State of Alaska
Department of Fish and Game
Sportfish Division

Nomination Form
Fish Distribution Database

JB

Region: SCN

USGS Quad(s): Seward D-6

Fish Distribution Database Number of Waterway: 247-60-10230

Name of Waterway: Twentymile River ☐ USGS Name ☐ Local Name

☐ Addition ☐ Deletion ☐ Correction ☐ Backup Information

For Office Use

Nomination #: 06-~~[illegible]~~083

Revision Year: 2007

Revision to: Atlas ____ Catalog ____ Both X

Revision Code: B-1

[signature] ADF&G Fisheries Scientist — Date: 10/19/06

[signature] ADNR OHMP Operations Mgr. — Date: 10/19/06

[signature] FDD Project Biologist — Date: 10/17/06

[signature] Cartographer — Date: 10/23/06

OBSERVATION INFORMATION

Species	Date(s) Observed	Spawning	Rearing	Present	Anadromous
Euchalon	2000, 2001	X	X	X	☑
					☐
					☐
					☐
					☐

IMPORTANT: Provide all supporting documentation that this water body is important for the spawning, rearing or migration of anadromous fish, including: number of fish and life stages observed; sampling methods, sampling duration and area sampled; copies of field notes; etc. Attach a copy of a map showing location of mouth and observed upper extent of each species, as well as other information such as: specific stream reaches observed as spawning or rearing habitat; locations, types, and heights of any barriers; etc.

Comments:

Observations made during Euchalon susistence use and ecology investigations of Cook Inlet, USFWS, USFS, UAF IMS Study # 00-041 (December 2003)

Add euchalon presence, ~~spawning, and/or rearing~~ to Twentymile River 247-60-10230
spawning or rearing

Name of Observer (please print): Rob Spangler

Signature: ____________ Date: ____________

Agency: ADF&G/USFS

Address: 333 Raspberry Road
Anchorage, AK 99518

This certifies that in my best professional judgment and belief the above information is evidence that this waterbody should be included in or deleted from the Fish Distribution Database.

Signature of Area Biologist: [signature] Date: 10/17/06 Revision 02/05

Name of Area Biologist (please print):

Barry Stratton AMB Anchorage

State of Alaska
Department of Fish and Game
Sportfish Division

Nomination Form
Fish Distribution Database

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For Office Use

Nomination # 06-083

Revision Year: 2007

Revision to: Atlas ____ Catalog ____ Both X

Revision Code: B-1

______ ADF&G Fisheries Scientist — Date: AUG 29 2006 ALASKA DEPT. OF FISH & GAME

______ ADNR OHMP Operations Mgr. — Date

[signature] FDD Project Biologist — Date: 08/29/06

______ Cartographer — Date

OBSERVATION INFORMATION

Species	Date(s) Observed	Spawning	Rearing	Present	Anadromous
Euchalon	2000, 2001	X	X	X	☑
					☐
					☐
					☐
					☐

IMPORTANT: Provide all supporting documentation that this water body is important for the spawning, rearing or migration of anadromous fish, including: number of fish and life stages observed; sampling methods, sampling duration and area sampled; copies of field notes; etc. Attach a copy of a map showing location of mouth and observed upper extent of each species, as well as other information such as: specific stream reaches observed as spawning or rearing habitat; locations, types, and heights of any barriers; etc.

Comments:
Observations made during Euchalon susistence use and ecology investigations of Cook Inlet, USFWS, USFS, UAF IMS Study # 00-041 (December 2003)

Add euchalon presence, spawning, and/or rearing to Twentymile River

Name of Observer (please print): Betsy McCracken/ Rob Spangler

Signature: ______ Date: ______

Agency: ADF&G/USFS

Address: 333 Raspberry Road
Anchorage, AK 99518

This certifies that in my best professional judgment and belief the above information is evidence that this waterbody should be included in or deleted from the Fish Distribution Database.

Signature of Area Biologist: ______ Date: ______ Revision 02/05

Name of Area Biologist (please print):

U.S. Fish and Wildlife Service
Office of Subsistence Management
Fisheries Resource Monitoring Program

Eulachon subsistence use and ecology investigations of Cook Inlet, 2000-2002

Final Report for Study 00-041

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December 2003

Final Report Summary Page

Title: Eulachon subsistence use and ecology investigations

Study Number: 00-041

Investigator(s)/Affiliation(s): Elizabeth A. Kitto Spangler, U.S. Fish and Wildlife Service; Robert E. Spangler, U.S. Forest Service; Dr. Brenda L. Norcross, University of Alaska Fairbanks.

Geographic Area: Cook Inlet (Region 2)

Information Type: Stock Status and Trends

Issue(s) Addressed: The Eulachon fishery in Turnagain Arm is a popular subsistence and personal use fishery as well as an important forage fish for the beluga whale, another subsistence resource. This fishery occurs within Federal Jurisdiction as well as on lands claimed by the State of Alaska. Although most harvest probably occurs from Anchorage residents, this fishery provides subsistence opportunities for the communities of Hope, Whittier, Moose Pass, and others.

Overall, very little is understood about the ecology or subsistence use of eulachon in Turnagain Arm, and there is currently no reliable method for determining population, status or trends. Some users believe that eulachon in Turnagain Arm may be declining; however, we lack conclusive evidence. If, in fact, the population is declining and harvest success is low, there could be resource allocation and/or conservation issues in the future. This project is designed to determine current subsistence use of the Turnagain Arm eulachon fishery and characterize the ecology of these fish to learn more about their status. The feasibility of using a larval index to estimate population trends will also be determined. The results of this work could help managers that regulate other eulachon fisheries in the state of Alaska.

Study Cost: $146,952

Study Duration: April 2000 to December 2002

Abstract: The subsistence use and ecology of eulachon *(Thaleichthys pacificus)* was studied at Twentymile River, a tributary of Turnagain Arm located in southcentral Alaska from 2000 to 2002. Harvest in 2002 was estimated at 14,940 kg with fishermen representing both rural (9%) and non-rural (91%) communities. A baseline larval monitoring program to index adult population strength was designed and implemented successfully on the Twentymile River. To aid managers in development of future monitoring programs on Twentymile and other rivers, we investigated the environmental factors associated with the migration of adult eulachon and downstream drift of larval

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British Columbia (Hart 1973; Bartlett 1994; Hay et al. 1997a). Eulachon are still considered to be an important subsistence and personal use fishery in Alaska (Bartlett 1994; Betts 1994).

Most subsistence harvest of eulachon occurs in the Twentymile River or in the estuary of Turnagain Arm. Historically, harvest averaged approximately 3700 kg in the Twentymile River (Mills 1991; Howe et al. 1998.) Fishermen have not been observed on Portage Creek or the Placer River in recent years though they reportedly fished there earlier in the twentieth century. The Placer River was reported to have a run much more substantial than the Twentymile River until the 1964 earthquake that caused a subsidence of approximately 2 m. According to local fishermen, effort then switched to the Twentymile River. Prior to this study, it was not known if eulachon populations still existed in the Placer River or Portage Creek. Occasionally, USFS biologists would note dead eulachon on the banks of these systems, but because of the strong tidal action of Turnagain Arm, these carcasses could have easily been washed up from the confluence with the Twentymile River.

Radio telemetry was used to study the migratory behavior of spawning eulachon. Initially, tagging methods were developed and verified with a radio tag retention test. Upon confirming the feasibility of using radio telemetry for eulachon, we investigated the migration movements of male and female fish. This included determining migration patterns for adult fish, retention time in freshwater, upstream spawning limits, and identifying spawning concentrations. Understanding the movements and spawning habitat of eulachon will provide the necessary information for managers to make informed decisions to safeguard essential eulachon spawning habitat.

There are no consistently reported environmental factors known to influence spawning run timing of adult eulachon throughout their range. In Washington, researchers reported a relationship with temperature (Smith and Saalfield 1955), whereas in Alaska, such a relationship is not evident (Barret et al. 1984). In B.C., there are differing reports of the association between spawning run timing and water temperature. In the Fraser River, Ricker et al. (1954) reported a positive relationship between adult catch per unit effort (CPUE) and water temperature, but Langer et al. (1977) found no such evidence. Tide height has been reported to be positively related to the intensity of adult migration in B.C. (Ricker et al. 1954; Langer et al. 1977), but in the limited work conducted in Alaska, tide height was reported not to influence the intensity or timing of migration (Barrett 1984). In British Columbia the timing and intensity of adult eulachon migration has been reported to be greatest at the minimum river discharge in the Nass River, but that is not the case in the Fraser River (Langer et al. 1977). Other researchers in B.C. have found a positive relationship between the density of predators and the timing and intensity of adult eulachon migration (Swan 1881; Langer et al. 1977). Although there have been no investigations in the role of light intensity in the run timing of eulachon, it is worthy of exploration. Light intensity has been reported to influence the migration timing of sockeye salmon (*Onchorhynchus nerka*), another anadromous fish (Egorova 1970).

METHODS:

Study Area

Twentymile River is a tributary of Turnagain Arm adjacent to the Portage and Placer Rivers in southcentral Alaska (Figure 1). Turnagain Arm has a large tidal range (> 10 m) with tapering basin geometry and water depths that systematically decrease upriver. These characteristics produce daily bore tides on the incoming tide, which are large (> 1 m) and advance quickly (up to 6.7 m/s). Bore tides are of greater amplitude with the onset of the spring tides. Twentymile River is a glacial system with a drainage area of approximately 115 km^2 and lacks any substantial man-made developments that could affect habitat quality. This system has a high-suspended sediment load with salinity effects on the lower river basin from tidal incursions (Blanchet 1995). There are two major unnamed tributaries to the Twentymile River in the upper drainage. The tributary to the west lacks substantial influence of glaciers resulting in water of greater clarity, whereas the tributary to the east is dominated by glacial runoff and is highly turbid. For the purposes of this study, they are referred to as the "Clear Fork" and "Glacier Fork." The Placer River (approximately 112 km^2) and Portage Creek drainages (approximately 140 km^2) have physical and chemical characteristics similar to those of Twentymile River. However, both systems have experienced human impacts from past gravel extractions, and other developments such as roads and/or the railroad.

