include small harvests from rivers near Ketchikan (P. Doherty, Alaska Department of Fish and Game, Ketchikan, personal communication). The fishery is managed for guideline harvest levels (GHL) in the Unuk/Chickamin (11,250 kg), Bradfield (2,250 kg), and Stikine Rivers (2,250 kg). Harvests are usually small (4.5 to 14 mt) and sporadic. 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). The precipitous decline of eulachon abundance from British Columbia south to California starting in the early 1990s has generated more eulachon research than 100 years of commercial fishing.

Objectives

This report summarizes a portion of eulachon investigations on the Copper River delta for 1998-2002. Our general objective was to gather basic biological data about the spawning runs of eulachon on the Copper River delta. Specific objectives are listed below:

(1) Describe the age, sex, and size (AWL) of the spawning runs, 1998-2002;
(2) Determine the temporal and spatial distribution of the spawning runs, 1998-2002;
(3) Determine the fecundity of females in the spawning run in 2000 and 2001;
(4) Estimate the spawning biomass of eulachon in Flag Point Channel of the Copper River, 2000 and 2001;
(5) Estimate the mean and variance of larval density at different river depths, 2002;
(6) Use the larval density at depth to adjust spawning biomass estimates for 2001.

METHODS

Study Area

The study area was the Copper River delta downstream of Miles Lake (Figure 1). The rivers of the Copper River delta drain into the central Gulf of Alaska. The study area ranged from the Eyak River (9.7 km, Copper River Highway) to the Copper River channel at ~ 60 km of the Copper River highway; however, most of the research effort focused on the Flag Point Channel. The Copper River highway first crosses the Copper River at 43.5 km from Cordova, approximately 16 km upstream of the river mouth.

Downstream of Miles Lake, the Copper River becomes a low gradient (1.1 m/km) alluvial plain crossed by eleven bridges between Flag Point and the Million Dollar Bridge (Brabets 1997). The Copper River proper has the sixth largest drainage basin in Alaska at 62,920 km^2 and the second largest average discharge at 1,722 m^3/sec (Brabets 1997). The Copper River carries on an annual basis approximately the same amount of suspended sediment as the Yukon River with ~1/5 the average discharge (Brabets 1997).

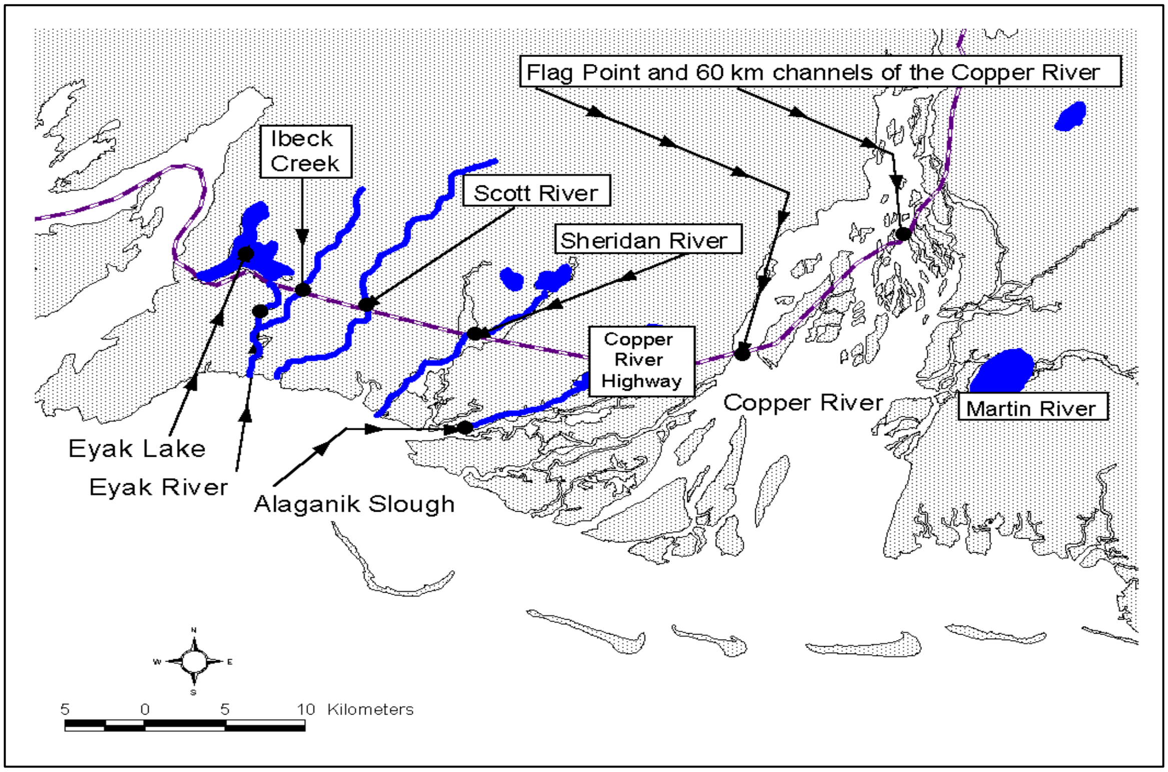

Figure 1. Copper River delta downstream of Miles Lake along with selected drainage systems.

Other systems crossed by the Copper River Highway from west to east include the Eyak River, Ibeck Creek, Scott River, Elsner River, Sheridan River, and Alaganik Slough. The Scott River, Elsner River, and Sheridan River are feed by glacial waters. All the other delta rivers have increased turbidity from glacial inflow on a seasonal or sporadic basis.

Age, Weight, Length, and Sex Ratio

In 1998 samples were collected daily from the commercial harvest at Flag Point Channel. We collected daily samples because we lacked information on the number of age classes in the run and the extent of temporal changes. An examination of the marginal precision gain with each stratum indicated very little increase after three strata (< 2%; Cochrane 1977). Therefore, after 1998 we attempted to collect samples from the early, middle, and late timing of each run. Sample sizes (n = 450) were set to simultaneously estimate all the age proportions within ± 5% of the true proportion, 90% of the time (Thompson 1992). This assumed random sampling from a multinomial population with less than 5% of the otoliths being unreadable.

In 2000 and 2001, samples were collected near the beginning, middle, and end of the major run in Flag Point Channel. Samples were also collected at Alaganik Slough in 2000 and Ibeck Creek in 2001. In 2002 samples were collected near the beginning and middle of the large run Flag Point channel with the same timing as in recent years. Another sample was collected from a group of spawners that entered the river about 2 weeks later. Samples were also collected from spawners in the channel at 60 km of the Copper River highway (60- km channel) and the Eyak River.

Fish collected for biological sampling were measured to the nearest mm (standard length), and weighed to the nearest gram. Some fish were frozen 1-3 months prior to sampling; however, no adjustments were made to size measurements. The sex of each fish was determined by examination of the gonads or by external characteristics. Male eulachon have much longer pectoral and pelvic fins; and breeding tubercules on the head, fins and scales (Morrow 1980). In most cases the presence of eggs or milt in spawning fish confirmed the sex.

Independent sex ratio samples were collected in 2000-2002. Sex ratio, S, was modeled as a binomial distribution to estimate the proportion of females, p, where S = 1/p. Variance of S is estimated as

$$Var(S) = \frac{S^2(S-1)}{n} \tag{1}$$

If sufficient fish were available we sampled 300 fish. This sample size should allow us to estimate the proportion of females within ± 5%, 90% of the time (Cochrane 1977). Sex ratios were estimated daily for most of the run at Flag Point Channel. We generally sexed live fish using the external, secondary sexual characteristics. If external characteristics were not sufficient, fish were squeezed to check gonad products for evidence of sex. Fish were captured with dip nets and either counted and sexed out of the net, or placed in a tote with water and counted back into the river.

Ages were determined by examining the sagittae otoliths. We examined scales, otoliths, and vertebrate for age; however, otoliths had the only easily discernible circuli patterns. The otoliths were removed by making a ventral cut through the transverse plane just posterior of the preoperculum. They were removed with forceps, cleaned of the saccule membrane, and dried. All otoliths were stored dry in depressions of black plastic trays covered with masking tape. The file name, harvest date, tray number, and fish numbers were written on the masking tape on each tray.

Binocular dissecting scopes with 10x eyepieces and variable objectives (0.8 to 4.0) were used to examine the otoliths. Whole otoliths were read in water, convex side up, on black plastic trays under reflected light. Submerging the otoliths in water reduces the glare and improves the contrast between the translucent (hyaline) and opaque zones. Translucent zones appear dark when using reflected light and a black background. Both otoliths were examined if possible; however, sometimes one otolith was missing or both otoliths were crystallized, or too transparent for age determination.

In 1998 several solutions were tested for reading otoliths including glycerin, a 50:50 solution of glycerin and water, and plain water. Many of the otoliths tended to clear out quickly even with just water and became so transparent that they would have to be cleaned and left to dry before attempting to read again. Therefore, otoliths were read by placing plain water to cover on no more than 10 otoliths at a time. All otoliths were examined by two readers. The first reader would examine the 10 otoliths and then the next reader. The two readers did not compare ages until between-reader differences were examined.

To assign an age to a fish, the translucent zones were counted out from the primordium or core. Readers counted the number of translucent zones in regions that were the easiest to read and had the highest count. At least two regions were counted, and if the counts from the first two regions did not agree, a third was counted. If two of the three areas had the same count, this count became the assigned age; otherwise the reader started again with area one. A translucent zone should be formed before spring spawning runs later than May. Therefore, the otolith edge was generally counted as a year; however, the timing of translucent zone deposition in eulachon has not been validated.

After all samples were examined, readers reexamined otoliths that were interpreted for age differently. The consensus age was used for any further analysis. If no consensus was reached, an error code was assigned and the fish was not included in the age composition.

Temporal and Spatial Distribution of Adult Spawners

Surveys were conducted from a jet skiff to map the distribution of spawning eulachon in the Copper River. Sites upstream of the bridge at Flag Point were sampled with a dip net for the presence of spawning adult eulachon. Particular attention was given to areas of bird activity and eddies where eulachon tend to concentrate. Locations sampled were recorded on a global positioning system (GPS). Other rivers along the Copper River Highway were examined for eulachon; however, no systematic program was in place for 1998-2002. Concentrations of bald eagles *Haliaeetus leucocephalus*, gulls, or harbor seals were used as indicators of the presence of eulachon. This was confirmed if possible using visual observations or dip nets

Run timing in Flag Point Channel was estimated with catch or catch per unit effort (CPUE) from the commercial fishery, test fishery, and project sampling. In 2002 we estimated run timing with dip net CPUE. The number of dips required to fill a 15 liter bucket was used as the measure of CPUE. Adult eulachon were sampled at a location about 50 m downstream of the bridge at Flag Point. We used dip nets with 15 mm wire mesh and a 50 cm diameter mouth mounted on a 1.8 m pole.

Fecundity

Fecundity was estimated using methods described by Pedersen et al. (1995). The eggs were preserved and hardened by placing in individually marked bottles containing 3.7% formalin for 1-3 weeks. Ovaries were then rinsed well in clean seawater under a hood until no fumes were detected. The ovaries were then weighed to the nearest 0.01 g, and forceps were used to remove eggs from the ovary connective tissue. A dissecting scope was then used to separate out 100 eggs. The eggs were vacuum-dried for one minute on damp filter paper and weighed to the nearest 0.1 mg. Three 100-egg samples were examined for each fish, and the mean weight of a single preserved egg estimated. As in Pedersen et al. (1995), if the three estimates of the weight of 100 eggs were not within ± 10%; three new 100-egg samples were weighed.

