FRED Reports

Nelson Island/Chevak Area
Salmon Enhancement Feasibility Study

by
Frederic R. Kraus
and
Carl Kalb

Number 116

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

SPECIAL REPORT TO
BERING SEA
FISHERMEN'S ASSOCIATION

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ABSTRACT

During 1990 and 1991, several candidate sites for potential fisheries enhancement projects were surveyed in the vicinity of Nelson Island and Chevak in western Alaska. The sites were visited in different seasons. At each site, the water quality and quantity were evaluated and the water temperature monitored with recording thermographs. Resident fish populations were also sampled.

During these surveys, no site was found suitable for a large-scale salmon egg-incubation project. Most of the sites had a relatively small volume of water available, except the Ikalugtulik River, which has enough flow to incubate 4 million salmon eggs. The test streams experienced periods of approximately 6 months of 32.0°F (0.0°C) water temperature. Water quality at most locations was acceptable for fish culture. The Chevak City wells could be a source of egg-incubation water, if there is enough volume and excessive concentrations of iron and manganese ions can be reduced by a filtration system.

Other sites need to be investigated and other salmon enhancement strategies considered. Brood stock sources should be developed and enhancement strategies must be coordinated with harvest-management concerns.

KEY WORDS: Enhancement, western Alaska, egg incubation, water quality, site surveys.

INTRODUCTION

Residents from the Nelson Island and Chevak areas are interested in salmon enhancement as a means for developing a commercial salmon fishery where presently none exists. Through the efforts of individuals from western Alaska associated with its economic development (e.g., Mr. Harold Spark, Bethel; Mr. Joe Paniyak, Kokechik Fishermen's Association; Mr. David Bill, Qaluyaat Fishermen's Association; and Mr. Jude Hensler, Bering Sea Fishermen's Association [BSFA]), the Alaska Department of Fish and Game (ADF&G), Division of Fisheries Rehabilitation, Enhancement and Development (FRED), was requested to conduct a preliminary survey to determine the feasibility of salmon production at selected sites. A variety of options for salmon enhancement that could result in terminal fisheries were to be explored with a focus on low cost, instream-incubation operations.

The objectives of this project were:

1. To collect and analyze physical, chemical, and biological data from potential streamside-incubator sites in the Nelson Island/Chevak area. This will include water flow, temperature, dissolved oxygen, water chemistry, turbidity, and dissolved gases.
2. To assess potential imprinting and release sites as well as potential donor sources to provide for the initiation of a demonstration project next fiscal year.
3. To provide to BSFA information, data, and technical assistance for this project.

METHODS

Preliminary reconnaissance surveys of area streams around Chevak and Nelson Island were conducted by FRED Division staff in March 1990. In September 1990, several potential salmon enhancement sites were examined and, of these, four were selected for further evaluation. Physical, biological, and chemical data were collected during each visit to these locations. Baseline information obtained to assess the feasibility of enhancement projects included: Water quality and quantity, water temperature, dissolved-oxygen concentrations, turbidity, stream gradient, and presence of resident fish. Activities and schedules were completed with permission from the refuge manager of the Yukon Delta National Wildlife Refuge.

DESCRIPTION OF STUDY AREAS

Four potential salmon enhancement sites were selected for study in September 1990 (Figure 1). Two of these sites are located near Chevak and will be referred to as the "Volcano Cone" and "Pike Stream" sites. The other two sites are located on Nelson Island and will be referred to as "Ikalugtulik River" and "Urumangnak River." Site-selection criteria were based primarily on local resident knowledge of the area. It was believed that the study sites remained ice-free in the winter with continuous water flow. Water samples were also collected during March 1990 from the two Chevak city wells.

CHEVAK AREA

Volcano Cone Site

This site is located approximately 45 miles (72.5 km) southeast of the new Chevak townsite at coordinates N 61 25.98' W 164 13.75' (Marshall Quadrangle B-6). The site is accessible by snowmachine and ski plane during the winter, or by boat and float plane during the summer.