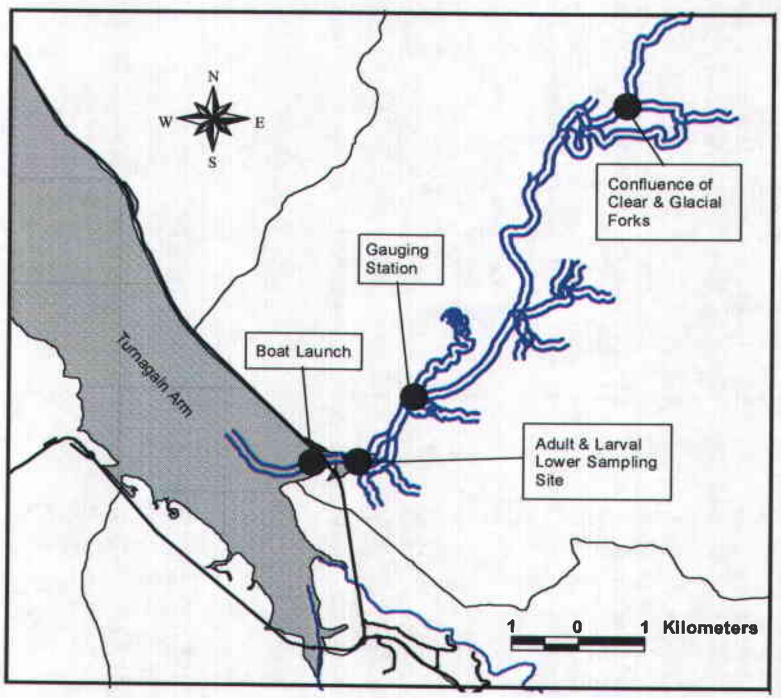

Figure 1. Study area map

$$\bar{y}_w = \frac{\sum_{i=1}^{n_w} y_{wi}}{n_w} \qquad (1)$$

i = sampling period
w = access site
y_{wi} = harvest obtained from the i[th] sampling period at the w^{th} access site
n_w = number of sampling periods at access site w

Next the mean harvest was expanded by the total possible number of sampling periods at an access site to obtain an estimate of total harvest by access site.

$$\hat{y}_w = N_w \bar{y}_w \qquad (2)$$

N_w= total number available for sampling periods at access site w

Finally, total harvest across all sampling sites was calculated by summing the individual access site harvest estimates.

$$\hat{y}_{total} = \sum_{w=1}^{T} \hat{y}_w \qquad (3)$$

T= total number of access sites

The variance of total harvest was estimated using the following equation.

$$V(\hat{y}_{total}) = \sum_{w=1}^{T} N_w^2 (\frac{N_w - n_w}{N_w})(\frac{s_w^2}{n_w}) \qquad (4)$$

where $s_w^2 = \sum_{i=1}^{n_w} \frac{(y_{wi} - \bar{y}_w)^2}{n_w - 1}$

Fishing effort and number in party and their variances were estimated by substituting the appropriate fishing effort/number in party statistics in place of harvest for equations 1 through 4 above.

Determine run timing and other aspects of eulachon life history (fecundity, age, et.) in Twentymile River (2000, 2001).

Life history characteristics were determined from the first 20 pre-spawn male and 20 pre-spawn females caught during each sampling episode. These fish were identified for sex by visually examining gonads. Fork length (1.0 mm), weight (0.01 g), and presence of teeth were recorded for sampled fish. Teeth presence or absence was assessed by gently rubbing a finger in the mouth of the fish. When teeth were present, they would catch on finger ridges. The ages of pre-spawn eulachon were determined by examining otoliths. A transverse cut was made above the preoperculum and both otoliths were removed with forceps. They were cleaned of saccule membrane and stored in vials with 10-15 percent ethanol. The otoliths were viewed with a stereomicroscope attached to a computer monitor. This allowed several people to view otoliths at the same time. To reduce glare otoliths were submerged in water. To improve contrast between the translucent and opaque zones otoliths were placed on a black background under a reflective light (Moffit 1999). The age of fish was assigned by counting the zones radiating out from the primordium. At least two regions on the otoliths 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 became the assigned age; otherwise, the process was repeated. Three individuals read all of the otoliths with the most common age assigned to each fish.

To determine fecundity, ovaries were removed, weighed to the nearest decigram and placed into individual marked vials containing 3.7 percent formalin in seawater. The ovaries were kept in a refrigerator and allowed to harden for two weeks. Fecundity was analyzed according to the methods of Hay et al. (1997b). The eggs were counted into three groups of 100 eggs and weighed. The three samples could not vary by more than 10 percent in weight. If they did, the process was repeated from the beginning. The weight of an egg was determined by dividing the mean weight by one hundred. Fecundity was determined by dividing the total egg sac weight by the weight of an egg.

Data Analysis

Sex ratio and teeth retention were modeled using generalized linear models (Agresti 1990; McCulloch 2001) as a binomial random variable using PROC LOGISTIC (SAS Institute, Inc. 20002) with a logit link function. Explanatory variables for sex ratio that were considered for inclusion in the model included time, length, weight, and age. Explanatory variables for teeth retention that were considered for inclusion in the model included sex and age.

Weight (male or female), length (male or female), age (male or female), and fecundity were modeled using generalized linear models (Agresti 1990; McCulloch 2001) as a gamma random variable using PROC GENMOD (SAS Institute, Inc. 20002) with a log link function. The explanatory variable for weight (male or female) and length (male or female) that was considered for inclusion in the model was age. The explanatory variable for age (male or female) that was considered for inclusion in the model was time. Explanatory variables for fecundity that were considered for inclusion in the model included length, weight, and age.

Likelihood ratio tests were used to develop the most parsimonious model possible for each response variable. Terms were eliminated in a stepwise fashion, until all remaining

7.3 mm in cross section with an antenna length of 30.0 cm and were 2.0 mm x 4.0 mm in cross section. The radio tags had an operational life of 14 days. In 2000, frequencies included 149.600, 149.620, 149.640, 149.660, and 149.680 mHz with codes ranging from 1 through 5. In 2001, frequencies included 148.600, 148.620, 148.640, 148.660, 148.680, 148.700, 148.720, and 148.740 mHz with codes ranging from 6 through 20. They were programmed with a five second burst rate in both years.

Gastric implantation was selected over surgical implantation since the procedure is easier and most suitable for short-term studies (Martinelli et al. 1998). Additionally, this method is less invasive and faster than surgical implantation. Radio tags were inserted in the esophagus. Fish were held, dorsal side up, while the tag was inserted into the mouth. The antenna of the radio tag was threaded through a small drinking straw. The straw was guided down the throat until slight resistance was felt at the anterior portion of the stomach (Adams 1998; Martinelli et al. 1998). The straw was removed from the fish leaving the radio tag in place.

Radio tag retention test

Thirty adult fish were selected for the radio tag retention test. Fifteen had gastric implants and another 15 (control) were handled but without tag implants. Unique fin clip combinations, such as an anterior clip on the dorsal and upper caudal clip allowed for identification of individual fish. Tagged fish were kept in a small live well in the river prior to release and monitored for 30 minutes. Then they were transferred to a larger live well (~1m^3) subjected to ambient water temperature, current, salinity and photoperiod conditions. After three days tagged eulachon were checked for radio tag retention and condition. Large tides and changes in the accumulations of tidal mud threatened the live well and precluded a longer holding time.

Tracking procedure

The number of fish tagged was dependent and proportional to the intensity of daily run: as catch per unit effort (CPUE) increased, we tagged and released more fish.

The tracking was conducted in Twentymile River with a 4-m inflatable boat with a jet outboard engine. The spark plugs in the engine were replaced with shielded spark plugs to reduce interference with signals from radio tags in fish. A four-element Yagi® antenna was mounted on the boat and was set for full rotation for access of all locations at any time. During each sampling period, the antenna was slowly rotated from left to right bank, including any side channels.

The radio-tracking route was conducted every day from 15 May to 22 June 2000 and 19 April to 20 June 2001. The route began approximately 11 km upstream of the mouth of Twentymile River (Figure 3). The fish were tracked as the observer drifted downstream in the boat to the estuary, two km downstream of the highway bridge (Figure 3). The Clear Fork was not included in the manual-tracking route (Figure 3). Surveys were timed to miss salinity concentrations greater than 3.0 psu in the low river during high tide as the higher conductivity during this time attenuated radio tag signals making the tagged fish difficult to detect.

This ensured that at least 50 percent of the total spawning habitat must have overlapped between years for it to be considered a common spawning area.

To determine if the tracking procedure was successful in locating the upstream migration limits, the water was sampled for the presence of larvae. The larval sampling period occurred from 21 June to 21 July 2000 and from 15 May to 17 August 2001. The larvae sampling site was located approximately 200 to 300 m past the most upstream location at which eulachon were detected with radio telemetry. Larval sampling was conducted with bongo nets using methods described in Objective 4. The earliest incubation time has been reported at 30 to 40 days (Smith and Saalfield 1955). Therefore, larval sampling was initiated 30 days after adults were detected in Twentymile River. Although tracking was not conducted in the Clear Fork (Figure 3), larval sampling was completed to verify if eulachon spawned there successfully.

Conduct larval and biomass assessments as indices of relative run strength. (2000, 2001)

In the first year, we tested equipment and developed adaptations for smaller river environments during the first part of the season. Sampling for larval fish was initiated three weeks after the first adults were detected in the system because previous studies suggest the shortest incubation time was approximately three weeks in duration (Parente and Snyder 1970; Scott and Crossman 1973). Sampling was also conducted at various points up the river to determine where most of the spawning was occurring. The sample sites were referred to by river mile (RM) starting below the Twentymile River Bridge upstream to the Glacier Fork. One site was sampled at the mouth of the Clear Fork (RMC) to determine if eulachon spawned there. Sampling sites were located at RM 1.2, RM 2.5, RM 4.1, RM 5.9, RM 6.6 and RMC 6.7 (mouth of Clear Fork; Figure 4).