Fecundity (eggs/female) was estimated as the preserved ovary weight divided by the mean egg weight. Extra ovarian tissue (<5% of the total) probably tends to bias the fecundity estimate high. The relative fecundity (eggs/gram of total body weight) was estimated as the total fecundity divided by the total body weight.

Larvae Sampling, 2000 and 2001

Larval samples were collected in the Flag Point Channel in 2000 and 2001 to estimate the total abundance of eggs and larvae. "Larval sampling" will be defined to include both eggs and larvae for simplicity. Equipment problems limited our sampling in 2000 to four days between 22 June and 1 August. In 2001 samples were collected on 16 days between 13 June and 31 July. Sampling started in 2001 approximately 2 weeks after the end of the spawning. The end of spawning was estimated from the proportion of spawned out fish in the commercial harvest. All sampling was done during day light hours. The stage of the tide was not considered because the sample sites were > 8 km upstream of the mean high tide line.

Methods used to collect larval samples were similar to those described by Pedersen et al. (1995). Samples were collected with a plankton net attached to a line, 1 meter above a lead weight. We initially tested a 350 µm mesh net with a 58 cm diameter mouth, but the high river velocity kept it from fishing effectively, even with a 22.5 kg lead weight. All 2001 samples were collected with a 350 µm mesh net, 65 cm long with a 19.5 cm diameter mouth. A calibrated flow meter was mounted in the net aperture to allow estimation of the volume of water through the net. In 2000, six sites were fished, three upstream of the bridge at Flag Point and three downstream. We used only the downstream sites to estimate biomass, and the upstream sites will not be discussed further. In 2001, only sites downstream of the bridge were fished. The three sites were in a line perpendicular to the river flow and divided the river into thirds (Figure 2).

The general site area was located with surveyors flagging on the west shore. After the general area was located, a GPS was used to locate the three sample sites. A skiff was anchored at each site to use as the sampling platform. Water depth (m) was read from the boat depth sounder. The plankton net line was matched to the river depth and attached to a davit. Two samples were collected at each of the three sites during each sampling event. The net was fished for 5 minutes, pulled up by hand, and rinsed well to gather all larvae in the net collection bucket. Each sample was placed in a labeled, 1-liter sample bottle. Data recorded for each sample included date, time, flow meter revolutions; water depth and sampling depth in meters.

Five-percent Formalin was used to preserve the first samples in 2000, but Ethanol diluted 1:1 with water was used to preserve all other samples. Rose Bengal stain was added to each sample at least 15 minutes prior to counting. Samples were then rinsed through a fine mesh colander and examined under a dissecting microscope or magnification lamp. Samples containing excess organic matter or glacial silt were divided into smaller portions and diluted with water to facilitate counting. The entire sample was examined for larvae and eggs. After counting, each sample was returned to the original sample bottle and diluted Ethanol was added. All samples were counted by two readers, and the average number of eggs and larvae for each sample was used in all further analysis.

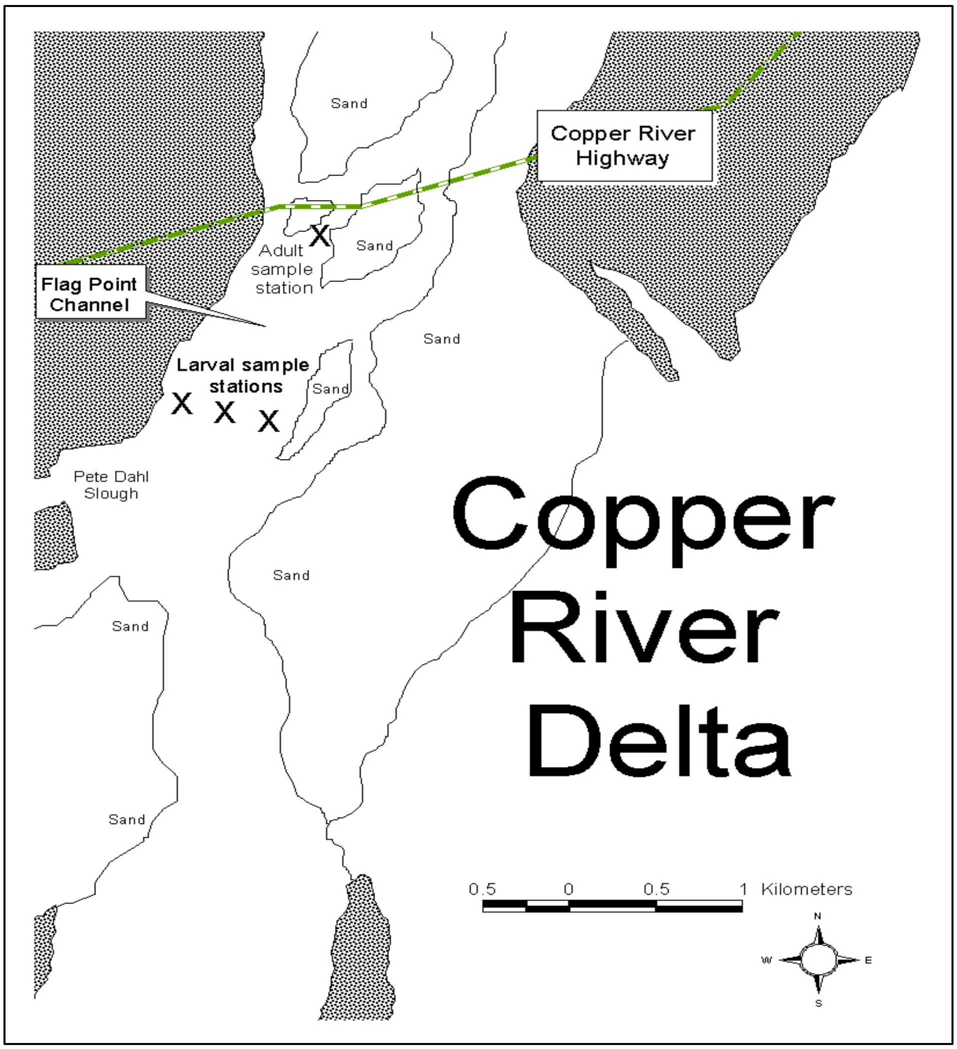

Figure 2. Location of eulachon larval sampling sites in 2000-2002, and adult sampling site in 2002..

Larval densities were estimated for each sample as the average count of eggs and larvae divided by the volume of water through the net as measured with the flow meter. Daily production was estimated as the mean larval density times the estimated daily river discharge in m^3. We assumed the larval density in the water column was relatively constant throughout the day. Larval production for days not sampled was estimated as the average of the two nearest adjacent days sampled.

Daily river discharge was estimated from the 1995 stage-discharge relationship determined by the U. S. Geological Survey (USGS) for the Copper River at the Million Dollar Bridge (Brabets 1997). The river profile at the Million Dollar Bridge has changed little between 1978 and 1995 (Brabets 1997); therefore, the 1995 stage-discharge relationship should provide reasonable estimates of the total discharge. Stage height was read each day between 16 May and 31 July by ADF&G employees at the Miles Lake sonar site. The readings were used to estimate the daily discharge at Miles Lake using the stage-discharge relationship. No adjustment was made to account for water entering the Copper River downstream of the Million Dollar Bridge.

Biomass Estimation, 2001

The total estimated egg and larval abundance was used to calculate the spawning biomass of adults similar to Pedersen et al. (1995). Biomass was estimated as

$$B = \left[T/f' \right](C) \tag{2}$$

Where

B	=	estimated spawning biomass in mt,
T	=	estimated total production of eggs and larvae in the area,
f'	=	estimated overall relative fecundity (no. eggs g^{-1} of body weight), and
C	=	a conversion factor, 10^{-6}, to convert grams to mt.

The overall relative fecundity was calculated assuming a sex ratio of 2.0 (equal proportions). The biomass range was calculated using estimates of the proportion of total discharge at Miles Lake that passed through the three bridges at Flag Point (proportions from 0.10 to 0.35). The spawning biomass range was set to account for the uncertainties in the data.

Distribution of Larvae in the Water Column, 2002

The study area was located about 1 km downstream of the Flag Point bridge over the Copper River (Figure 2). A location >3 m deep was selected to allow 3 separate depth samples. The sample area had a flat sandy bottom about 75 m from the left bank (looking upstream). A 500 µm mesh plankton net was used to sample three depths: 1 m off the bottom, 2 m off the bottom, and just below the surface (~ 3 m off the bottom). The plankton net was 135 cm long with a 25 cm diameter mouth.

Equal sample sizes were collected at the three depths on 3 June (n = 3 x 3 depths), 8 June (n = 5 x 3 depths), and 12 June (n = 10 x 3 depths). Fifty-four samples were collected, eighteen at each depth. The line required at each site was determined with the boat depth sounder. The net was attached to the weighted line at the desired depth, and fished from a davit on an anchored skiff. Sample collection and lab counting procedures are as described earlier.

Prior to larval sampling, we estimated the timing of adult eulachon spawning using CPUE from dip net sampling. This allowed us to match larval sampling with approximately the peak hatch chronology of eulachon (30-40 days; Hart 1973).

Analysis of 2002 Larval Data

We used a 2-way analysis of variance (ANOVA) to test for differences in mean egg and larval densities among the three sampled depths (fixed effect) with sample day as random effect. Data was log transformed because an association was found with the variance and the mean.

We recalculated the 2001 biomass estimates using the 2002 density differences at the three depths. The 2001 daily larval and egg production estimates were originally calculated by assuming that egg and larval densities were the same at each depth. The total egg and larval production on days sampled was recalculated as

$$P = \sum_{i=1}^{3} \sum_{j=1}^{n} \left(P_j / 3 \right) (d_i) \qquad (3)$$

Where

P = estimated total production of eggs and larvae on days sampled (j = 1 to n).

P_j = original estimate of the total production of eggs and larvae on day j.

$d_{i,}$ = The proportion of the mean density at depth i divided by the mean bottom density, i.e., the mean density from the middle and surface samples as a proportion of the mean bottom density.

For example, the mean near-surface density in 2002 was 56 percent of the bottom density. Therefore, the density in the top third of the water column was estimated as one third of the original density times 0.56. The total production of eggs and larvae was then estimated as the sum of the daily productions. Interpolations for days not sampled was as described earlier.

RESULTS

Age, Sex, and Size

Flag Point Channel of the Copper River

Most of our age, sex, and size samples are from Flag Point Channel because the commercial fishery and test fisheries facilitated sampling. The age of eulachon based on otolith samples ranged from 2 to 6. The majority of the fish in all years sampled (1998, 2000-2002) were age 3, 4, or 5. One or two age classes predominated in all years. The 1998 run was mostly age-5 fish (89.4%) while the 2002 run was mostly age-4 fish (96.1%: Figure 3).