The main features of this site are two large lakes; the lower lake connects to the Manokinak River by a slow-moving stream that is approximately 6 miles (7.7 km) long. The Manokinak River drains into salt water at Hazen Bay. The upper lake lies within an extinct volcano cone with no visible surface outlet. It is about a 1,200-ft (365 m) distance from the lower

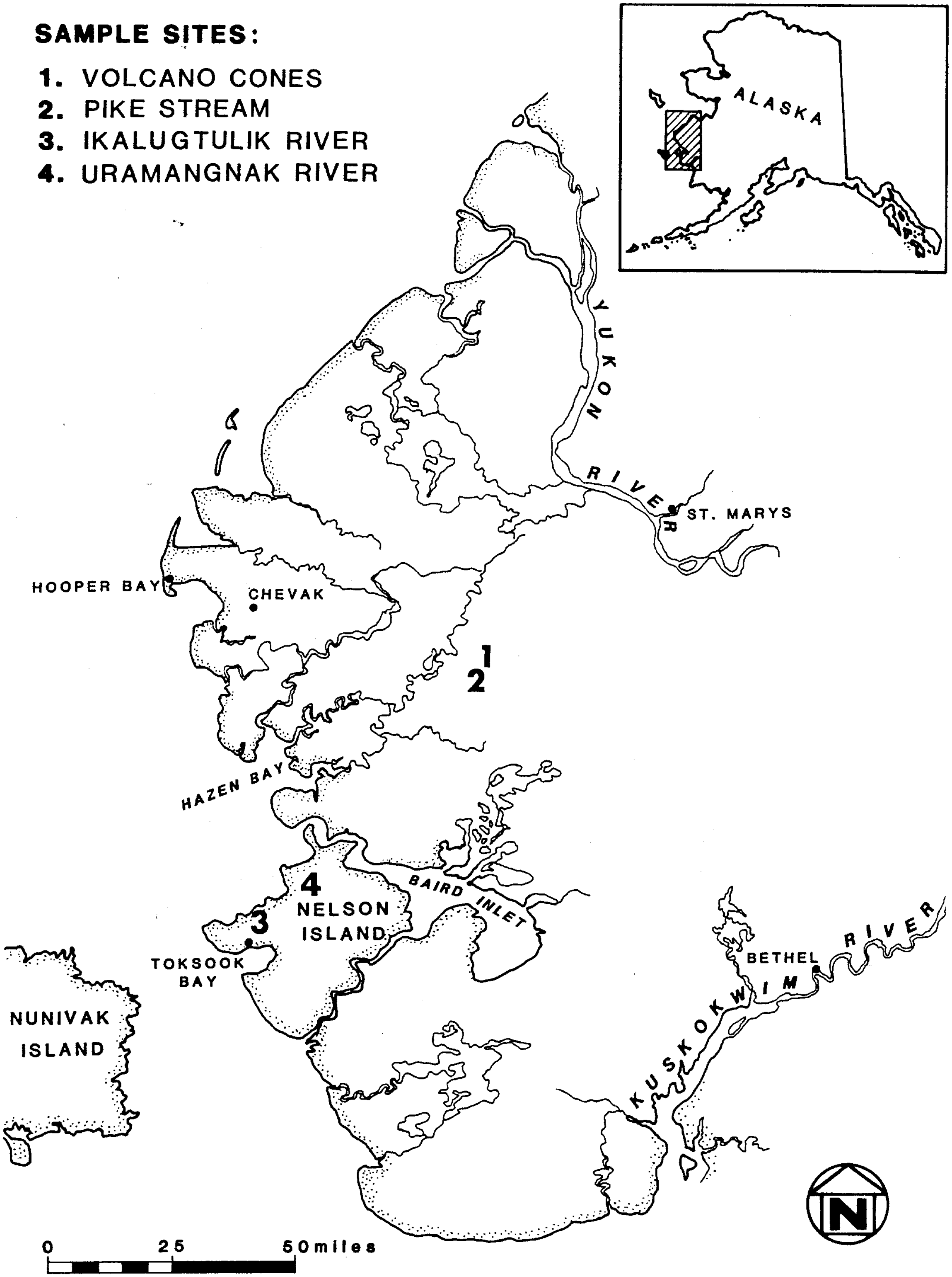

Figure 1. Study locations for potential fishery enhancement projects in the vicinity of Nelson Island and Chevak.