The sampling materials included bongo rings, nets, and codends (Hay et al. 1997b; McCarter and Hay 2001). The bongo rings were fabricated from steel with a bar in the center of one ring for the attachment of the Swoffer™ flow meter and YSI™ for water temperature. The rings had an outer diameter of 21.9 cm, inner diameter of 20.3 cm, and depth of 15.2 cm (Figure 5). The bongo nets were attached to rings with 2 hose clamps. The nets were 120 cm in length; 7.6 cm in diameter with 333 micron mesh net. The ends of the nets were attached to plastic piping with codends. The codends were 16.5 cm in length; 7.6 cm in diameter, and had 4 holes that were 1.3 cm in diameter constructed of 333 micron mesh material (Figure 6)

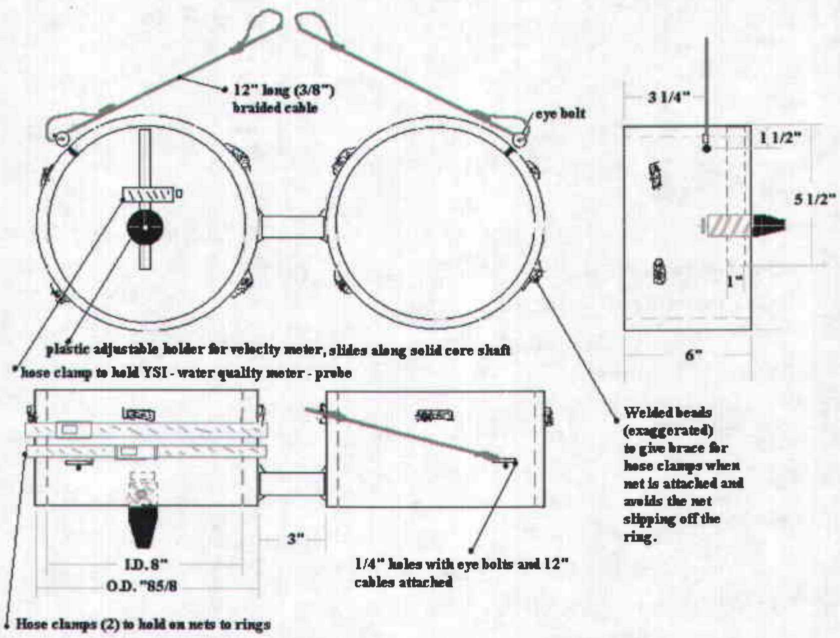

Figure 5. Bongo ring design for larval fish sampling Twentymile River Alaska (Eller, A.; USFS, Glacier Ranger District, Girdwood, Alaska).

$V_f = \pi r^2 (f*t)$, where radius (r) was the opening size of the net, (f) was the flow of water in m/s, and (t) was the amount of time fished in seconds.

$$D_t = \text{number of larvae} / V_f$$

The larval productivities (P_t) during the sampling time were compared among the three water depths (surface, mid water, bottom) to estimate vertical distribution in the water column. At each depth, three productivity samples (P_t) were obtained and the mean productivity was determined for each depth.

Incubation periods were estimated by calculating the number of days between peak daily abundances of adult CPUE and larval productivity. These peaks were plotted as smoothed curves from five-day running averages. Both adult CPUE and larval productivity were superimposed on each other to determine corresponding peaks. Incubation periods were classified with accumulated thermal units (ATU) using mean daily water temperature.

The daily P of larval eulachon was compared with simultaneous environmental factors including water temperature, tide height, river discharge, and light intensity. Water temperature, tide height and river discharge data were collected in the same manner as described for adults. To test if larval productivity was related to light intensity, a series of paired "day" and "night" samples were collected during the study. Samples were taken within 24-hr periods (0000 – 2400 h) that contained "day" (> 5 lumens) and "night" (≤ 5 lumens) light intensities. Times of low light intensity corresponding with low tide are limited at northern latitudes at this time of year. Therefore there were few opportunities to conduct paired day and night comparisons.

Data Analysis

Catch per unit effort of adults was modeled as a gamma random variable (continuous) using explanatory variables. The analysis began by fitting all measured environmental factors into a generalized linear model (Agresti 1990; McCulloch 2001). The analysis was completed using PROC GENMOD (SAS Institute, Inc. 2002) with a log link function. Initially, all variables were placed into the model. Terms were analyzed in a stepwise fashion, until all remaining environmental variables were statistically significant. A significance level of 0.05 was used to define statistical significance during model development.

Productivity of larvae was modeled as a gamma random variable using day of the year (DY), water temperature (W), tide height (T), and river discharge (D) as explanatory variables. The analysis began by fitting all measured environmental factors into a generalized linear model (Agresti 1990; McCulloch 2001). The analysis was completed using PROC GENMOD (SAS Institute, Inc. 2002) with a log link function. Initially, all variables were placed into the model. Terms were analyzed in a stepwise fashion, until all remaining environmental variables were statistically significant. A significance level of 0.05 was used to define statistical significance during model development. A paired t-

Table 1. Residency of fishermen contacted during the eulachon creel survey, Twentymile River, 2002.

Rural or Non Rural	Community	# Fishermen
Rural	Delta Junction	15
	Glenallen	2
	Hope	9
	Kotzebue	3
	Moose Pass	2
	Ninilchik	2
	Port Graham	5
	St. Marys	4
	Talkeetna	1
	Whittier	1
	Willow	6
Non Rural	Anchorage	422
	Anchor Point	2
	Chugiak	2
	Eagle River	8
	Fairbanks	1
	Fresno, CA[a]	5
	Homer	1

[a] illegal fishermen

Table 2. Estimated total fishing effort and harvest of Eulachon by dipnetters at 20-mile River.

Date	Total hours fished	SE	Total number party	SE	Total weight (kg)	SE
Site 1	309	99.9	481	161.0	3660.8	1676.5
Site 2	452	138.7	644	172.5	3880.0	2069.0
Site 4	731	357.2	909	430.9	7353.9	5203.1
Site 5	117	112.4	260	249.8	46.2	44.4
Total	1,609	708.2	2294	1,014.2	14,940.9	8,993.0

Determine run timing and other aspects of eulachon life history (fecundity, age, et.) in Twentymile River. (2000, 2001).

Run timing

Fish were detected from 4 May to 21 June 2000 and 17 April to 9 June 2001 during dip net sampling. There was one fish caught on 21 June 2000, but sampling had to be terminated that year due to limited funding. The spawning run started 18 days earlier in 2001 than in 2000. A total of 394 fish were caught in 2000 and 3,815 fish in 2001. The increased fishing effort in 2001 aided in the collection of more eulachon. The maximum

Table 3. Life history dependent and independent variables in 2000.

Dependent Variables 2001	Independent Variables 2001	P_{2001}	n	β	SE
Sex Ratio	Day of the Year	< 0.6687	31	-.0214	0.0501
	Length	< 0.0001	271	0.0482	0.0099
	Weight	< 0.0001	271	0.0397	0.0102
	Age	< 0.0013	272	0.7419	0.2312
Teeth Retention	Sex	< 0.0001	271	-5.3752	0.5813
	Age- Males	< 0.9874	222	0.0092	0.5837
	Age- Females	< 0.7094	49	-0.1990	0.5338
Age	Day of the Year- Males	< 0.0001	223	0.0060	0.00010
	Day of the Year- Females	< 0.1137	49	0.0041	0.0026
Weight	Age- Males	< 0.0001	222	0.2097	0.0167
	Age- Females	< 0.0001	49	0.3078	0.0458
Length	Age- Males	< 0.0001	222	0.0619	0.0048
	Age- Females	< 0.0001	49	0.0885	0.0015

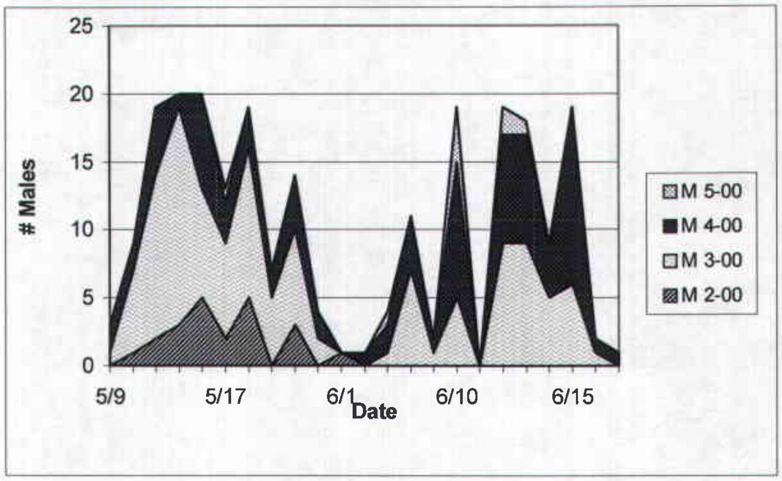

Figure 8. The age distribution over run timing for male eulachon, 2000

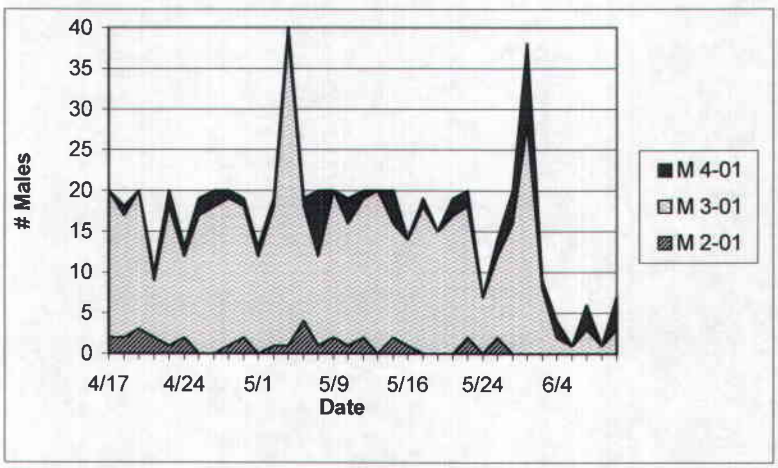

Figure 9. The age distribution over run timing for male eulachon, 2001.

Table 5. Male and female mean, minimum, and maximum fork lengths Twentymile River.