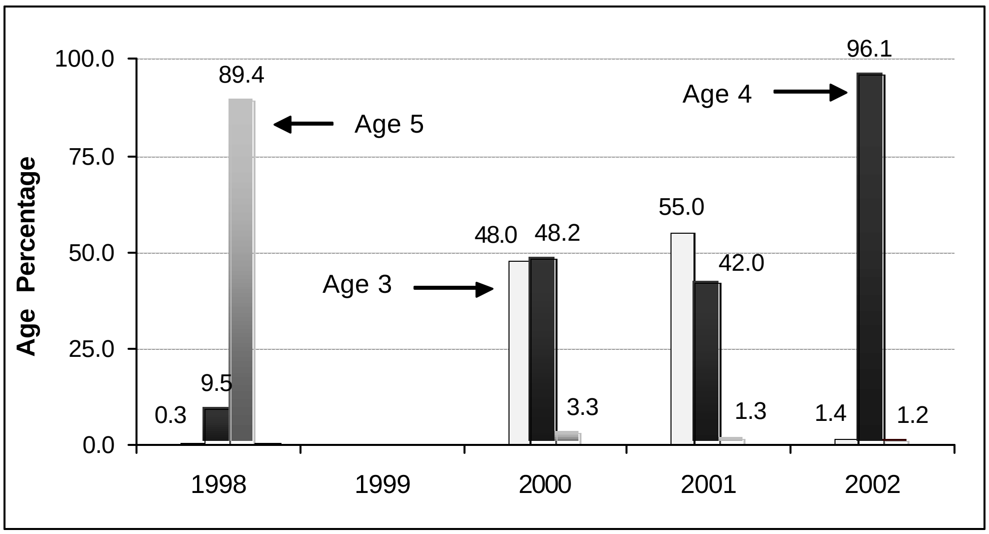

Figure 3. Age percentages of eulachon sampled from Flag Point Channel of the Copper River, 1998 -2002. The 1999 run was not sampled because fish were only documented on one day.

The overall mean lengths ranged from 174 to 183 mm (Table 2). Mean lengths were significantly different among years for males (ANOVA, F = 248.84, df = 5,501, P < 0.0001) and females (ANOVA, F = 79.84, df = 1441, P < 0.0001). For males, all pairwise comparisons (Sheffe 95% CI) were significant except 1998 vs. 2002. Pairwise comparisons of female lengths indicated that the 1998 and 2002; and 2000 and 2001 were not significantly different (Sheffe 95% CI).

The mean lengths of males and females were also significantly different within each year (Two-tailed t-test, P< 0.001). Length-at-age was smaller for females in all years by 4-8 mm for age classes with sample sizes > 30 fish (nonstatistical comparison = NSC). Additionally, male and female 4-year old fish from Flag Point Channel were significantly smaller than male and female 4-year old fish from 60-km Channel further up the Copper River (male mean lengths = 183 mm; n = 1,128 and 187 mm; n = 593 respectively; t- test, t = 6.26, P < .0001), (Female mean lengths = 178 mm; n = 179 and 181 mm; n = 226 respectively; t-test, t = 2.45, P = 0.015).

The mean weights ranged from 47 to 57 g (Table 3). The mean weights of males and females were also significantly different within each year (Two-tailed *t*-test, $P < 0.001$; Table 4). Age, sex, and size information by sample are in Appendix A.2, A.4, A.6, and A.7.

Table 2. Sample size, mean, standard deviation, minimum, and maximum length of eulachon from Flag Point Channel of the Copper River, 1998-2002.

			Standard length (mm)			
Year	Sex	*n*	mean	SD	min	max
1998	Male	2,020	183	8	153	216
	Female	581	177	9	145	209
	Total	2,601	181	9	145	216
2000	Male	1,126	175	10	146	208
	Female	213	170	12	137	204
	Total	1,339	174	10	137	208
2001	Male	1,249	177	10	149	208
	Female	478	169	11	143	198
	Total	1,727	174	11	143	208
2002	Male	1,128	183	9	153	222
	Female	179	178	9	151	203
	Total	1,307	182	9	151	222

Table 3. Sample size, mean, standard deviation, minimum, and maximum weight of eulachon from Flag Point Channel of the Copper River, 1998-2002.

			Weight (g)			
Year	Sex	*n*	mean	SD	min	max
1998	Male	2,020	55	8	33	96
	Female	581	51	9	27	93
	Total	2,601	54	9	27	96
2000	Male	1,126	47	10	24	83
	Female	213	44	11	22	83
	Total	1,339	47	10	22	83
2001	Male	1,249	50	9	29	91
	Female	478	46	9	28	78
	Total	1,727	49	9	28	91
2002	Male	1,128	57	9	31	94
	Female	179	52	8	35	92
	Total	1,307	57	9	31	94

Table 4. Results of heteroscedastic *t*-test of male and female eulachon size in Flag Point Channel of the Copper River, 1998-2002.

	Length (mm)			Weight (g)		
Year	df	*t*-statistic	*P*-value [a]	df	*t*-statistic	*P*-value [a]
1998	857	13.83	< 0.0001	1251	10.58	< 0.0001
2000	270	6.58	< 0.0001	287	3.74	0.0002
2001	842	13.88	< 0.0001	847	7.78	< 0.0001
2002	237	6.38	< 0.0001	250	7.36	< 0.0001

[a] All *P*-values are two-tailed.

The mean annual percentage of males, all 4 years of sampling combined, was 67% and ranged from 60% in 2002 to 78% in 1998 (Table 5). The percentages of males in commercial and test fishing harvests were significantly higher than 50% in all years ($?^2$, $P < 0.0001$; Table 6). The sex ratio at the midpoint of the spawning run was not significantly different from 50:50 in 2001 and 2002; however, in 1998 and 2000 it was significantly different than 50:50 (Table 6). In 4 years of sampling, the run usually started with approximately equal proportions of males and females, but shifted to mostly males starting about the midpoint of the run (NSC: Figure 4).

Table 5. Eulachon sex ratios from sampling in Flag Point Channel of the Copper River 1998-2002.

Year		Male	Female	Total	Sex Ratio (S)	Var (S)
1998	Count	1,992	572	2,564	4.48	0.0273
	Percentage	78%	22%	100%		
2000	Count	4,220	2,859	7,079	2.48	0.0013
	Percentage	60%	40%	100%		
2001	Count	2,805	1,088	3,893	3.58	0.0085
	Percentage	72%	28%	100%		
2002	Count	1,479	668	2,147	3.21	0.0107
	Percentage	69%	31%	100%		

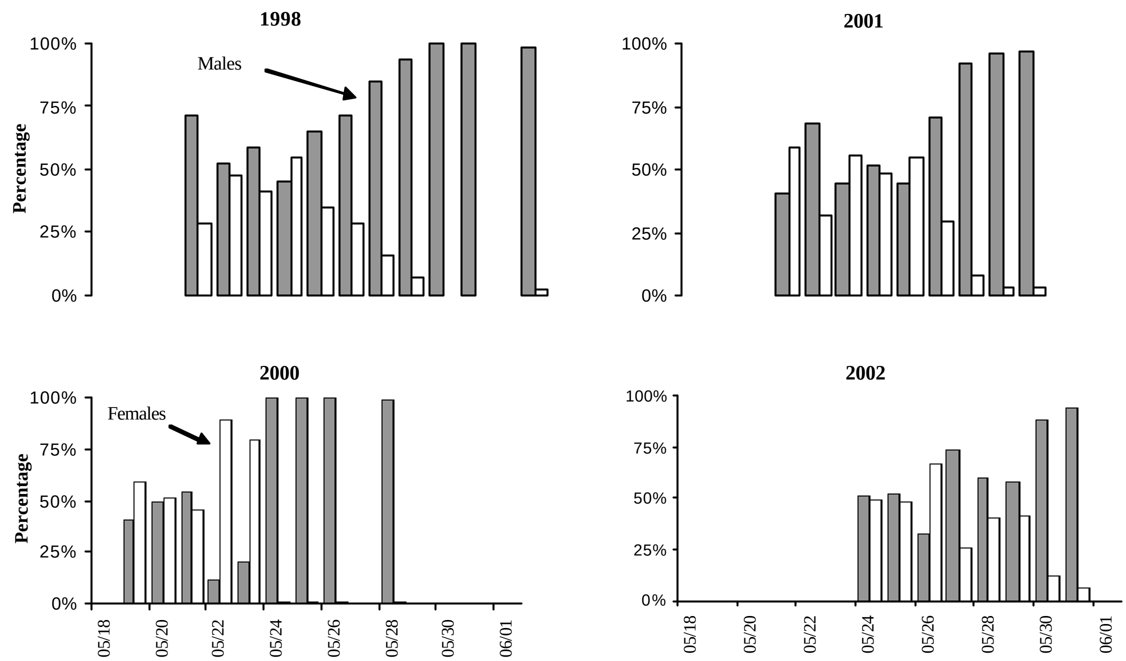

Figure 4. Eulachon sex ratio by day for samples collected in Flag Point Channel of the Copper River in 1998 and 2000-2002.

Table 6. Chi-square tests of the year end and run midpoint male:female proportions and a hypothesized equal proportions.

	Year end totals		Run mid-point totals	
Year	?^{2} value	*P*-value	?^{2} value	*P*-value [a]
1998	786.43	>0.00001	54.49	>0.00001
2000	261.66	>0.00001	924.36	>0.00001
2001	757.28	>0.00001	0.57	0.4507
2002	306.34	>0.00001	11.97	0.0005

[a] The run mid-point *P*-value for 2002 is statistically significant, but probably not biologically significant (55% male).

60-km channel of Copper River

Eulachon samples were collected in the Copper River at kilometer 60 of the Copper River highway on 29 and 31 May, 2002. The samples were predominated by age 4 fish (97%), similar to Flag Point Channel samples in 2002 (Appendix A.7). Males were 61% of the sample on 29 May and 85% on 31 May.

Alaganik Slough

Fish were sampled for AWL data in Alaganik Slough in 1998 and 2000. In 1998, the majority of our sample, 91%, was age 5. There were a larger percentage of younger females (age 3) than males in 2000 (NSC), and most of the fish were age 3 and 4

(Appendix A.1 and A.3). Length-at-age was similar for males and females in 2000, but only one sample size was >30. The age-3 fish in 2000 were much smaller (>10 mm) at age than age-3 fish from all years of Flag Point Channel samples (NSC). Samples in both years had a high proportion of males, 91% in 1998 and 68.7% in 2000.

Ibeck Creek
Eulachon were sampled from Ibeck Creek in January and February, 2001. The combined samples were 96% age 4 (Appendix A.4). Three samples collected for AWL data from 28 January to 1 February were >90% male. Three independent samples were collected to estimate the sex ratio. The percentage males in the samples was 98% on 29 January, 82% on 30 January, and 89% on 4 February. Data for the Eyak River are in Appendix A.9.

Temporal and Spatial Distribution of Adult Spawners

Flag Point Channel of the Copper River
Run timing of the eulachon in Flag Point Channel of the Copper River was estimated for all years, 1998-2002 (e.g., Figure 5). We documented the approximate beginning and ending dates for the May run. Fish arrived at the Flag Point Channel bridge as early as 19 May and as late as 25 May (Table 7). The runs lasted between 8 to 14 days; however, in 1999 we only captured fish on 21 May.

We did occasional surveys of the river earlier in the year if road conditions allowed. Prior to early May, the Copper River is generally low and dear. In 2001, three eulachon were captured on 17 March. A group of 15 bald eagles on the river bank suggested that fish were present; however, the fish abundance appeared to be very low. On 29 and 30 April; and 3 May there were >200 gulls, ~ 5 bald eagles, and several harbor seals at Flag Point Channel, but no fish were documented.