lake and 45 ft (14 m) higher in elevation. A number of small springs, appearing first as heavy seepage, flow from the base of a ridge approximately 150 ft (46 m) from the upper lake. The spring waters gradually collect into large rivulets, eventually forming a 1.5-ft-wide (46 cm) and 4- to 6-in-deep (10 to 15 cm) stream. The springs on the hillside are about 975 ft (305 m) from the lower lake, and there is an old, inactive beaver dam 140 ft (43 m) from the lower lake.

The spring-fed creek has a bottom of fine gravel and silt. It has abrupt grassy banks bordered by small willow, sedge, moss, grasses, and berry bushes. During the winter of 1990-1991, this site experienced heavy snowfall that resulted in a 3- to 5-ft (1-1.5 m) snow bridge over the entire length of the stream.

Pike Stream Site

This site is located approximately 3.5 miles (5.6 km) south of the Volcano Cone site and 50 miles (80.5 km) from the new Chevak townsite. Site coordinates are N 61 22.56' W 164 14.70' (Marshall Quadrangle B-6). Access is by snowmachine during the winter months.

This stream flows into a large lake that drains into the Manokinak River, 7.5 mi (12.0 km) away. A fast-flowing stream about 200-ft long (60 m) connects two slackwater sections of the creek. The stream is 15- to 20-ft wide (4.5 to 6 m) with a rocky bottom and abrupt, grassy banks. Heavy snowfalls blanket the entire area, including the stream, during the winter.

NELSON ISLAND

Ikalugtulik River

This site is located in mountainous terrain approximately 7.5 mi (12.0 km) north of Toksook Bay at coordinates N 60 39.92' W 165 06.42' (Baird Inlet Quadrangle C-7). This site is accessible by snowmachine during the winter months and by boat/foot during the summer months.

The Ikalugtulik River drains a large, broad valley into Hazen Bay. The survey site is located on a small creek that flows into the Ikalugtulik River about 3/4 mi (1.2 km) from its outlet to the sea. The creek drops rapidly off the slope of Killinupak Mountain, but is quite level for the last 1/4 mi (0.4 km). There is an active beaver dam about 115 ft (35 m) downstream from the study site.

Vegetation around the site includes small willows, grasses, sedge, and berry bushes. The stream substrate consists mainly of gravel. Heavy snowfalls during the winter of 1990-1991 resulted in a 5- to 6-ft (1.5-2 m) snowpack that covered the stream and surrounding area.

Urumangnak River

This site is located approximately 21 mi (34.0 km) northeast of Toksook Bay at coordinates N 60 40.26' W 164 38.10' (Nunivak Island Quadrangle C-1). Access is by snowmachine during the winter months and by boat and foot during the summer.

The Urumangnak River flows through a broad, gentle valley and is notable for many beaver dams in its upper section. The sample site is located between two beaver ponds and has a gravel bottom. The surrounding vegetation includes moss and grass. The Urumangnak River drains into the Kolavinarak River to the east. Heavy snowfalls in the winter of

1990-1991 resulted in a 5- to 6-ft (1.5-2 m) snowpack that covered the stream and surrounding area: There were open areas in this river where snow had collapsed into the water.

TEMPERATURE

A single, battery-operated Omnidata® Datapod, Model 212, timed temperature-recording device was placed adjacent to each test stream. The datapods were programmed to record average ambient air and water temperatures once every 24 hours. This information was stored on a computer microchip in the datapod.