			Eulachon Fork Length (mm)		
Year	Sex	*n*	Mean ± SE	Minimum	Maximum
2000	Male	222	215.4 ± 0.9	166.0	242.0
	Female	49	202.1 ± 3.0	143.0	234.0
2001	Male	585	209.1 ± 0.5	100.0	241.0
	Female	425	202.5 ± 0.6	99.0	253.0

The mean weight was significantly different (Table 3, $p < 0.0001$) between males and females in 2000. The significant difference (Table 4, $p < 0.0001$) was also seen in 2001 between males and females. The male fish consistently had greater mean weights than females (Table 6), though the smallest eulachon found were males.

Table 6. Male and female mean, minimum, and maximum weights, Twentymile River.

			Eulachon Weight (g)		
Year	Sex	*n*	Mean ± SE	Minimum	Maximum
2000	Male	222	69.9 ± 1.0	26.5	104.0
	Female	49	60.0 ± 2.8	29.0	101.0
2001	Male	585	65.8 ± 0.5	6.0	106.0
	Female	425	60.1 ± 0.5	28.0	122.0

Male and female eulachon showed a significant difference in presence of teeth between sexes in 2000 (Table 3, $p < 0.0001$) and 2001 (Table 4, $p < 0.0001$). During both years of the study, few spawning males had teeth compared with females (Table 7).

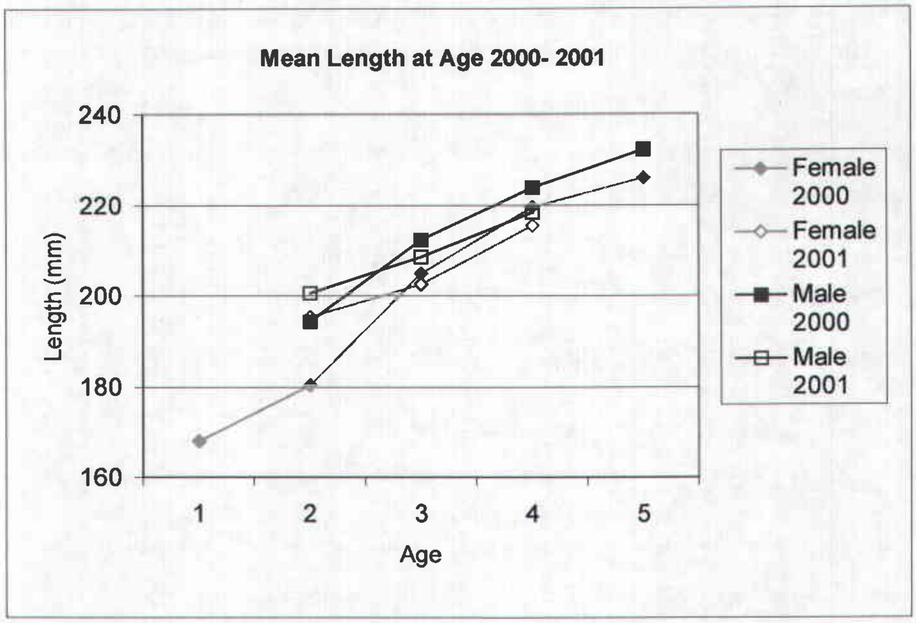

Figure 12. The mean length at age for male and female eulachon, 2000- 2001.

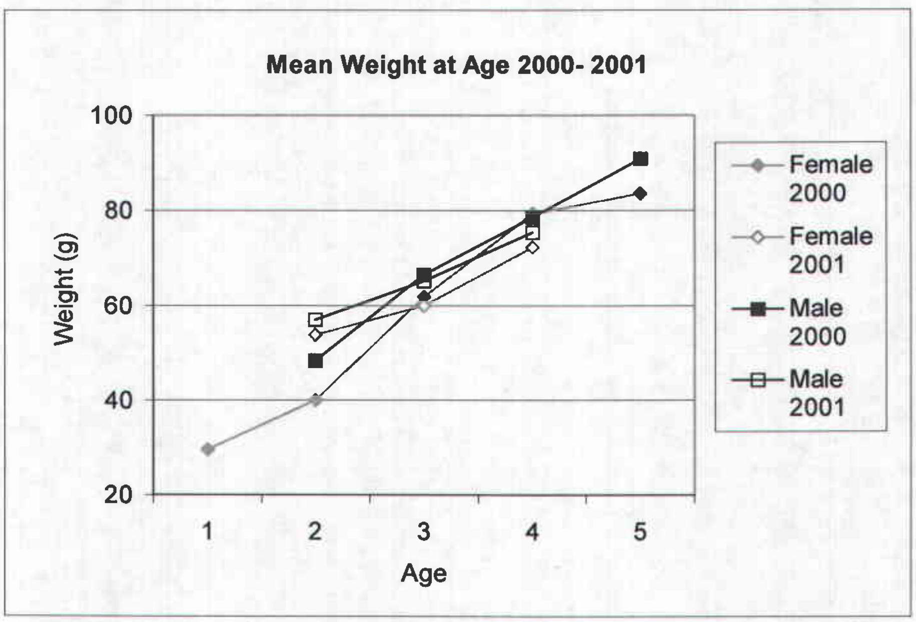

Figure 13. The mean weight at age for male and female eulachon, 2000- 2001.

In 2001, fecundity ranged from 8,532 eggs to 67,507 eggs per female (Table 9). Fecundity was significantly related to age (Table 4, $p < 0.0397$), length (Table 4, $p < 0.0001$), and weight (Table 4, $p < 0.0001$). Females became more fecund with increasing

Table 11. Adult CPUE compared with environmental factors, 2001.

Environmental Factors	p_{2001}	n	β	SE
Day of the Year	< 0.0001	64	-0.0281	0.0031
Water Temperature	< 0.0001	64	-0.0507	0.0103
Tide Height	< 0.0001	64	-0.2251	0.0255
River Discharge	< 0.0001	64	-0.0185	0.0023
Light Intensity	< 0.0001	64	0.0000	0.0000
Predators	< 0.0001	50	0.0220	0.0009

All variables were positively related to CPUE except for light intensity that had an inverse relationship. During the adult spawning run, water temperatures ranged from 1.6° C to 12.7° C in 2000 and from 0.5° C to 10.7° C in 2001. At the peak of the run, water temperatures were 4.6° C in 2000 and 6.0° C in 2001. High tide heights ranged from 6.86 m to 9.81 m in 2000 and 6.58 m to 9.57 m in 2001. In 2001, the river discharge ranged from 8.16 $m^3 s^{-1}$ to 77.93 $m^3 s^{-1}$ with the greatest CPUE occurring at 21.56 $m^3 s^{-1}$. The light intensity ranged from 0 to 7.4 x 10^4 lumens, with greatest CPUE at low light intensities (< 5.0 lumens) in 2001.

The number of bald eagles (E) was positively related to CPUE of eulachon ranging from 1 to 139 birds with a daily mean of 37 birds (Table 11). The number of bald eagles increased as CPUE increased for eulachon (Figure 14).

$$\text{Log (E)} = b_o + b_1 \text{ CPUE} + b_2 \text{ (DY)}$$

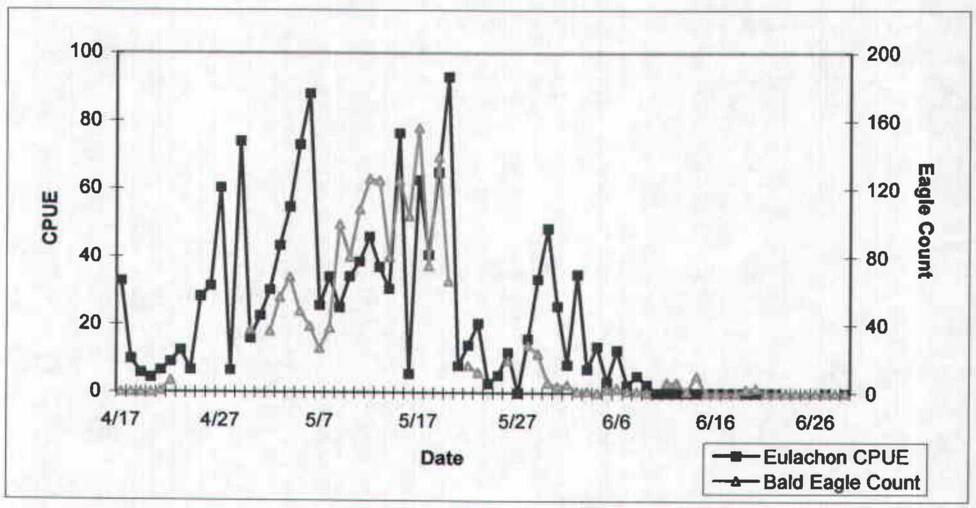

Figure 14. Bald eagle presence compared to CPUE of adults, 2001.

Migratory behavior

The mean and furthest upstream distances were calculated for fish moving upstream and downstream above the initial tagging site (category one) and fish moving only upstream, followed by no movement until the life expectancy of the tag was reached (category two). In 2000, the maximum upstream distance for males was 9,470 m (n = 13; Fig. 15; 2000) and 8,097 m (n = 40; Fig. 15; 2001). The mean upstream distance for males was 3,684 m (n = 13; SE ± 201 m; Fig. 15) in 2000 and 3,688 m (n = 40; SE ± 45 m; Fig. 15) in 2001. Female maximum upstream distance was 6,855 m (n = 4; Fig. 11; 2000) and 7,761 m (n = 43; Fig. 11; 2001). The mean upstream distance for females was 3,919 m (n = 4; SE ± 1006 m; Fig. 11) in 2000 and 2,723 m (n= 43; SE ± 41 m; Fig. 11) in 2001. Males consistently spent more time in freshwater than females (Table 2). These variables were not calculated for categories three (limited movement adjacent to the tagging site) and five (only detected on day of initial tagging) because these movement patterns could be the result of a tagging effect.