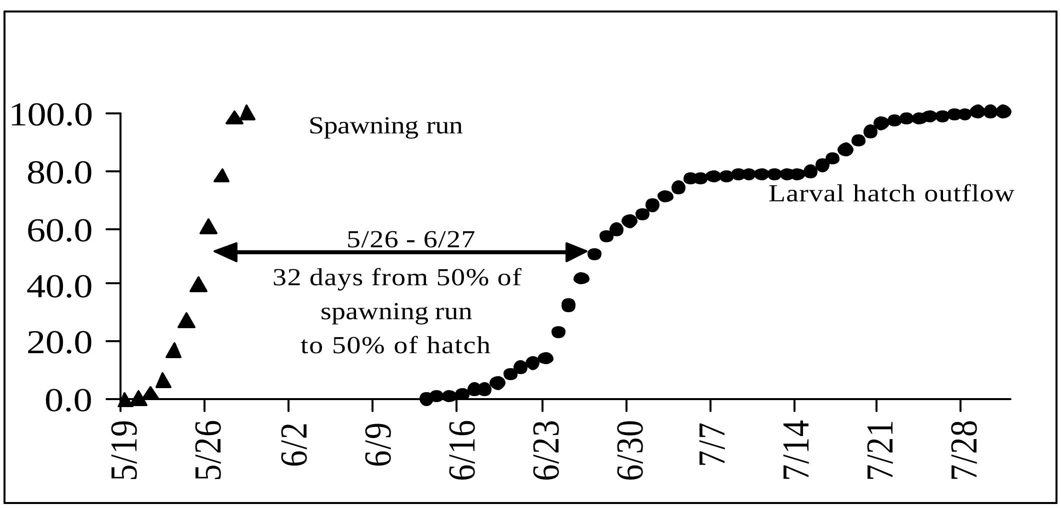

Figure 5. Timing of spawning run and estimated larval hatch, 2001.

Table 7. Approximate run timing of eulachon in Flag Point Channel of the Copper River at the bridge crossings, 1998-2002.

	Year				
Date	1998	1999	2000	2001	2002
Earliest				**03/17**	
5/19			1	1	
5/20	1		2	2	
5/21	2	**1**	3	3	
5/22	3		4	4	
5/23	4		**5**	5	
5/24	5		6	**6**	
5/25	6		7	7	1
5/26	**7**		8	8	2
5/27	8		9	9	3
5/28	9		10	10	**4**
5/29	10			11	5
5/30	11			12	6
5/31	12				7
6/1	13				8
6/2	14				
Latest					**06/24**

In 2002, commercial fishers observed prespawn female eulachon in the Copper River District during the 11 June salmon fishery. An aerial survey of the lower Copper River on 15 June saw large concentrations of gulls on the lower river. On 17 June, prespawn fish were sampled with dip nets from Flag Point Channel of the Copper River. Approximately 20-50 fish were caught per dip net sweep, but fish were deeper (1.5-2.0 m deep) than the earlier run. The latest that eulachon have been documented in Flag Point Channel of the Copper River is 24 June 2002 (Heather Maxcy, National Park Service, Cordova, personal communication).

In 2000 and 2001 we surveyed Flag Point Channel upstream of the bridge for adult eulachon. We captured eulachon with dip nets up to 8.1 km (5 miles) upstream of the bridge in 2000 and 2001 (Figure 6). The farthest upriver fish were approximately 24 km (15 miles) upstream of the mouth.

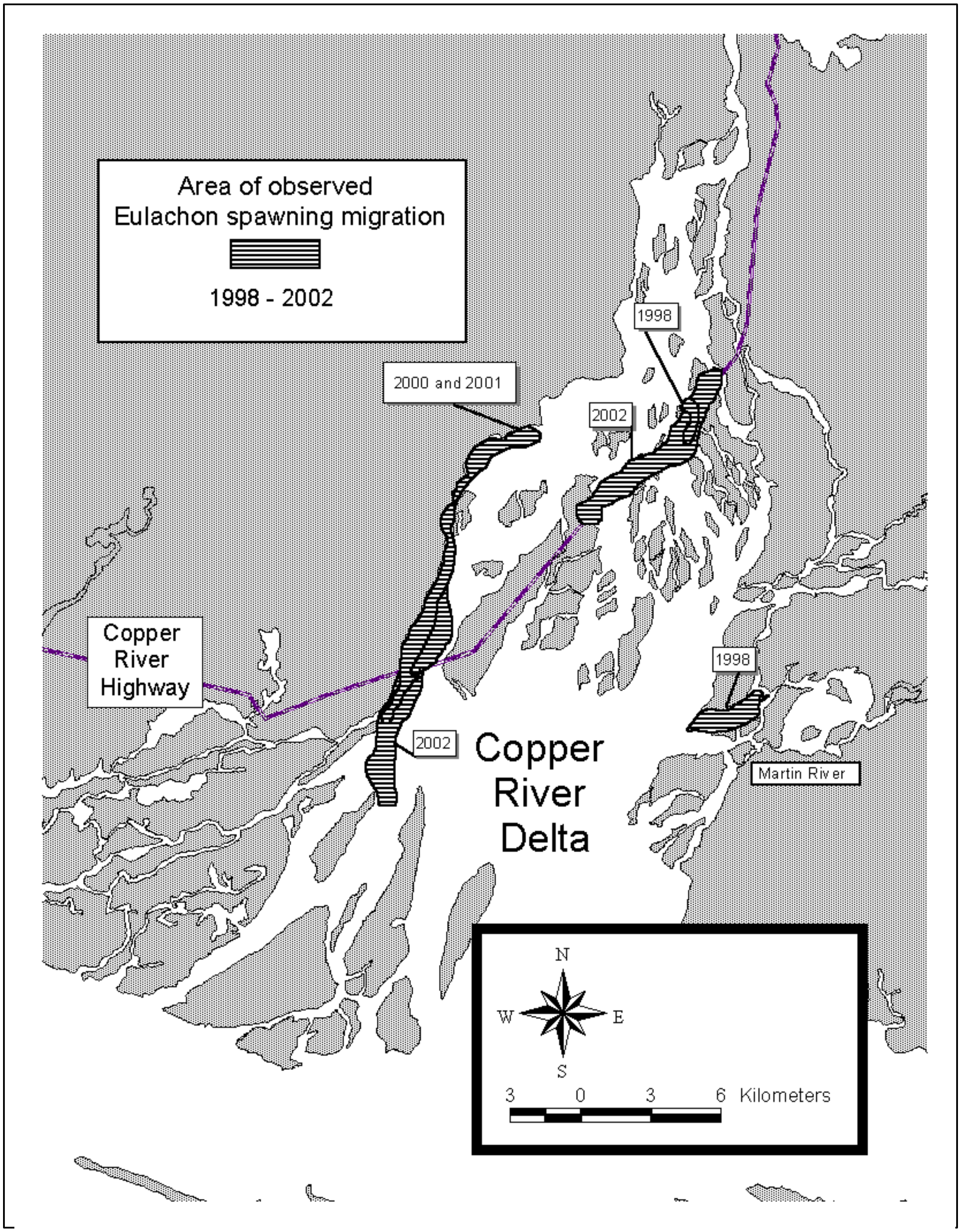

Figure 6. Location of adult eulachon in the Copper River, 1998-2002. This does not represent documented spawning areas, but only areas where adult eulachon were present.

Copper River channel at 60 km, Copper River highway

Eulachon were documented in the 60 km channel of the Copper River in 1998 and 2002. This channel was examined intermittently, so timing and distribution information are imprecise. The 60 km bridge is approximately 32 km (20.5 miles) upstream of the river mouth. Fish were documented at 60 km channel in 1998 about 25 May on a single survey. In 2002 fish were first noted on 28 May. Fish were still present on 29 May, but were gone by 1 June (Figure 7). On 28 May, fish were passing upriver of the bridge along the west bank. Along the east bank, fish were not documented upstream of the upriver spur dike. Visual observations indicated that the high river velocity off the end of the spur dike prevented passage. No fish were captured with dip nets or observed upstream of the spur dike on 28 and 29 May.

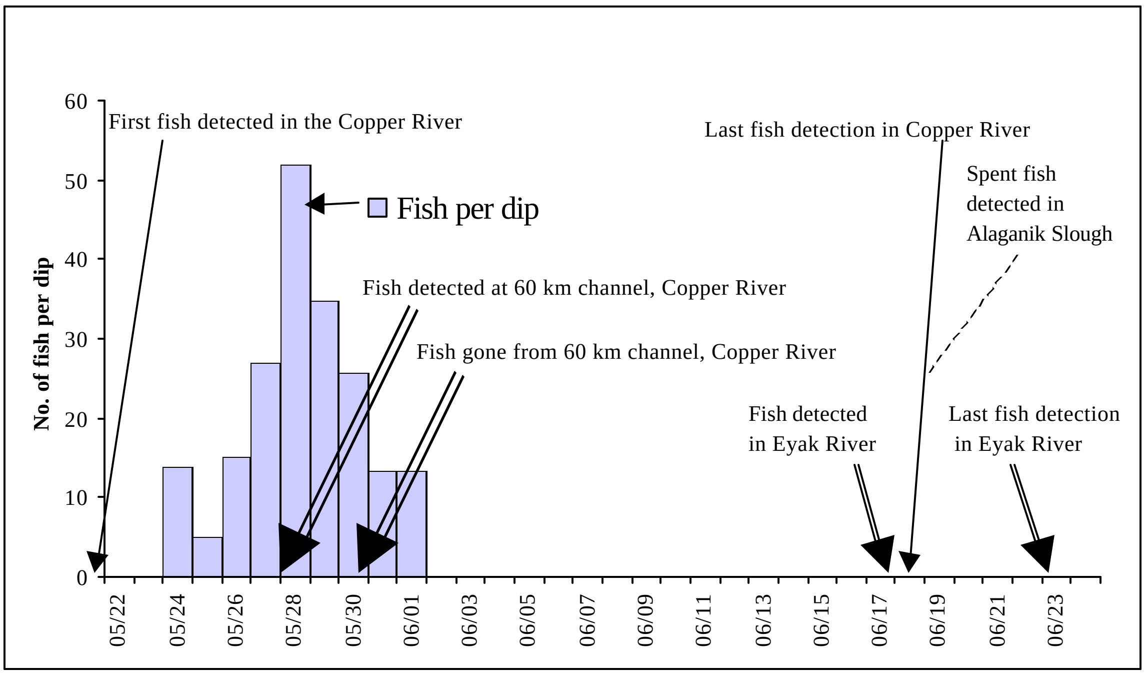

Figure 7. Eulachon CPUE at Flag Point Channel of the Copper River and fish timing information for other Copper River delta systems in 2002.

Other systems

On 28 May 2002, eulachon were captured with dip nets in six river channels along the Copper River Highway between Flag Point and 60 km (Figure 7). This was the only survey of the other river channels of the Copper River completed, 1998-2002.

Eulachon were documented in Alaganik Slough as early as 9 February in 2001 and as late as 18 June in 2002. The maximum upriver extent was about 200 m upstream of the Copper River Highway bridge. The presence of gulls (>200 in March 2000) or bald eagles (>100 in February 2001) near mile 20 of the Copper River Highway were indicators that eulachon were present.

The 2001 run of eulachon in Ibeck Creek arrived at the Copper River Highway bridge on 28 January and lasted until 17 March. Fish were observed 2.5 km upstream of the bridge, or about 11 km upstream of the river mouth. No other fish were documented in Ibeck Creek from 1998-2002. Concentrations of bald eagles and subsistence fishers were indicators of fish availability.