Each datapod was mounted inside a weatherproof container (ammunition box) attached to a steel fencepost that had been driven into the streambank. Cables for air and water temperature thermistors were taped to the steelpost. The air-temperature probe was secured within a 6-in-long (150 mm) piece of 1/2-in-diameter (12.7 mm) PVC pipe to protect it from direct solar radiation. This pipe was fastened to the fencepost directly below the ammunition box. The water-temperature probe and excess cable were laid inside an experimental streamside headbox buried in the stream bottom. Cable was covered to prevent possible animal and/or ice damage. A desiccant capsule was placed inside the battery compartment of the datapod before the compartment was sealed with electrical tape. More desiccant was then placed in a cup inside the protective container before it was closed.

One Ryan® J-180 battery-operated chart-recording thermograph was placed inside the experimental headbox at the Volcano Cone site to accumulate water temperature data. All temperature-recording equipment was calibrated prior to deployment.

® Mention of commercial products and trade names does not constitute endorsement by the ADF&G, FRED Division.

Datapods were installed on 10 September 1990 in the Chevak area streams and on 11 September 1990 on Nelson Island. The Chevak sites were revisited on 2 March 1991, while Nelson Island sites were checked on 4 April 1991. These scheduled visits were made to perform routine maintenance and to retrieve and replace microchips. The Ryan thermograph was installed at the Volcano Cone site on 10 September 1990 and was not retrieved prior to writing this report.

Temperature data was converted from the microchip to a computer diskette format using a Omnidata Model 217D Reader.

TEMPERATURE UNITS

The approximate schedule of important salmon early life history-developmental stages was forecasted from the stream-temperature data and accumulated thermal units (ATU). One temperature unit is accumulated for each 1°C for a 24-hour duration. These cumulative daily water temperatures were used to calculate the timing of eyed egg, hatching (alevin), and fry-emergence stages.

WATER QUALITY

Chemistry

Water-quality information was collected during each visit to the Chevak and Nelson Island sites. Two 1.1-qt (1-liter) water samples were collected from the streams in plastic bottles and sent to the ADF&G Limnology Laboratory in Soldotna for general and nutrient analysis. A portion of each sample was also forwarded to Elemental Research Industries in Vancouver, British Columbia, Canada, for metals analysis. Detailed results of water-chemistry tests were received and compared to several salmonid water quality-requirement criteria.

Dissolved Oxygen

Dissolved-oxygen concentrations were tested during each visit to the Chevak and Nelson Island sites using the Winkler Titration Method. A 6.8-oz (200 ml) sample was collected and titrated using a Hach® digital titrator. Samples collected during July were analyzed on-site. Those samples obtained during March and April were fixed and transported to warmer facilities where analysis was completed.

Turbidity

Water turbidity was measured in the field during initial site selection using a Lamotte® Chemical Model 2008 Turbidity Meter. Water turbidity was also measured from the water samples that were analyzed at the ADF&G Limnology Laboratory in Soldotna; results are included in the general water-quality report.

WATER QUANTITY

Stream discharge (or amount of flow) was measured during the initial study-site selection using a Marsh-McBirney® flow meter. Actual flow was calculated using the U.S. Geological Survey Midsection Method. The Robins-Crawford method for estimating the approximate flow was used during subsequent visits. The stream discharge was calculated according to the formula:

$$Q = \text{sum}(a \times v)$$

where: Q = discharge (volume of water per time unit);

a = average cross-sectional area (average depth x width) within a width increment; and

v = average velocity within a width increment.

After the discharge was calculated, it was possible to calculate the egg-incubation capacities for that site according to a formula described by McLean and Raymond (1983). The following formula was derived for single-pass systems and assumes a required flow of 100 gallons (378 liters) per million eggs.

$$C = Q / 100$$

where: C = capacity in millions of eggs; and

Q = total stream flow for that site in gallons.

MISCELLANEOUS

Stream Gradient

Stream gradient was measured using a hand level and rod.

Juvenile Fish Sampling

Minnow traps were set in study streams in July while equipment installation and testing was performed. Each trap was fished for approximately 2 hours. The catch of each species was enumerated and recorded.

Headboxes

Experimental, small-scale, streamside-incubator headboxes (incubator-intake box) were placed in each test stream. The boxes were buried in the stream substrate. Each box measured 2 x 2 ft (0.6 x 0.6 m).