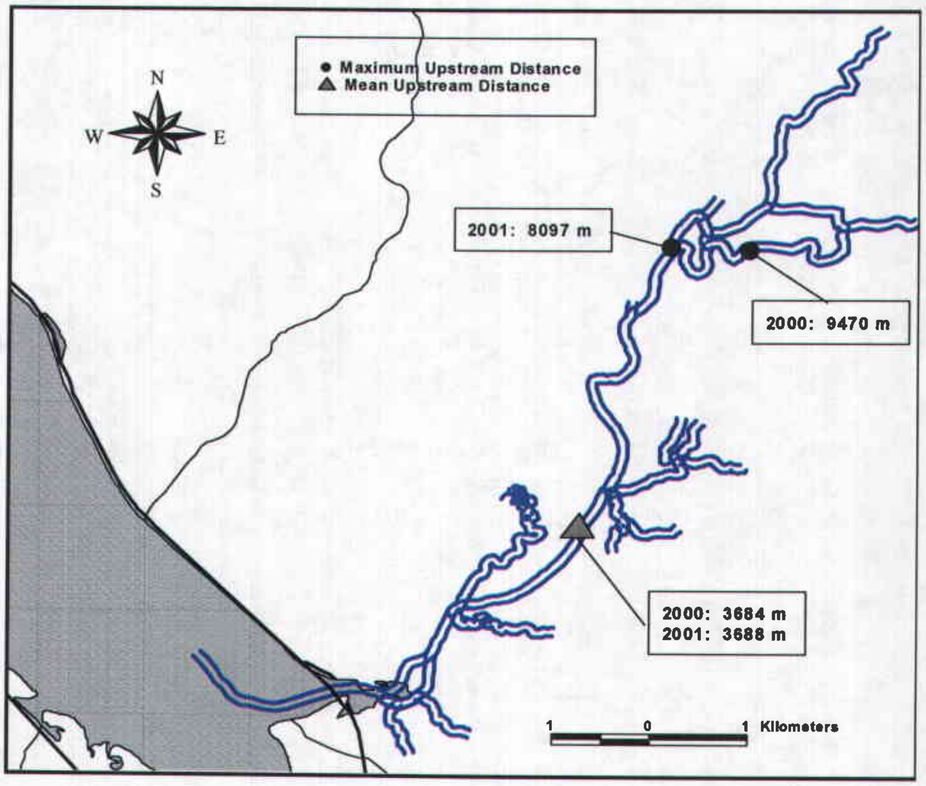

Figure 15. The maximum and mean upstream migration positions for males (2000, 2001).

larval fish were caught (3 larvae in 2000 samples; $n = 55$; and 12 in 2001 samples, $n = 158$). when compared with the lower river (617 larvae in 2000 samples; $n = 60$ and 66,519 larvae in 2001 samples; $n = 765$). Therefore, it is reasonable to assume that we captured most of the spawning areas. Larval sampling in the Clear Fork confirmed there were no spawning eulachon as no larvae were detected in either year.

The furthest upstream migration positions identified four possible concentrated areas of spawning in 2000 and five possible concentrated areas of spawning in 2001 (Figures 17 and 18). Four of the spawning sites were similar between years varying in centrums between 24 and 330 m (Table 14). In 2001, there was one additional site located at 4479 m.

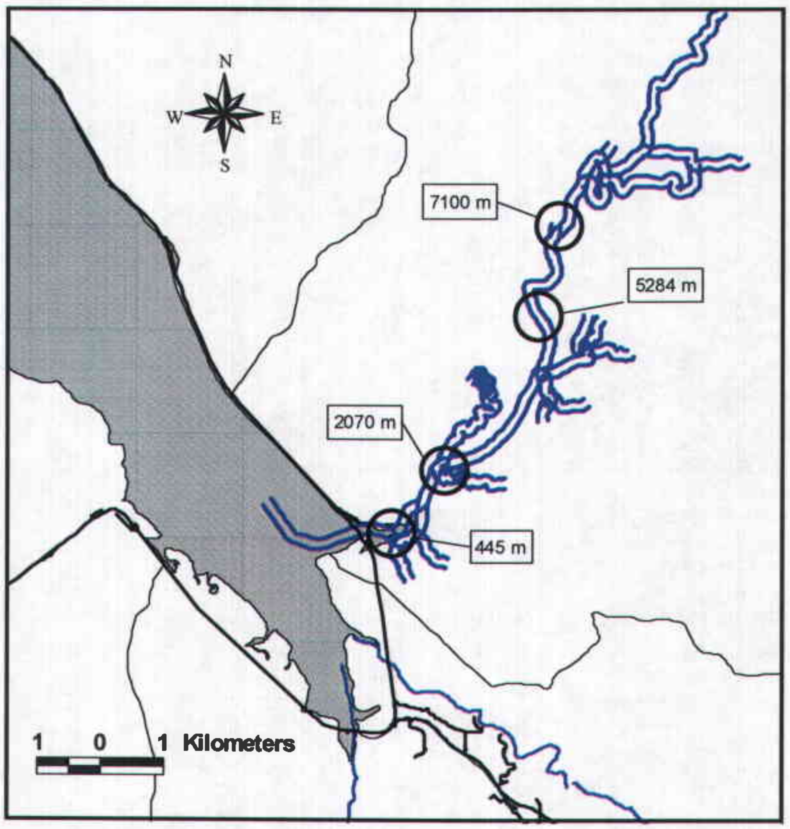

Figure 17. The most common upstream migration areas for eulachon, 2000

Conduct larval and biomass assessments as indices of relative run strength. (2000, 2001)

2000: A stream gauging station was installed to provide instantaneous flow estimates for developing the productivity estimates. Larval sampling methods were successfully adapted for use in small rivers. One site at RM 1.2 was found to be the most stable and repeatable for sampling over the range of flows during out migration. Eulachon egg and larvae samples were collected at six locations in Twentymile River from 21 June to 21 July 2000. Maximum densities of larvae occurred at RM 1.2 (Figure 19).

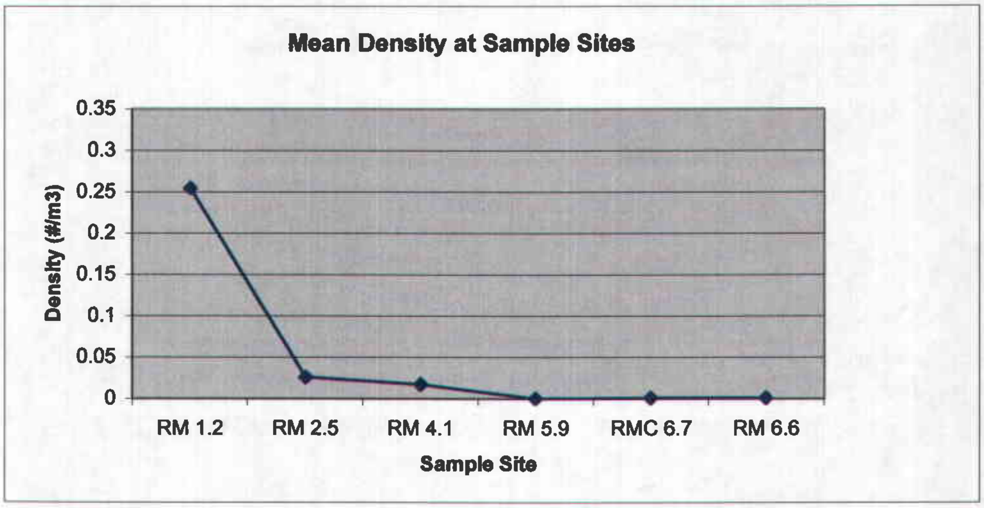

Figure 19. Density at different sampling sites.

2001: Larval fish were detected from 8 May 2001 to 28 August 2001, 113 days. The first larval fish were observed 22 days after the first adults were detected in the system on 17 April 2001. The last larval fish were captured 81 days after the last pre-spawning adults were detected entering the river (Figure 20). The daily mean productivity (P) was 16,947, ranging from 0 to 96,382 larval fish per sampling session. The period of greatest productivity was detected from 17 June to 20 July 2001 with a mean of 42,859 larval fish per sampling session.

corresponding peaks between adult CPUE and larval productivity. Each of the corresponding peaks was similar in intensity. The first peak in CPUE was similar in intensity to the first peak in larval productivity. This trend occurred for all three peaks. When comparisons were made between corresponding peaks, the number days were similar at 47, 50, and 47 days. The peak periods were as follows: first corresponding peak period from 5 May (adult) to 20 June (larval), the second corresponding peak from 17 May (adult) to 5 July (larval), and the third peak from 1 June (adult) to 17 July (larval). For each of these three time periods, accumulated thermal units (ATU) were calculated using mean daily water temperatures. The incubation period ranged was from 294 to 321 ATU.

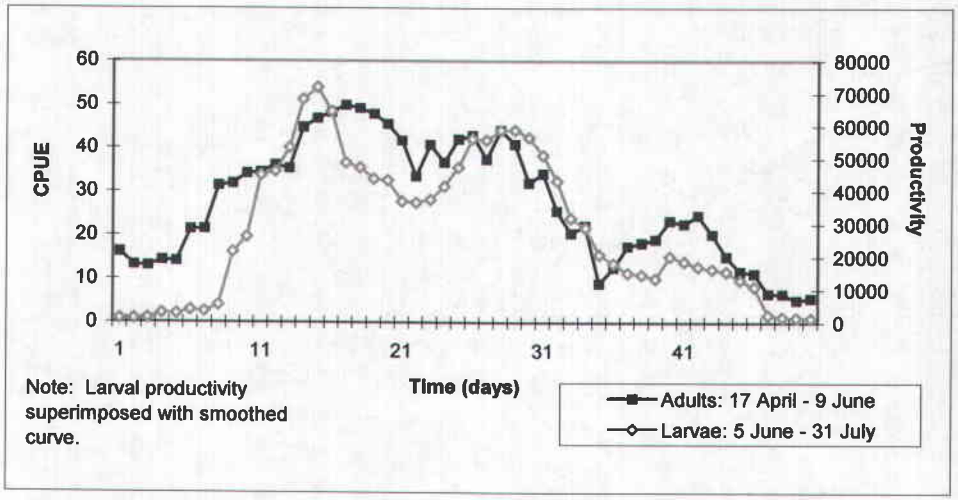

Figure 22. Larval productivity superimposed on adult CPUE, 2001.