In 2002 a run to the clear waters of the Eyak River reached as far as the Eyak Lake outlet. Fish were observed from 15 June to 23 June. Eulachon were entering Eyak Lake over the water control structure in the evenings of 15-18 June. There were several mt of fish >3 km downstream of the bridge on 21 June, but almost all were gone on 23 June and many dead fish were on the river banks. Eulachon were also documented in the Scott River as far upstream as the Copper River Highway on 1 February 2001. The Scott River froze up three days later, so the complete run timing is unknown.

Fecundity

In 2000, 50 prespawn females were sampled for fecundity from Flag Point Channel of the Copper River. The mean fecundity was 35,519 eggs, and the range was 12,202- 52,722 (Table 8). Mean relative fecundity was 790 eggs g^{-1} of female body weight. Assuming a sex ratio of 50:50, the relative fecundity was 395 eggs g^{-1} of body weight. Using the estimated sex ratio from sampling in 2000 (30.5% female), the relative fecundity would be 241 eggs g^{-1} of body weight. The linear relationship between fish body weight and fecundity had an $r^2 = 0.79$ (Figure 8), and the model was significant at $p < 0.0001$.

Forty-nine prespawn females were sampled in 2001 from Flag Point Channel. The mean fecundity was 36,202 eggs and the range was 18,645-62,855 (Table 8). Mean relative fecundity in 2001 was 792 eggs g^{-1} female body weight. Again, assuming a sex ratio of 50:50, the overall mean relative fecundity was 396 eggs g^{-1} body weight. The relative fecundity adjusted for the measured sex ratio in 2001 is 221 eggs g^{-1} body weight. The relationship between body weight and fecundity has an r^2 of 0.71 (Figure 8). The regression model fit is significant at $P < 0.0001$.

No difference was found in weights of fish sampled for fecundity analysis (mean = 45g, n= 49) and fish from independent samples to estimate population weight (mean = 45g, n = 429) (*t*-test, $t = 0.3006$, $P = 0.764$).

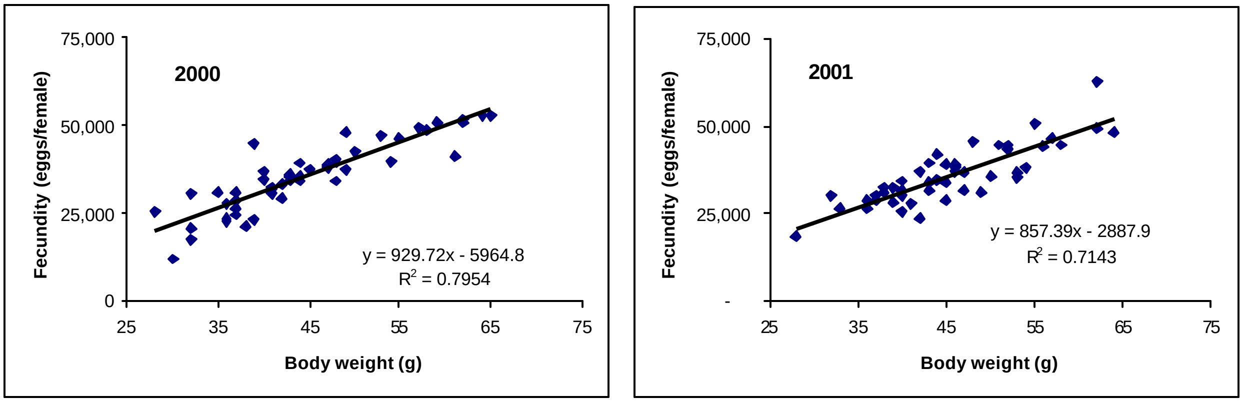

Figure 8. Regression of body weight and fecundity for eulachon from Flag Point Channel of the Copper River, 2000 and 2001.

Table 8. Fecundity data for eulachon from the Copper River in the Flag Point Channel, 2000 and 2001.

	Female Body weight (g)	Egg [a] weight (g)	Total [b] Fecundity	Ovary Weight (g)	Relative [c] Fecundity
2000					
Count	50	50	50	50	50
Mean	45	3.04E-04	35,519	11	790
Minimum	28	2.07E-04	12,202	4	407
Maximum	65	3.66E-04	52,722	17	1,146
Standard error [d]	1	3.26E-05	9,790	0	120
2001					
Count	46	49	49	49	49
Mean	46	3.25E-04	36,202	12	792
Minimum	28	2.58E-04	18,645	6	570
Maximum	64	3.95E-04	62,855	17	1,014
Standard error [d]	1	3.24E-05	8,179	0	94

[a] Egg weight is calculated as the mean of three 100 egg sub-samples.

[b] Total fecundity is calculated as ovary weight divided by mean egg weight.

[c] Relative fecundity is calculated as total fecundity divided by body weight of female.

[d] Standard errors shown as 0 are <0.5.

Larval Density and Biomass Adjustment

Egg and larval densities of eulachon were significantly different among depths within the Copper River in 2002 (ANOVA, F = 43.9, df = 2, P = 0.002). The uppermost net had significantly lower densities then the lower two (Table 9), but no significant difference was found between the lower net and the middle net. The mean densities for each depth were 260 eggs and larvae per m^3 for the bottom samples, 230 for the middle samples, and 146 for the net fished just below the surface. The combined SE from all three days of sampling was larger for the middle and bottom nets.

Table 9. Eulachon egg and larvae sampling summary data from Flag Point Channel of the Copper River, 2002.

			Larval counts (no.)		Larval density (no. / m^3)	
Date	Depth (m)	*n*	Mean	SE [a]	Mean	SE [a]
	0.1	3	887	51	90	4
07/03/02	1.1	3	1,030	25	117	6
	2.1	3	1,090	70	173	22
	0.1	5	1,078	92	115	10
07/08/02	1.1	5	1,531	217	174	23
	2.1	5	1,460	130	206	22
	0.1	10	1,702	59	178	8
07/12/02	1.1	10	2,345	102	292	18
	2.1	10	2,180	63	313	13
Combined	0.1	18	1,393	94	146	10
Totals	1.1	18	1,899	149	230	21
	2.1	18	1,798	118	260	17

[a] Standard Error

The estimated 2001 eulachon spawning biomass was between 2,367 and 8,108 mt (Table 10). This is an estimate of the biomass that spawned in Flag Point Channel of the Copper River. The estimate was adjusted based on results of the 2002 test for differences among depths in egg and larval density. The percentage of the mean middle (88%) and mean near surface (56%) densities relative to the bottom density were applied to the daily production estimates. Total production of eggs and larvae was estimated to range between 9.09×10^{11} and 3.18×10^{12}. The relative fecundity assuming a sex ratio of 50:50 was 396 eggs/g of body weight. The biomass was calculated by dividing the estimated total production of eggs and larvae by the relative fecundity. The range of exploitation rates in 2001 given the 71 mt harvest is 0.87 % to 2.99% (Table 10).

Table 10. Estimated total biomass, spawning biomass, and exploitation rate of eulachon in the Flag Point Channel of Copper River, 2001. The range of the total Copper River discharge through the three bridges at Flag Point during the larval survey was probably between 10% and 35%.

	Percentage of the total discharge estimated at Miles Lake that flows through Flag Point channels [a]								
	10%	15%	20%	25%	30%	35%	40%	45%	50%
Total biomass (mt)	2,367	3,515	4,664	5,812	6,960	8,108	9,256	10,404	11,552
Harvest (mt) in 2001	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8
Spawning biomass (mt)	2,296	3,444	4,593	5,741	6,889	8,037	9,185	10,333	11,481
Exploitation rate in 2001	2.99%	2.01%	1.52%	1.22%	1.02%	0.87%	0.76%	0.68%	0.61%

[a] Brabets (1997) estimated that in 1995, 51% of the total Copper River discharge at Miles Lake flowed through the three channels at Flag Point.

DISCUSSION

Age, Weight, Length, and Sex Ratio

The range of ages we found (age 2 to 6) is in agreement with estimates of age in other areas. Most studies have stated that age-3 and age-4 fish predominate the spawning runs (Smith and Saalfeld 1955; Langer et al. 1977; Pedersen et al. 1995). McHugh (1939) found mostly age-2 fish with some age-3 fish in the Fraser River, while Higgins et al. (1987) estimated mostly age-4 and age-5 fish in the Fraser River. In Alaska, Franzel and Nelson (1981) reported mostly age-3 fish from the Stikine River and B. Kitto-Spangler, USFS, Girdwood, personal communication) found mostly age-3 fish in the Twentymile River.

Although the age range (2-6) we documented was similar to other research, the age proportions were not. Our 1998 samples were mostly age-5 fish (89.4%). Only Triton (1991) found a similar high proportion of age-5 fish in the Kemano and Wahoo Rivers of B.C. The recruits from the 1998 brood year returned in 2002 as mostly (96.1%) age-4 fish. The 2000 and 2001 age proportions were estimated as almost evenly split between age-3 and age-4.

Most studies used otoliths to estimate age (Smith and Saalfeld 1955; Langer et al. 1977; Pedersen et al. 1995; Higgins et al. 1987). McHugh (1939) used scales and their estimates of age were less than others. Higgens et al. (1987) concluded that the burnt surface of otoliths was easier to interpret than direct reading with reflected light or otolith cross sections. Pedersen et al. (1995) also used the burnt surface of otoliths to interpret age. Most other studies did not specify a method and were assumed to use surface readings of otoliths. The method employed may have a large effect on the estimate of age. Most studies also used very small samples sizes (< 300) to estimate age. A small sample size could lead to a very biased age composition that does not represent the population structure. Eulachon age has not been validated from any of the methods employed and must be used with caution (Beamish and McFarlane 1983).

The range of standard lengths (137-222 mm) and weights (22-96 g) documented in the Copper River area are similar to those found elsewhere. Please note that our reported weights include some post-spawn fish, and subsequently are not appropriate for comparison to gravid fish. Smith and Saalfeld (1955) reported a mean length of 170.1 mm for male fish from the Cowlitz River, but the type of length measurement is not clear. Langler et al. reported a range of 112-226 mm, standard length, from samples in 1969-1971. B. Kitto-Spangler, USFS, Girdwood, personal communication and Franzel and Nelson (1981) measured fork lengths, so no comparison was completed. Paired standard and fork lengths were collected on Copper River eulachon, but the results are not reported here.

We found a significant difference in length among years by sex for Copper River fish. The difference in the mean length of males between 2000 and 2002 was almost 8 mm. We also found significant differences in length between males and females in all years of the study. Langer et al. (1977) and Triton (1991) reported no significant difference in length by sex, except in age-2 fish for Langer et al. (1997). Higgins et al. (1987) reported significant differences in mean length between males and females. Differences in mean length by sex may be related to spawning behavior of eulachon. Langer et al. (1977) suggests that as broadcast spawners, it is advantageous for males to move further upstream than females. A larger body size would allow males to swim further upstream (Bernatchez and Dodson 1987). Larger body size may benefit both males and females by increasing their upriver range and allowing them to move through high velocity areas (Higgins et al. 1987). We found a significant difference in the length of both age-4 male and female lengths between fish captured in a low velocity section of the Flag Point Channel and the much higher velocity 60-km Channel in 2002. Finding larger fish further upstream in a higher velocity area suggests that there are velocity barriers in the Copper River for some eulachon size classes. In 2002 we observed that the upstream end of the east-bank spur dike at 60-km Channel created a complete velocity barrier to eulachon.