Productivity of larvae in 2001 (Table 15) was significantly related with day of the year (DY), water temperature (W), and river discharge (D) in the generalized linear model. There was no significant relationship between tide height and the productivity of larval fish (Table 15).

$$\text{Log } (P_t) = b_o + b_1DY + b_2W + b_3D$$

Determine presence/absence of eulachon in the Portage Creek and Placer River drainages. (2000, 2001)

Placer River was sampled twice per week from 5 May through 15 June 2000 and 17 April through 20 June 2001. Eulachon were detected with low catch per unit effort (CPUE) in 2000. The presence of eulachon was not detected in any sampling events in 2001. CPUE was 0.3 fish/ hour in 2000 and 0 fish/ hour in 2001.

Portage Creek was sampled twice per week from 3 May through 14 June 2000 and 17 April through 20 June 2001. Eulachon were detected with low CPUE during both years. CPUE was 0.2 fish/ hour in 2000 (n = 3) and 0.7 fish/ hour in 2001 (n = 18).

Collect samples for larger eulachon study to determine stock composition and interception in the Pacific. (2001)

One hundred samples were sent to Dr. Doug Hay, at the Department of Fish and Oceans, Nanaimo, British Columbia. These data are currently under analyses, but the final product is dependent upon collection of samples from other regions. Therefore the date of completion is unknown.

DISCUSSION:

User demographics and harvest

The eulachon fishery at Twentymile River is an important resource for rural and Anchorage residents. It was particularly surprising that there was the participation by eleven rural communities with residents from as far away as St. Marys, Delta Junction and Talkeetna. Often, residents from these distant rural communities were visiting relatives in Anchorage or other rural communities closer to Twentymile River.

The estimated harvest of 14,941 kg in 2002 is higher than reported by ADF&G for Twentymile River or for any other river with a personal use fishery. From 1977-1997 the estimated average statewide harvest of smelt (eulachon and capelin *Mallotus villous*) was approximately 210,000 smelt (6,930 kg), with 54% taken from the Twentymile River (Mills 1991; Howe et al. 1998). The 2002 harvest in Twentymile River exceeds that of any other harvest of eulachon in the state of Alaska with the exception of the Copper River where annual harvest can be up to 78,300 kg (Moffitt, 2002).

Run timing and life history

The eulachon run lasts over a longer period of time in the Twentymile River than in any other river for which data are available (Table 16). The observed differences among the Twentymile River and other river systems could be due to environmental conditions or to sampling methods. Year-class strength or ocean rearing conditions can also influence the run timing and duration of anadromous fish such as sockeye salmon (*Onchorhynchus nerka*, Gilhousen 1960). Ocean temperature, the temperature gradient between ocean and indicators of the run duration on Twentymile River. If indeed this one-week lag period occurred, then the actual run duration would have been longer than reported. Additional bias using creel survey data could occur from fishermen use patterns. Fishermen were more prevalent on days of good weather or on the weekends.

Different environmental conditions in northern latitudes may explain the larger body size of eulachon in the Twentymile and Susitna Rivers than in populations further south (Tables 17 and 18). High latitude ecosystems such as the Bering Sea support some of the most productive and valuable fisheries of the world (Bakun 1996). This is due to the enrichment from seasonal overturns and tidal mixing occurring in shallow areas. Although recent and rapid increases in temperature from global warming and atmospheric oscillations may have caused declines in forage fishes in the Gulf of Alaska (Anderson and Piatt 1999), rearing conditions still may be better than those present in southern latitudes. Although caution must be used when comparing samples between rivers during different years, there was a general trend of smaller and older fish in the Fraser River when compared with fish from the Twentymile River (Tables 19 and 20). This may be reflective of more productive rearing conditions in northern latitudes. Additionally, it is interesting to note, although sample sizes were too small to include in our comparisons, the smallest mean lengths were reported in the southern extent of eulachon range. In California, Russian River males and females had a mean length of only 143 mm (Odemar 1964).

Table 18. Geographic studies with male and female age and mean length (mm).

River (latitude)	Year	Sex	Age at Length (mm)						
			1	2	3	4	5	6	7
Twentymile	2000	M		194	212	224	232		
(60° 84′N		F	168	180	205	220	226		
148° 99′W)	2001	M		201	209	218			
		F		195	203	216			
Copper	1998	M			179	182	183	176	
(60° 20′N		F							
145° 00′W)					181	175	177	186	
Fraser	1954	M			140	143	144		
(49° 09′N		F			156	164	148	151	
123° 12′W)	1986	M				172	183	196	205
		F				158	169		

Table 20. Mean age by geographic area for eulachon

River (Latitude)	Geographic Area	Year	Sex	*n*	Mean Age	Max Age	Min Age	Source
Twentymile	USA/ Alaska/	2000	M	168	3.3	5	2	Spangler
(60° 84′N	Cook Inlet/		F	49	2.9	5	1	et al.
148° 99′W)	Turnagain	2001	M	586	3.0	4	2	2002
	Arm		F	425	2.9	4	2	
Copper	USA/ Alaska/	1998	M	2012	5.0	6	3	Morstad
(60° 20′N	central coast		F	503	4.5	6	3	1998
145° 00′W)	of Alaska							
Fraser	Canada/	1954	M	18	3.5	5	3	Higgins
(49° 09′N	British		F	23	3.5	6	3	et al.
123° 12′W)	Columbia							1986
		1986	M	10	4.5	7	4	Ricker
			F	10	4.5	5	4	et al.
								1954

spawning behavior of smelt. Fertilization success would increase with more available milt in the water increasing the probability of eggs being fertilized. Therefore, the skewed ratio may be a key element to successful spawning (Smith and Saalfeld 1955). However, there is some debate, as little is understood of their spawning behavior. Although it is not known if eulachon are iteroparous or semelparous, we found males to be older than females. If males were capable of spawning multiple years, and if females were limited to one spawning season then the sex ratio would also favor males even after oceanic mortality. Highly skewed sex ratios are often observed with hermaphroditic fish species, but this phenomenon is currently unknown for eulachon (Maynard-Smith 1984).

Previously documented sex ratios may not be true representations of eulachon populations. Errors can result from sampling gear bias, sampling positions in the river, timing of sampling, and misidentification of sex. Sex ratios can vary with different gear types and caution must be used when determining methods of capture (McHugh 1939). In this study, we found differences in sex ratio with sampling gear. Because dip nets are of a fine mesh (5 mm) and the opening of the net was large enough to capture all sizes of fish, we feel this method was not size selective in our study.

The location in the river (across and upstream) at which eulachon were collected has been proposed to cause variations in sex ratio. Males have been reported to occupy areas closer to shore, whereas females remained in the center of the river (Hart and McHugh 1944). This distribution would explain greater percentages of males collected by dip netting from a position standing on the riverbank.

Contrary to other researchers, we found no significant relationship associated with sex ratio and migration time in the Twentymile River in 2001. However, in 2000, we did observe two time periods when females were more prevalent. The run in 2000 was bimodal and females seemed to run at the beginning of each pulse. Some researchers suggest a differential migration timing by sex with the number of males increasing as the spawning run continues over time (Langer et al. 1977; ADF&G 1966; Smith and Saalfeld 1955). Another report suggests the number of males decreases as the spawning season progresses (McHugh 1939). In both of these studies, it was unclear if the counts contained fish that were only in pre-spawning condition. We found higher numbers of males later in the spawning run, but found most spawned out and moving downstream. Therefore, these fish were not counted in our sex ratio estimate. This is similar to the eulachon dip net fishery on the Cowlitz River in Washington where most of the fish caught at the end of the fishing season were males that had spawned (G. Bargmann, Washington Department of Fish and Wildlife, Olympia, Washington; personal communication).

For studies using external visual observation of morphological characteristics to identify sex, misidentification can occur. This is especially true in the later portions of eulachon spawning runs. Females, migrating downstream after spawning look similar to pre-spawning males that lack some of the secondary sexual characteristics such as the presence of tubercles. These well-developed, visible tubercles are also identified on male rainbow smelt (Buckley 1989). Caution should be used in visual sex determinations to area may be vulnerable to multiple fishing efforts and as such, this segment of the population could receive a higher proportion of overall fishing effort.

Adult eulachon spent a relatively short period of time in freshwater. This is similar to the retention time of anadromous rainbow smelt (four to ten days; Rupp 1968; Buckley 1989). This short retention time within the river would have several advantages. First, this behavior may be an adaptation to avoid predation. The density of predators is much higher during the eulachon runs than observed for migrations of other fish species such as salmon (R. Spangler, USFS, Glacier Ranger District, Girdwood, Alaska; personal communications). Large aggregations of predators feed on spawning eulachon (Swan 1881; Langer et al. 1977). By spawning quickly in great numbers, eulachon may decrease exposure to predation thereby increasing the opportunity to produce offspring. Second, spending little time in freshwater would allow fish to spend more energy on gamete production instead of using valuable energy reserves maintaining positions in the river when they are not feeding.

Although radio telemetry is a useful tool to study migratory behavior of eulachon, other methods should be used to determine the upper limits of spawning. In both 2000 and 2001, radio telemetry failed to establish the upstream limits of spawning. More tagged fish may have reduced this error, but increasing the number of tags is expensive. Additionally, increasing the number of tags still represents a small percentage of the total spawning population. Larval sampling at an area considered to be the upstream limits of spawning will include all fish passing this location. Additionally, the sampling method is simple and relatively inexpensive when compared to the cost of radio telemetry equipment.

Eulachon appear to be selecting similar areas each year for spawning in the Twentymile River. One spawning area identified by Browning in 1976 on the Twentymile River was confirmed by our work in 2001. This area also was identified in 2000, but was not the most concentrated spawning area. These results suggest that eulachon are selecting certain spawning areas. It is important to realize however, that our observations were made during the day. As spawning behavior has been reported at night (Franzel and Nelson, 1981) our observations may not reflect spawning site selection. Fish could be using the deeper water for cover during the day and using different adjacent areas for spawning at night. Female rainbow smelt have been documented at spawning beds at night and moving back into the estuary during the day (Buckley 1989). However, male rainbow smelt tend to stay near the spawning beds at all times.