The length-at-age for eulachon in the Flag Point Channel was significantly larger in 2002 and continued a trend of increasing length-at-age since 2000. The increase in length-at-age is in contrast to Copper River sockeye salmon, which have not increased in size at age 1998-2002 (Richard Merizon, ADF&G, Cordova, personal communication). Length-at-age changes in eulachon since 2000 may result from better marine conditions.

Sex Ratios

Sex ratios in eulachon have often been noted as highly variable or male biased (Smith and Saalfeld 1955; Franzel and Nelson 1981; Pedersen et al.1995; Higgins et al. 1987; B. Kitto-Spangler, USFS, Girdwood, personal communication). Our results were similar. We found males composed a mean of 68% of our 1998-2002 samples from Flag Point. Samples from all the areas had a higher proportion of males. In contrast to Flag Point where we generally had a balanced sex ratio prior to the peak of the run, three samples from Ibeck Creek in 2001 were all > 90% male (Appendix A.5).

The large number of males is possibly a consequence of the broadcast spawning strategy used by eulachon in a riverine environment (Smith and Saalfeld 1955). Vincent-Lang and Queral (1984) and Triton (1991) documented eulachon spawning in river velocities up to 0.75 $m \cdot sec^{-1}$. In high velocity rivers, a large number of males upstream may increase the probability of egg fertilization.

Langer et al. (1977) indicated that the proportion of males increased with distance upriver and with time. We did not examine sex ratio with distance upstream on the Copper River, but we noted the sex ratio of eulachon in Ibeck Creek varied on a small spatial scale. In 2001, three samples showed a decrease in the percentage of males (91%,75%, and 56%) as sampling moved downstream over a 200 m stretch of river. In Flag Point Channel, the proportion of males increased to >90% by the end of the run for all years of our study. In contrast, both Higgins et al. (1987) and B. Kitto-Spangler (USFS, Girdwood, personal communication) found no change in the proportion of males through time.

All reported sex ratios for eulachon should be interpreted with caution. Eulachon sex ratios in the literature probably vary because of gear selectivity, low sample sizes, and the temporal and spatial scale of sample collections. Reported sex ratios have been collected from gillnets in the Columbia River, Stikine River, and Nass River (Smith and Saalfeld 1955; Franzel and Nelson 1981; Langer et al. 1977), and from beach seines in the Stikine and Kitimat Rivers (Franzel and Nelson 1981; Pedersen et al. 1995). Franzel and Nelson (1981) tested gillnets for sex selectivity, but they only used two mesh sizes.

We used dip nets from shore in the Copper River. There is probably no gear selectivity bias, but bias may enter because of temporal or spatial variation in migratory patterns or behavior differences by sex. Bernatchez and Dodson (1987) reported that using the most energy efficient travel corridor (bank and bottom orientation) is only important for fish when all energy reserves would be used during migration, e.g., sockeye salmon. In years of lower river flows, and subsequent lower velocity (< 1.0 m·sec^{-1}), fish may travel offshore and the catchability of shore-based sampling gear would decrease.

Shore-based sampling may be particularly biased after the initiation of spawning. The sex ratio in the Copper River from dip net samples changes to mostly males at approximately the temporal midpoint of the run. The midpoint is also when we usually start to find post-spawn fish (ADF&G, unpublished data). We suspect that when spawning begins, females disperse to offshore spawning locations and do not return. The downstream migration of spawned females may occur at night or away from the river bank.

In 2000, we sampled eulachon in the Flag Point channel for sex ratio every 3 h for 24 h following the start of spawning. Nine samples averaged 1% female; therefore, we suggest that the females disperse offshore to spawn and migrate downstream offshore post spawning. Males may partially spawn and continue to move upstream for future spawning events. Determining an accurate sex ratio for eulachon may require sampling at night, using only prespawn samples, and more intensive sampling at locations across the river cross section.

Temporal and Spatial Distribution of Adult Spawners

Spawning populations of eulachon use different rivers within the delta, and different channels within the Copper River among years. Most notably, few fish returned to the Flag Point Channel of the Copper in 1999, whereas in 1998, 2000, and 2001, large amounts were harvested from large runs. In 1998 and 2002 spawning eulachon were caught in the 60-km Channel of the Copper River, but not in 2000 and 2001. In 2001 a large winter run occurred in January on Ibeck Creek, and in 2002 a large spawning run entered Eyak River, ascending into Eyak Lake. Runs were not found in either Eyak River or Ibeck Creek in other years. The annual variability in spawning run locations is consistent with other studies of eulachon (Smith and Saalfeld 1955, Marston at al. 2002).

Eulachon populations contain some genetic structure within a particular area, but the majority of the total variation is found within populations (McLean et al. 1999). Eulachon populations in Alaska do not demonstrate a strong population structure, and given their life history, they may not become adapted to a specific system as do some salmon species, e.g., sockeye salmon (McLean et al. 1999). Eulachon larvae are flushed out of the Copper River probably within 24 h after incubating for approximately 25 to 60 days. This leaves little time to imprint on a specific river, but if larvae spend several weeks in an estuary area, there may be sufficient time to imprint on the general water chemistry of an estuary (McLean et al. 1999). If eulachon do not imprint on a specific system, that could help explain the apparently large variation in spawning rivers and spawn timing on the Copper River delta.

The Copper River eulachon population may be common to the delta, but may employ specific run timing and locations dependent on environmental conditions, and possibly run size. Temperature, water velocity, and water chemistry situations have been shown to impact eulachon and other smelt migrations (Smith and Saalfeld 1955, Snyder 1970, Rodgers et al. 1990, Lyle and Maitland 1997). As such, years similar to 1999, when few fish showed up at Flag Point Channel of the Copper River may occur again. The 1999 Copper River stage height almost matched the 1983-1988 historical low until 9 June, well after the normal eulachon run timing. Extensive surveys for spawners at alternative sites were not conducted in 1999, so the run may have spawned in another system, e.g., the eastern side of the Copper River below the Copper River Highway.

Fecundity

We estimated fecundity of eulachon in the Flag Point Channel of the Copper River. Our estimates of fecundity, 12,202- 52,722 with a mean of 35,519 eggs, in 2000 and 18,645-62,855 with a mean of 36,202 eggs in 2001, appear to match well with other estimates. Smith and Saalfeld (1955) reported fecundities from 18 Columbia River females of 20 to 60 thousand. Pedersen et al. (1995) showed a range of 3,242 to 47,798 eggs for fish from 149 to 187 mm standard length. One hundred-twenty eight fish from the Kemano River in B.C. had an average fecundity of 27,880 eggs (Triton 1991). An Alaskan study estimated 18,137-43,620 eggs for Stikine River fish (Franzel and Nelson 1981).

Fecundity was found to be significantly related to the natural log of body weight (Triton 1991), preserved ovary weight (Pedersen et al. 1995), and fork length (Franzel and Nelson 1981). We tested fecundity and body weight, and the relationship was significant for 2000 and 2001. B. Kitto-Spangler (USFS, Girdwood, personal communication) noted significant relationships between fecundity and length, weight, and age. Triton (1991) did not find a relationship between fecundity and age. This may indicate problems with the interpretation of age. It is also possible that older fish may have larger, but fewer eggs. Pedersen et al. (1995), however, did not find a relationship between egg weight and body length.

Biomass Estimation

There are few estimates of the spawning biomass of eulachon (Pedersen et al. 1995; Triton 1991) because most spawning rivers are glacial systems not amenable to methods employed for other species. Depending on the characteristics of the spawning system, abundance could be estimated from aerial surveys or foot surveys; acoustics programs, egg deposition surveys, or larval surveys. Estimates of relative abundance could be based on CPUE for systems with a long time series of commercial harvests such as the Columbia River (Hay et al. 1997).

All methods have inherent difficulties in obtaining a precise estimate of spawning biomass. Visual surveys introduce error from observer efficiency for single surveys; and observer efficiency, survey interval, and stream life for multiple surveys (e.g., Bue et al. 1998). Acoustics estimates require expensive equipment and knowledge of the migratory behavior at a fixed location to prevent duplicate counting in turbid systems. Egg deposition surveys present difficulties with observer calibration and egg loss (Willette et al. 1998) and could not easily be ported from the marine, nearshore environment to turbid, high velocity rivers. The use of CPUE may provide an index to abundance. CPUE data can be very misleading because schooling forage fish may show hyperstability in the relationship between CPUE and abundance (Hilborn and Walters 1992). The CPUE may stay high even as the stock size declines because eulachon are concentrated in schools during upstream migration. The larval survey method also has limitations including estimating the river discharge and the larval abundance.

Our estimate of biomass from larval surveys is an approximation with a large amount of uncertainty. The lower end of the range is probably conservative because most of the factors that introduce uncertainty would bias the estimate low. The basic data needed to estimate biomass from a larval survey include estimates of river volume discharge, larval production; and spawner length, weight, fecundity, and sex ratio. There is uncertainty involved in the estimates of all the parameters, but we tried to minimize any upward bias in the estimate of spawning biomass.

We expanded our estimates of larval density ($no \cdot m^{-3}$) to total daily production using daily estimates of river volume ($m^3 \cdot sec^{-1}$) discharge at the Million Dollar Bridge. Brabets (1997) estimated that between 1991 and 1995, 51% of the discharge estimated at the Million Dollar Bridge flowed through the three bridges closest to Flag Point. Beginning in about 2000, a larger proportion of the river discharge appears to be flowing through channels further east. In the absence of recent estimates of river discharge at Flag Point, we chose 10% of the total Copper River discharge as our lower bound. The lower bound is probably a very conservative.

The estimates of discharge were not corrected for water inflow downstream of the Million Dollar Bridge. Childs Glacier and Goodwin Glacier would provide additional water inflow that would not be measured at the Million Dollar Bridge. Brabets (1997) developed a relationship between the discharge at the Million Dollar Bridge and the other bridges along the Copper River Highway. Brabets (1997) relationship suggests that our estimates of the 2001 Copper River discharge are about 20% low. The daily production of eggs and larvae was estimated as the daily discharge ($m^3 \cdot sec^{-1}$) times the estimated daily larval density ($no. \cdot m^{-3}$). This means that our estimates of total larval production, and subsequently biomass, are biased low by 20%.

The larval survey was completed just upstream of the Pete Dahl fork. The biomass estimate is assumed to only include fish that migrated through Flag Point Channel and spawned upstream of our larval sampling sites in Flag Point Channel. The estimate would be biased high if fish migrated up other channels of the Copper River and spawned upstream of the bridge at 60-km channel (Figure 5). Although adults were observed at or slightly above the 60-km bridge in 1998 and 2002, no eulachon were observed above the bridge in 2001. In 2002, the east-bank spur dike was observed to create a velocity barrier to upstream eulachon migration. This suggests that larvae from other channels are probably minimal at Flag Point. Additionally, if eulachon from the Flag Point Channel are spawning any further upstream than we documented in 2000 and 2001, larvae could be flushed down Copper River channels further east. This would bias our biomass estimate low.

Our sampling sites were approximately 15 km above the mouth of the Copper River, so there may be considerable spawning below our sample sites (Figure 5). Downstream, the Copper River splits into three channels that would be difficult to sample effectively for larvae. Eulachon spawning below our sampling sites are not included in our biomass estimate.