Radio telemetry, with acknowledged precautions, is an effective method for evaluating the migratory behavior of eulachon. Procedures were straightforward to implement and success rates were similar to those reported for other telemetry studies. However, there are several precautions that should be taken to accurately characterize a spawning migration. First, it is critical to mark equal percentages of males and females as our study suggests differential movement and retention in the river system between sexes. Second, it is important to be able to successfully identify pre-spawning and tagged fish at the leading edge of the run because of the short fish-residency time in the river. This short

High CPUE values of adult eulachon during low light levels may be a behavioral adaptation to escape predation. In Twentymile River bald eagles, gulls, beluga whales, harbor seals, Dolly Varden char (*Slavelinus malma*), and humans were observed preying on eulachon (author's observations). Some predators use visual observation for capturing eulachon, therefore lower light intensities could favor survival. Often eulachon return in such high numbers that it is efficient for predators to focus on this one prey source. An original description in the Nass River (Swan 1881, cited in Langer et al. 1977) notes porpoises, seals, dogfish, ground sharks, halibut, gulls, ducks, and other sea birds accumulate in the immediate vicinity when the eulachon spawning run begins. Here, in excess of 300 bald eagles and thousands of gulls have been reported associated with the eulachon spawning migration. The report indicates the greatest density of predators occurring only one day before the peak of eulachon collected using trawl net tows (Langer et al. 1977). We found the highest counts of bald eagles occurred three days before the peak of the eulachon spawning run.

Our results were similar to other studies indicating that peaks in larvae occur during periods of stable water temperature. In Twentymile River, water temperatures did not vary by more than 1.9° C during peak downstream drift. Variation in water temperature was also relatively small (2.8° C) on the Cowlitz (Smith and Saalfeld 1955), Fraser (Hart 1973), and Nass Rivers (Langer et al. 1977) during peak downstream drift. As eulachon larvae are sensitive to large fluctuations in water temperatures (Blahm and McDonnell 1971), perhaps larvae time movement out of rivers corresponding with periods of stable water temperature to avoid death or adverse metabolic effects.

Our findings support the idea that the number of ATU needed to incubate eulachon eggs increases with latitude (Pedersen et al. 1995). In a northerly direction the order of rivers and the ATU are as follows: Columbia River, 188 (Smith and Saalfeld 1955), Kemano River, 242 (Triton 1990), Kitimat River, 258 (Pedersen et al. 1995), and Twentymile River, 303 (this study). These observed differences may suggest that these fish populations are either from separate stocks or adapted to the local environments. Very little genetic work has been conducted on eulachon. However, in one study conducted on stocks of eulachon from the Bering Sea, Alaska, B.C., Washington, and Oregon, 97 percent of all genetic variation occurred within local populations (McLean et al. 1999), indicating high gene flow among populations from different geologic areas. More research is needed to determine the uniqueness between eulachon populations.

Generally we found that as discharge increased, the downstream larvae increased in number. Eulachon are demersal spawners with the eggs settling on the bottom and adhering to the substrate (Snyder 1970). They spawn on the bottom of a stream or river, typically on substrates of sand, organic demersal debris and small gravel (McHugh 1940; Smith and Saalfield 1955; Samis 1977). As discharge increases, bedload movement and substrate scour are more pervasive. This in turn, has the ability to dislodge fish and eggs from gravel and transport them downstream. Although we did not measure turbidity, we observed lower water visibility during periods of higher discharge. Larvae may also be timing migration with lower water visibility to avoid predation.

CONCLUSIONS AND RECOMMENDATIONS:

1. Approximately 9% of all fishermen are from rural areas representing 11 different rural communities.
2. To determine proper sampling design for run strength and life history for adult fish, the environmental factors that should be considered include water temperature tide height, river discharge, and light intensity. If resources are severely limited, the presence of bald eagles could be used to determine the start and peak of the eulachon run.
3. There may be a proportion of the adult population spawning in the estuary. Further research is needed to determine if eulachon are capable of spawning in the euryhaline conditions of the estuary. If fish are capable of spawning in the estuary, larval sampling could be missing a segment of the population leading to erroneous results.
4. The larval monitoring index appears to be an effective tool for determining population trends. To develop an efficient and valid sample design, environmental factors considered should include water temperature, river discharge, and light intensity. Sampling should be stratified by depth. Calculations of ATU can also help to time the start of larval sampling and increase sampling efficiency reducing cost. In Twentymile or similar river, cost of larval monitoring is estimated at $35,000 per year.
5. Adult eulachon spend relatively short periods of time in fresh water limiting exposure to harvest. Eulachon do not migrate to spend many days or weeks congregating and spawning as some salmon do.

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Literature Cited:

Adams, N.S., D.W. Rondorf, S.D. Evans and J.E. Kelly. (1998) Effects of surgically and gasterically implanted radio transmitters on growth and feeding behavior of juvenile chinnok salmon. Transactions of the American Fisheries Society. 127(1): 128-136.

Agresti, A. 1990. Categorical data analysis. John Wiley and Sons, New York.

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

Betts, M.F. 1994. The subsistence hooligan fishery of the Chilkat and Chilkoot Rivers. Alaska Department of Fish and Game. 213: 1-69.

Blahm, T.H. and R.J. McDonnell 1971. Mortality of adult eulachon *Thaleichthys pacificus* subjected to sudden increases in water temperature. Northwest Science. 45 (3): 178-182.

Blanchet D. 1995. Geomorphic and hydrologic evaluation of the Twentymile watershed. Chugach National Forest, Anchorage, Alaska. 1-42.

Browning, R. 1976. Portage area fisheries habitat inventory and analysis. Alaska Department of Fish and Game. pp. 81-84.

Buckley, J. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)- rainbow smelt. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.106). U.S. Army Corps Engineers, TR EL-82-4. 11p.

Carragher, J.F. and J.P. Sumpter. 1991. The mobilization of calcium from calcified tissues of rainbow trout (*Oncorhynchus mykiss*) induced to synthesize vitellogenin. *Comp.* Biochem. Physiol. 99A: 169 – 172.

Clemens, W.A. and G.V. Wilby. 1961. Eulachon. In: Fishes of the Pacific coast of Canada. W.E. Ricker (ed.). Ottawa Press. 68 (2): 122-124.

Cochran, W.G. 1977. Sampling techniques, 3rd ed. John Wiley and Sons, Inc. New York

Egorova, T.V. 1970. Reproduction and development of sockeye in the Basin of Ozernaya River. Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 73: 39- 53. (Transl. from Russian; Fish. Res.Board Can.Transl. Ser. 2619).

Franzel, J. and K. Nelson. 1981. unpublished report. Stikine River hooligan (Thaleichthys pacificus). U.S.D.A. Forest Service, Petersburg, Alaska.

Gilhousen, P. 1960. Migratory behavior of adult Fraser River sockeye. Int. Pac. Salmon Fish. Comm. Prog. Rep. 7: 78 p.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. UBC Press. Vancouver.

Hart, J.L. 1973. Eulachon. Pacific Fishes of Canada. Bult. Fish. Res. Bd. Canada. pp. 148-150.

Lall, S.P. 1989. The minerals, pp. 219 – 257. In: Fish Nutrition. J.E. Halver. Academic Press, New York.

Langer, O.E., B.G. Shepherd and P.R. Vroom. (1977) Biology of the Nass Eulachon (*Thaleichthys pacificus*). Fisheries and Environment of Canada. PAC/ T-77-10.

Lindsey, C.C. 1966. Body sizes of poikilotherm vertebrates at different latitudes. Evolution. Vol 20(4), pp. 456 – 365.

Martinelli, T.L., H.C. Hansel and R.S. Shively. 1998. Growth and physiological responses to surgical and gastric radio transmitter implantation techniques in subyearling chinook salmon (*Onchorhynchus tshawytscha*). Hydrobiologia. 371/372: 79-87.

Maynard-Smith, J. 1984. The ecology of Sex. In: Behavioural Ecology: An Evolutionary Approach. J.R. Krebs and N.B. Davies. Blackwell Scientific Publications, Oxford.

McCarter, P. and D. Hay. 2001. Eulachon embryonic egg and larval outdrift sampling manual for ocean and river surveys. PSARC Working Paper.

McCubbing, D. J., B. D. Bayliss, and V. M. Locke. 1988. Spawning migration of radio tagged landlocked Arctic Charr, Salvelinus alpinus L. in Ennerdale Lake, the English Lake District. In J. P. Lagardere, M. L. Begout Antras and G. Claireaux (eds), Advances Invertebrates and Fish Telemetry. Hydrobiologia. 371/372: 173-180.

McCulloch, C.E. and S.R. Searle. 2001. Generalized linear, and mixed models. John Wiley and Sons, New York.

McHugh, J.L. 1939. The eulachon. Prog Rep Pac Biol St. and Pac. Fish. Exper. *St.* 40: 17-22.

McHugh, J.L. 1940. Where does the eulachon spawn? Fisheries Research Board of Canada. 44: 18-19

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

Mills, D.D. 1982. Historical and contemporary fishing for salmon and eulachon at Klukwan: an interim report. Alaska Department of Fish and Game. 69: 1-28.

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.

Samis, S.C. 1977. Sampling eulachon eggs in the Fraser River rsing a submersible pump. Fisheries and Marine Service Canada. PAC/ T-77-18. 1-10.

SAS Institute Inc. 1999. SAS/STAT User's Guide, Version 8. SAS Institute Inc., Cary, NC.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fish Res. Bd. Canada. Bull. 184.

Seaman, G.A., L.F. Lowry and K.J. Frost. 1982. Foods of belukha whales (*Delphinapterus Leucas*) in western Alaska. *Cetology*. 44: 1-19.

Simkiss, K. 1974. Calcium metabolism of fish in the relation to ageing, pp. 1 – 12. In: Ageing of fish. T.B. Bagenal. Unwin Brothers Ltd, Surrey, UK.

Smith, G.W., R.N.B. Campbell and J.S. MacLaine. 1998. Regurgitation rates of intragastric transmitters by adult Atlantic salmon (*Salmo salar* L.) during riverine migration. Hydrobiologia. 371/372: 117 – 121.

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

Snyder, G.R. (1970). Thermal pollution of Columbia River might threaten smelt. *Commercial Fisheries.* 32 (12): 58-64.