All of our larval sampling occurred in day light hours. Several researchers have found a higher abundance of migrating eulachon larvae at night. Orr (1984) reported that Levings (1980) found larger catches of eulachon larvae at night. B. Kitto-Spangler (USFS, Girdwood, personal communication) found larval abundance to be significantly related to light intensity in the Twentymile River. Migration at night is a common life history trait for many fish species larvae (Kelso and Rutherford 1996). A larger abundance of eulachon larvae migrating at night would bias our 2001 biomass estimate low.

We started our larval sampling on 13 June; about 26 days after the first fish were harvested in the Flag Point Channel. We probably missed eggs that failed to adhere to substrate and moved downstream immediately after the main spawning event. Langer et al. (1977) and Samis (1977) found eggs on a variety of substrates. Langer et al. (1977) suggested eulachon may broadcast their eggs into the current rather than directly onto a specific substrate. Eggs may also vary in their ability to adhere to different substrates. If eggs were displaced downstream after spawning, this would bias our estimate low.

We captured larvae on both our first survey on 13 June and our last survey on 31 July, a span of 49 days (Figure 5). The first and last surveys had some of the lowest densities in our survey, but indicate that we missed larvae. Our estimate of a mean hatch timing of 32 days in 2001 matched Smith and Saalfeld (1955) estimate of 30-40 days at 40-45 ?F. We first captured eulachon larvae 26 days after adult eulachon were first detected at Flag Point. However, in 2001 we documented adults in the channel as early as 17 March

(Table 7). Missing larvae at the beginning and end of our survey biased our estimate low.

Total relative fecundity (eggs·g^{-1} of body weight) is estimated as the relative fecundity of females times the estimated proportion of females in the spawning population. The estimate of sex ratio can have a large influence on the biomass estimate. We assumed that the population was 50% females to calculate the relative fecundity because of the inherent problems in estimating the proportion of females in the population. If we had used our actual season-total female percentage of 28% (Table 5), our biomass range bounds would increase by almost 100%.

Our larval sampling in 2001 was all completed at a depth 1-m off the bottom. This depth allowed us to avoid debris and the low velocity area at the river bottom. In calculating the production of larvae, we assumed that the same density was found throughout the water column. However, eulachon larval density varies with depth (Hymer 1994; Smith and Saalfeld 1955; B. Kitto-Spangler, USFS, Girdwood, personal communication). In 2002 we investigated the vertical distribution of eulachon larvae in the Flag Point Channel of the Copper River. Our assumption that eulachon larval density is constant with depth was not supported with the 2002 data. As such our biomass estimates for 2001 were probably too high. We cannot be sure that the same vertical distribution occurred in 2001 as in 2002, but it is probable that some depth gradient of larval density occurred. Our adjusted 2001 biomass estimates based on the observed densities differences of larvae and eggs found in 2002, was 18% lower.

The sources of uncertainty in the estimate of spawning biomass would mostly bias the estimate low. Although the lower bound is a very conservative, it is still robust to an error of 50%, i.e., if the biomass was actually 50% lower than the lower bound, the exploitation rate would have increased to ~ 6%.

In the future, more precise adult biomass estimates could be obtained with increased larval sampling effort on both temporal and spatial scales. This would include shorter time intervals between larval samples, multiple samples at different depths across the river cross section, and more complete spatial distribution information on the adult spawners. In addition, daily determination of river volume discharge at Flag Point Channel would significantly reduce the uncertainty in the estimates.

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APPENDIX

Appendix A.1 Length, weight, and sex ratio at age for eulachon sampled from Alaganik Slough, 1998.

Area				Brood year and age class						
Alaganic slough				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Date	06/02/98	Male	Mean length (mm)		179	175	179			179
			Standard error [a]		3	2	0			0
			Mean weight (g)		53	44	48			48
			Standard error [a]		4	1	0			0
			n	0	6	35	377	0	0	418
			% Male		100.0	94.6	90.4			90.9
		Female	Mean length (mm)			172	175			175
			Standard error [a]			2	1			1
			Mean weight (g)			34.5	39.9			39.7
			Standard error [a]			1	1			1
			n	0	0	2	40	0	0	42
			% Female			5.4	9.6			9.1
		Total	Mean length (mm)		179	174	179			178
			Standard error [a]		3	2	0			0
			Mean weight (g)		53	43	47			47
			Standard error [a]		4	1	0			0
			N	0	6	37	417	0	0	460

Appendix A.2 Length, weight, and sex ratio at age for eulachon sampled from the Copper River at the Flag Point bridge, 1998.

Area				Brood year and age class						
Flag Point Channel of Copper River				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Dates	05/20/98	Male	Mean length (mm)			180	184	175	190	183
	05/22/98		Standard error [a]			2	1	2	2	1
			Mean weight (g)			57	59	50	66	59
			Standard error [a]			2	1	2	4	1
			n	0	0	32	232	2	2	268
			% Male			54.2	61.9	100	100	61.2
		Female	Mean length (mm)			176	179			179
			Standard error [a]			2	1			1
			Mean weight (g)			49	52			51
			Standard error [a]			2	1			1
			n	0	0	27	143	0	0	170
			% Female			45.8	38.1			38.8
		Total	Mean length (mm)			178	182	175	190	181
			Standard error [a]			1	0	2	2	0
			Mean weight (g)			53	56	50	66	56
			Standard error [a]			1	1	2	4	0
			N	0	0	59	375	2	2	438

Area				Brood year and age class						
Flag Point Channel of Copper River				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Dates	05/23/98	Male	Mean length (mm)			184	181	182	175	181
	05/24/98		Standard error [a]			3	1	2	4	1
			Mean weight (g)			63	58	62	56	59
			Standard error [a]			4	1	2	4	1
			n	0	0	15	220	2	2	239
			% Male			30.0	54.6	100	66.7	52.0
		Female	Mean length (mm)		181	172	175		185	174
			Standard error [a]		2	2	1			1
			Mean weight (g)		56	51	52		54	52
			Standard error [a]			2	1			1
			n	0	2	35	183	0	1	221
			% Female		100	70.0	45.4		33.3	48.0
		Total	Mean length (mm)		181	176	178	182	178	178
			Standard error [a]		2	2	0	2	4	0
			Mean weight (g)		56	55	55	62	55	55
			Standard error [a]		8	2	0	2	2	0
			N	0	2	50	403	2	3	460

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Area				Brood year and age class						
Flag Point Channel of Copper River				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Dates	05/25/98	Male	Mean length (mm)		179	179	181	166		181
	05/26/98		Standard error [a]		2	2	0			0
			Mean weight (g)		55	57	56	39		56
			Standard error [a]		5	2	0			0
			n	0	2	26	285	1	0	314
			% Male		100	53.1	71.4	33.3		69.0
		Female	Mean length (mm)			177	178	186	183	178
			Standard error [a]			3	1	11	11	1
			Mean weight (g)			50	50	67	55	50
			Standard error [a]			3	1	14	8	1
			n	0	0	23	114	2	2	141
			% Female			46.9	28.6	66.7	100	31.0
		Total	Mean length (mm)		179	178	180	179	183	180
			Standard error [a]		2	2	0	9	11	0
			Mean weight (g)		55	54	55	58	55	55
			Standard error [a]		5	2	0	12	8	0
			N	0	2	49	399	3	2	455

Area				Brood year and age class						
Flag Point Channel of Copper River				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Dates	05/27/98	Male	Mean length (mm)			182	182			182
	05/28/98		Standard error [a]			3	0			0
			Mean weight (g)			54	54			54
			Standard error [a]			3	0			0
			n	0	0	25	277	0	0	302
			% Male			78.1	90.5			89.3
		Female	Mean length (mm)			181	180			180
			Standard error [a]			4	1			1
			Mean weight (g)			50	49			49
			Standard error [a]			5	2			2
			n	0	0	7	29	0	0	36
			% Female			21.9	9.5			10.7
		Total	Mean length (mm)			182	181			181
			Standard error [a]			2	0			0
			Mean weight (g)			53	54			54
			Standard error [a]			2	0			0
			N	0	0	32	306	0	0	338

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Area				Brood year and age class						
Flag Point Channel of Copper River				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Dates	05/29/98	Male	Mean length (mm)		181	186	183	176	192	183
	05/30/98		Standard error [a]		5	2	0	1	6	0
			Mean weight (g)		53	57	54	51	60	54
			Standard error [a]		4	2	0	1	5	0
			n	0	3	22	418	2	3	448
			% Male		100	100	99.5	100	100	99.6
		Female	Mean length (mm)				189			189
			Standard error [a]				4			4
			Mean weight (g)				55			55
			Standard error [a]				5			5
			n	0	0	0	2	0	0	2
			% Female				0.5			0.4
		Total	Mean length (mm)		181	186	183	176	192	183
			Standard error [a]		5	2	0	1	6	0
			Mean weight (g)		53	57	54	51	60	54
			Standard error [a]		4	2	0	1	5	0
			N	0	3	22	420	2	3	450

Area				Brood year and age class						
Flag Point Channel of Copper River				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Date	06/01/98	Male	Mean length (mm)		178	184	184			184
			Standard error [a]		8	2	0			0
			Mean weight (g)		49	54	53			53
			Standard error [a]		3	2	0			0
			n	0	2	31	416	0	0	449
			% Male		100	88.6	98.3			97.6
		Female	Mean length (mm)			168	171			170
			Standard error [a]			3	2			2
			Mean weight (g)			37	39			39
			Standard error [a]			4	2			2
			n	0	0	4	7	0	0	11
			% Female			11.4	1.7			2.4
		Total	Mean length (mm)		178	182	184			184
			Standard error [a]		8	2	0			0
			Mean weight (g)		49	53	53			53
			Standard error [a]	0	3	2	0	0	0	0
			N		2	35	423			460

Combined catch Totals

Area				Brood year and age class						
Flag Point Channel of Copper River				1996	1995	1994	1993	1992		
				2	3	4	5	6	Unknown	Total
Catch Dates	05/20/98 - 06/02/98	Male	Mean length (mm)		179	182	183	176	187	183
			Standard error [a]		3	1	0	2	4	0
			Mean weight (g)		52	57	55	52	60	55
			Standard error [a]		2	1	0	3	3	0
			n		7	151	1,848	7	7	2,020
			% Male		77.8	61.1	79.4	77.8	70.0	77.7
		Female	Mean length (mm)		181	175	177	186	184	177
			Standard error [a]		1	1	0	10	6	0
			Mean weight (g)		56	49.6	51.1	67	54.7	50.9
			Standard error [a]		8	1	0	14	5	0
			n		2	96	478	2	3	581
			% Female		22.2	38.9	20.6	22.2	30.0	22.3
		Total	Mean length (mm)		180	180	182	178	186	181
			Standard error [a]		2	1	0	3	3	0
			Mean weight (g)		53	54	55	55	59	54
			Standard error [a]		2	1	0	4	2	0
			N		9	247	2,326	9	10	2,601

[a] Standard errors displayed as 0 are <0.5.

Appendix A.3. Length, weight, and sex ratio at age for eulachon sampled from Alaganik Slough, 2000.