Swan, J.G. 1881. The eulachon or candle-fish of the Northwest coast. Proc.U.S. Nat. Mus. 1880(3): 257-264.

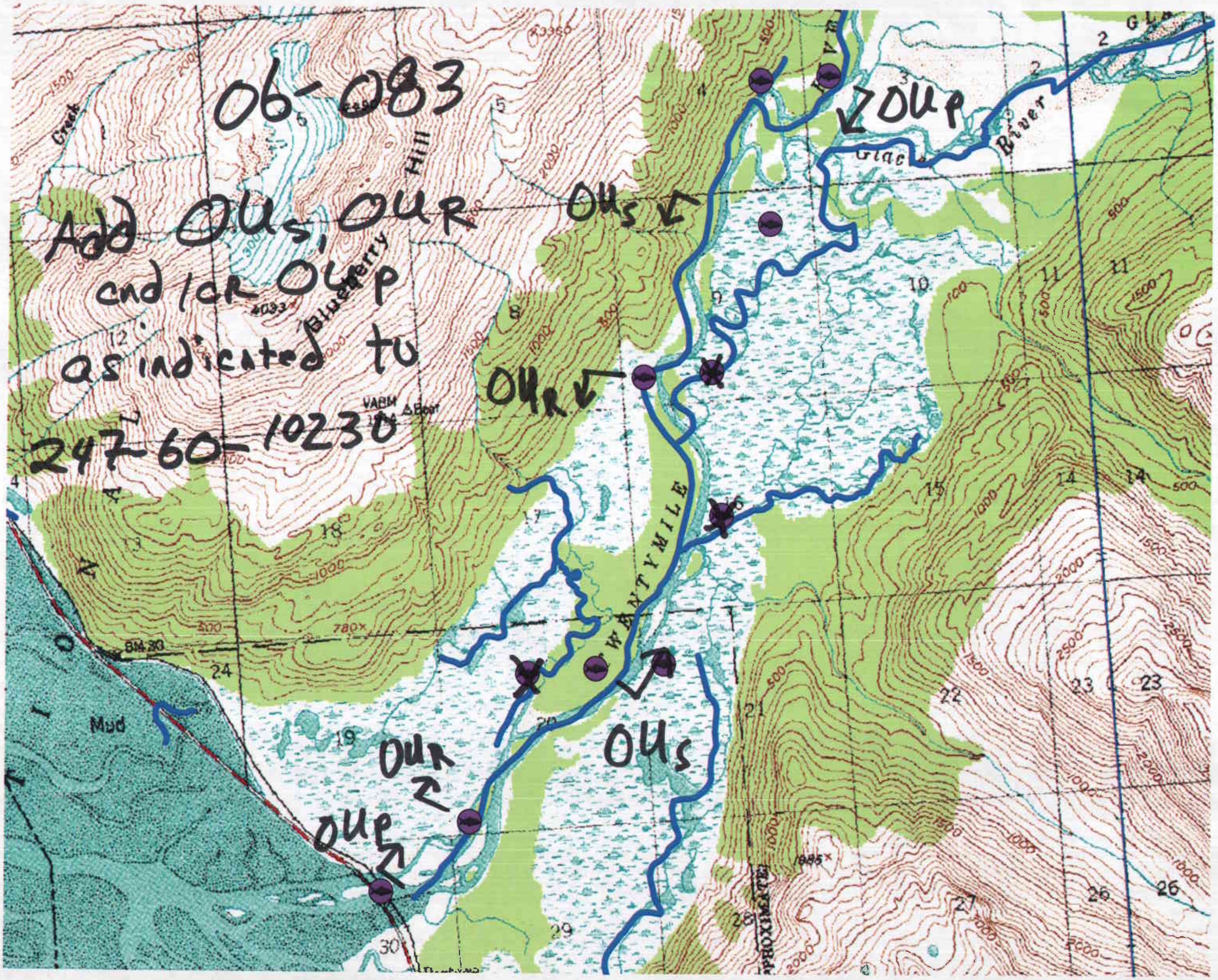
Tisler, T. and R.E. Spangler. 2002. Unuk river eulachon subsistence use and life history investigations, U.S. Forest Service, Ketchikan, Alaska.

Triton Environmental Consultants. 1990. Life history of eulachon, *Thaleichthys pacificus*, of the Kemano and Wahoo Rivers, B.C. results of 1989 investigations. Draft reprt prepared for Aluminum Company of Canada LTD. Triton Ref: 2039/ WP 3677, 51 p.

Wilford, D., D. Maloney, and S. Osborn. 1998. Eulachon: A significant fish for first nations communities. Forest Sciences. 32: 1-60.

Winter, J.D. 1983. Underwater biotelemetry. In L.A. Nielsen and D.L. Johnson (eds.), Fisheries Techniques. American Fisheries Society, Bethesda, Maryland, USA: 371-395.

Wright, S. 1999. Eulachon Petition: Endangered Species Act. Federal Register. 64 (228): 10 pp


06-083
Add OUs, OUR and/or OUP as indicated to
24760-10230
OUP
OUs
OUR
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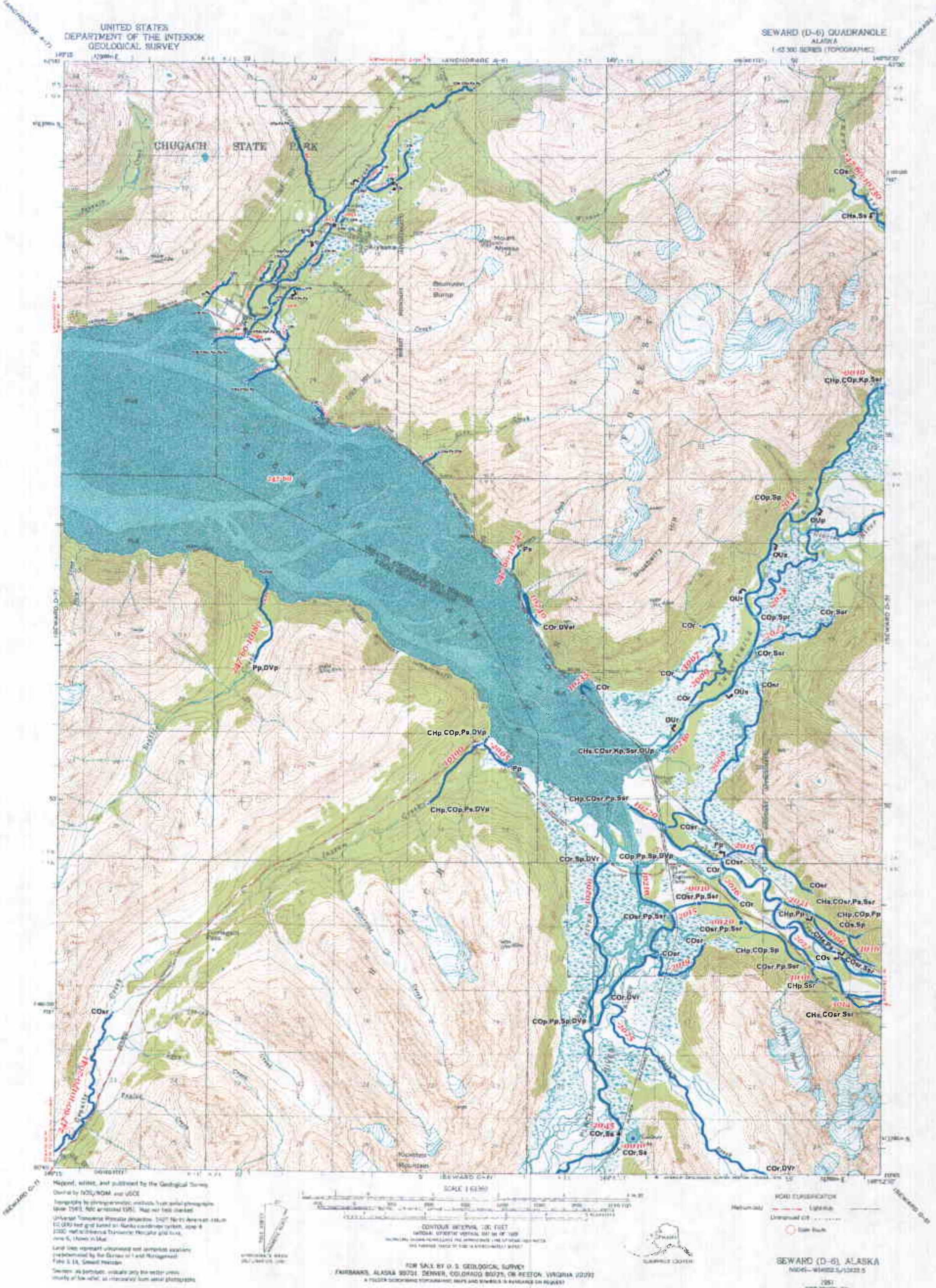
TWENTYMILE
Glacier River
Blueberry Hill
Creek
Mud
APPROXIMATE
VABM
BM 30



- Lower/Upper Point of Stream
- Midstream Species Begin/End Point
- Short Stream (Under 660 feet)
- Lake
- Barrier
- Anadromous Streams
- Anadromous Areas
- AWC Stat Area
- Regional Boundary

Waters Important to Anadromous Fish are listed pursuant to AS 41.14.870. Specified species distribution and life functions reflect known data. Actual distribution and use may extend beyond specified limits. Migration upstream and/or downstream is assumed for specified stream reaches.

SPECIES CODES

CO	coho salmon
CH	chum salmon
K	chinook salmon (king)
P	pink salmon
S	sockeye salmon
AC	Arctic char
CT	cutthroat trout
DV	Dolly varden
SH	steelhead
SF	inconnu (sheefish)
W	whitefishes
OU	eulachon
SM	smelts
ST	sturgeon
AL	Arctic lamprey
LP	lamprey (undifferentiated)
PC	Pacific lamprey
LV	river lamprey

LIFE STAGE CODES

p	Present
m	Migration
r	Rearing
s	Known Spawning

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Fish Distribution Database Atlas

Quad No. 053

Seward D- 6

Revision Date 10/23/2006