Area				Brood year and age class					
Alaganik Slough				1998	1997	1996	1995	1994	
				2	3	4	5	6	Total
Catch date	04/06/00	Male	Mean length (mm)		160	174			164
			Standard error [a]		1	3			1
			Mean weight (g)		37	48			40
			Standard error [a]		1	3			1
			n	0	47	21	0	0	68
			% Male		65.3	77.8			68.7
		Female	Mean length (mm)		160	173			162
			Standard error [a]		2	9			2
			Mean weight (g)		35	43			37
			Standard error [a]		2	6			2
			n	0	25	6	0	0	31
			% Female		34.7	22.2			31.3
		Total	Mean length (mm)		160	173			164
			Standard error [a]		1	3			1
			Mean weight (g)		36	47			39
			Standard error [a]		1	3			1
			N	0	72	27	0	0	99

[a] Standard errors displayed as 0 are <0.5.

Appendix A.4 Length, weight, and sex ratio at age for eulachon sampled from the Copper River at 27-mile bridge, 2000.

Area				Brood year and age class					
Flag Point Channel of Copper River				1998	1997	1996	1995	1994	
				2	3	4	5	6	Total
Catch date	05/21/00	Male	Mean length (mm)	182	175	175	176		175
			Standard error [a]		1	1	6		1
			Mean weight (g)	55	51	51	51		51
			Standard error [a]		1	1	6		1
			n	1	130	106	6	0	243
			% Male	100	55.3	52.5	54.5		54.1
		Female	Mean length (mm)		168	172	164		170
			Standard error [a]		1	1	5		1
			Mean weight (g)		43	47	39		45
			Standard error [a]		1	1	3		1
			n	0	105	96	5	0	206
			% Female		44.7	47.5	45.5		45.9
		Total	Mean length (mm)	182	172	174	171		173
			Standard error [a]		1	1	4		1
			Mean weight (g)	55	47	49	45		48
			Standard error [a]		1	1	4		1
			N	1	235	202	11	0	449

Area				Brood year and age class					
Flag Point Channel of Copper River				1998	1997	1996	1995	1994	
				2	3	4	5	6	Total
Catch date	05/25/00	Male	Mean length (mm)		172	177	184		175
			Standard error [a]		1	1	3		0
			Mean weight (g)		45	47	56		47
			Standard error [a]		1	1	4		0
			n		197	231	13	0	441
			% Male	0	98.5	98.7	100		98.7
		Female	Mean length (mm)		166	174			170
			Standard error [a]		0	6			3
			Mean weight (g)		39	45			42
			Standard error [a]		2	3			2
			n	0	3	3	0	0	6
			% Female		1.5	1.3			1.3
		Total	Mean length (mm)		172	177	184		175
			Standard error [a]		1	1	3		0
			Mean weight (g)		45	47	56		47
			Standard error [a]		1	1	4		0
			N	0	200	234	13	0	447

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Area				Brood year and age class					
Flag Point Channel of Copper River				1998	1997	1996	1995	1994	
				2	3	4	5	6	Total
Catch date	05/30/00	Male	Mean length (mm)		174	176	184	192	176
			Standard error [a]		1	1	2		0
			Mean weight (g)		47	45	52	60	46
			Standard error [a]		1	1	2		0
			n	0	207	210	24	1	442
			% Male		99.5	100	100		99.8
		Female	Mean length (mm)		165				165
			Standard error [a]						
			Mean weight (g)		40				40
			Standard error [a]						
			n	0	1	0	0		1
			% Female		0.5				0.2
		Total	Mean length (mm)		174	176	184	192	176
			Standard error [a]		1	1	2		0
			Mean weight (g)		47	45	52	60	46
			Standard error [a]		1	1	2		0
			N	0	208	210	24	1	443

Combined catch totals

Area				Brood year and age class					
Flag Point Channel of Copper River				1998	1997	1996	1995	1994	
				2	3	4	5	6	Total
Catch dates	5/21/2000 -	Male	Mean length (mm)	182	174	176	183	192	175
	05/30/00		Standard error [a]		0	0	2		0
			Mean weight (g)	55	47	47	53	60	47
			Standard error [a]		0	0	2		0
			n	1	534	547	43	1	1,126
			% Male	100	83.0	84.7	89.6		84.1
		Female	Mean length (mm)		168	172	164		170
			Standard error [a]		1	1	5		1
			Mean weight (g)		43	47	39		45
			Standard error [a]		1	1	3		1
			n	0	109	99	5	0	213
			% Female		17.0	15.3	10.4		15.9
		Total	Mean length (mm)	182	173	176	181	192	174
			Standard error [a]		0	0	2		0
			Mean weight (g)	55	46	47	51	60	47
			Standard error [a]		0	0	2		0
			N	1	643	646	48	1	1,339

[a] Standard errors displayed as 0 are <0.5.

Appendix A.5. Length, weight, and sex ratio at age for eulachon sampled from Ibeck Creek, 2001.

Area				Brood year and age class						
Ibeck Creek				1999	1998	1997	1996	1995		
				2	3	4	5	6	Unknown	Total
Catch date	01/28/01	Male	Mean length (mm)		182	178	186		182	179
			Standard error [a]		3	0	5		3	0
			Mean weight (g)		55	51	57		52	51
			Standard error [a]		3	0	8		4	0
			n	0	17	417	3	0	4	441
			% Male		100	98.1	100		100	98.2
		Female	Mean length (mm)			175				175
			Standard error [a]			4				4
			Mean weight (g)			49				49
			Standard error [a]			3				3
			n	0	0	8	0	0	0	8
			% Female			47.1				1.8
		Total	Mean length (mm)		182	178	186		182	179
			Standard error [a]		3	0	5		3	0
			Mean weight (g)		55	51	57		52	51
			Standard error [a]		3	0	8		4	0
			N	0	17	425	3	0	4	449

Area				Brood year and age class						
Ibeck Creek				1999	1998	1997	1996	1995		
				2	3	4	5	6	Unknown	Total
Catch date	01/30/01	Male	Mean length (mm)		180	177				177
			Standard error [a]		3	0				0
			Mean weight (g)		53	51				51
			Standard error [a]		3	0				0
			n	0	11	277	0	0	0	288
			% Male		100	90.8				91.1
		Female	Mean length (mm)			171				171
			Standard error [a]			2				2
			Mean weight (g)			49				49
			Standard error [a]			2				2
			n	0	0	28	0	0	0	28
			% Female			9.2				8.9
		Total	Mean length (mm)		180	176				176
			Standard error [a]		3	0				0
			Mean weight (g)		53	50				50
			Standard error [a]		3	0				0
			N	0	11	305	0	0	0	316

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Area				Brood year and age class						
Ibeck Creek				1999	1998	1997	1996	1995		
				2	3	4	5	6	Unknown	Total
Catch date	02/01/01	Male	Mean length (mm)		178	176	187			176
			Standard error [a]		3	0	5			0
			Mean weight (g)		51	49	66			49
			Standard error [a]		3	0	4			0
			n	0	12	395	2	0	0	409
			% Male		85.7	91.0	100			90.9
		Female	Mean length (mm)		164	170				170
			Standard error [a]		4	1				1
			Mean weight (g)		38	44				44
			Standard error [a]		2	1				1
			n	0	2	39	0	0	0	41
			% Female		14.3	9.0				9.1
		Total	Mean length (mm)		176	175	187			175
			Standard error [a]		3	0	5			0
			Mean weight (g)		49	49	66			49
			Standard error [a]		3	0	4			0
			N	0	14	434	2	0	0	450

Combined catch Totals

Area				Brood year and age class						
Ibeck Creek				1999	1998	1997	1996	1995		
				2	3	4	5	6	Unknown	Total
Catch dates	1/28/01-	Male	Mean length (mm)		180	177	186	182		177
	02/01/01		Standard error [a]		2	0	3	3		0
			Mean weight (g)		53	50	60	52		50
			Standard error [a]		2	0	5	4		0
			n	0	40	1,089	5	4	0	1,138
			% Male		95.2	93.6	100	100		93.7
		Female	Mean length (mm)		164	171				171
			Standard error [a]		4	1				1
			Mean weight (g)		38	46				46
			Standard error [a]		2	1				1
			n	0	2	75	0	0	0	77
			% Female		4.8	6.4				6.3
		Total	Mean length (mm)		179	177	186	182		177
			Standard error [a]		2	0	3	3		0
			Mean weight (g)		52	50	60	52		50
			Standard error [a]		2	0	5	4		0
			N	0	42	1,164	5	4	0	1,215

[a] Standard errors displayed as 0 are <0.5.

Appendix A.6. Length, weight, and sex ratio at age for eulachon sampled from the Copper River at 27-mile bridge, 2001.

Area				Brood year and age class					
Flag Point Channel of Copper River				1999	1998	1997	1996		
				2	3	4	5	Unknown	Total
Catch date	5/21/01	Male	Mean length (mm)		170	179	178	188	174
			Standard error [a]		1	1	4		1
			Mean weight (g)		45	52	50	68	48
			Standard error [a]		1	1	4		0
			n	0	199	167	7	1	374
			% Male		95.2	98.2	100	100	96.6
		Female	Mean length (mm)		163	178			167
			Standard error [a]		3	1			3
			Mean weight (g)		38	47			40
			Standard error [a]		3	5			3
			n	0	10	3	0	0	13
			% Female		4.8	1.8			3.4
		Total	Mean length (mm)		170	179	178	188	174
			Standard error [a]		1	1	4		1
			Mean weight (g)		45	51	50	68	48
			Standard error [a]		1	1	4		0
			N	0	209	170	7	1	387

Area				Brood year and age class					
Flag Point Channel of Copper River				1999	1998	1997	1996		
				2	3	4	5	Unknown	Total
Catch date	5/23/01	Male	Mean length (mm)		172	176	179	180	174
			Standard error [a]		1	1	4	4	1
			Mean weight (g)		51	55	59	60	53
			Standard error [a]		1	1	7	4	1
			n	0	124	101	4	6	235
			% Male		49.6	55.8	67	100	53.0
		Female	Mean length (mm)		165	172	166		168
			Standard error [a]		1	1	3		1
			Mean weight (g)		44	49	47		46
			Standard error [a]		1	1	2		1
			n	0	126	80	2	0	208
			% Female		50.4	44.2	33.3		47.0
		Total	Mean length (mm)		168	175	175	180	171
			Standard error [a]		1	1	4	4	0
			Mean weight (g)		47	52	55	60	50
			Standard error [a]		1	1	5	4	0
			N	0	250	181	6	6	443

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Combined catch Totals									
Area				Brood year and age class					
Flag Point Channel of Copper River				1999	1998	1997	1996		
				2	3	4	5	Unknown	Total
Catch dates	5/21/01 - 5/31/01	Male	Mean length (mm)		174	180	179	179	177
			Standard error [a]		0	0	2	2	0
			Mean weight (g)		48	52	52	54	50
			Standard error [a]		0	0	2	2	0
			n	0	643	571	21	14	1,249
			% Male		67.8	78.7	91	50.0	72.3
		Female	Mean length (mm)	154	167	172	166	171	169
			Standard error [a]		1	1	3	4	0
			Mean weight (g)	37	45	48	47	49	46
			Standard error [a]		1	1	3	4	0
			n	1	306	155	2	14	478
			% Female	100	32.2	21.3	8.7	50.0	27.7
		Total	Mean length (mm)	154	172	178	178	175	174
			Standard error [a]		0	0	2	2	0
			Mean weight (g)	37	47	51	51	52	49
			Standard error [a]		0	0	2	2	0
			N	1	949	726	23	28	1,727

[a] Standard errors displayed as 0 are <0.5.