RESULTS AND DISCUSSION

It has been proposed that streamside-incubation boxes may be a useful method to enhance salmon populations in western Alaska streams. To successfully incubate salmon eggs using this technique, the site must meet several requirements:

1. The water supply must be at a suitable temperature and quality.
2. The water supply must have adequate flow and head to deliver water to the incubator.
3. There should be access to the site for periodic inspections.
4. There should be ice-free conditions.
5. There should be no flood or dry periods.

Each test stream that was visited exhibited similar temperature patterns starting in mid- to late-October, with the exception of the Volcano Cone site (Tables 1 and 2). Stream temperatures dropped and leveled off at 32.0°F (0.0°C). These temperatures remained constant through early April in Nelson Island streams, although flowing water was present. McLean and Raymond (1983) reported that streams in the lower Yukon River region also exhibited these characteristics from October through April and were not suitable for salmon culture unless the supply was heated.

It is probably safe to assume that these western Alaska streams will follow a similar pattern for 6-7 months. The Pike Stream site was actually frozen, eliminating it as a potential

Table 1. Maximum, minimum, and average stream and air temperatures (°C) and ranges for test streams in the vicinity of Chevak during 10-day intervals, 10 September 1990 through 4 April 1991.

		Volcano Cones			Pike Stream		
Date		Mean	Max	Min	Mean	Max	Min
11-20 Sep.	Water	5.0	7.5	3.0	5.0	9.0	3.0
	Air	5.9	19.5	-5.5	5.7	17.5	-4.5
21-30 Sep.	Water	3.8	7.0	2.0	2.6	7.0	0.5
	Air	2.7	18.5	-5.5	1.9	17.0	-8.0
1-10 Oct.	Water	4.0	6.0	2.5	2.9	5.0	1.0
	Air	3.6	10.5	-6.0	3.5	12.0	-6.0
11-20 Oct.	Water	2.3	5.5	1.0	0.5	4.0	-0.5
	Air	-0.6	7.5	-12.5	-1.1	6.0	-12.0
21-31 Oct.	Water	1.5	3.5	0.5	0.0	1.0	-0.5
	Air	-4.2	2.5	-15.5	-4.4	2.5	-15.0
1-10 Nov.	Water	0.9	2.5	0.0	0.0	0.5	0.0
	Air	-8.8	4.0	-27.0	-9.1	4.0	-25.5
11-20 Nov.	Water	1.2	2.0	0.0	0.0	0.0	0.0
	Air	-3.1	3.0	-22.5	-3.1	3.0	-22.5
21-30 Nov.	Water	0.7	2.0	0.0	-0.2	0.0	-0.5
	Air	-13.0	2.0	-36.0	-14.1	2.0	-37.0
1-10 Dec.	Water	1.3	2.5	0.0	-0.2	0.0	-0.5
	Air	-24.3	-15.0	-38.0	-24.9	-15.0	-37.5
11-20 Dec.	Water	1.4	2.5	1.0	-0.1	0.0	-0.5
	Air	-14.4	1.0	-34.5	-14.4	1.0	-33.0
21-31 Dec.	Water	1.1	2.0	0.0	0.0	0.5	0.0
	Air	-6.3	2.0	-21.5	-6.4	2.0	-20.5
1-10 Jan.	Water	1.5	2.0	1.0	0.0	0.0	0.0
	Air	-12.7	-3.5	-27.0	-12.7	-3.5	-27.0
11-20 Jan.	Water	1.3	2.5	1.0	-0.1	0.0	-0.5
	Air	-23.6	0.0	-41.0	-23.4	0.0	-38.5
21-31 Jan.	Water	1.7	2.5	1.5	0.0	0.0	-0.5
	Air	-7.1	1.5	-24.0	-7.3	1.5	-27.0
1-10 Feb.	Water	1.5	2.5	1.0	-0.1	0.0	-0.5
	Air	-23.8	-4.5	-33.5	-24.3	-5.0	-37.5
11-20 Feb.	Water	1.8	2.5	1.5	-0.1	0.0	-0.5
	Air	-12.9	-2.0	-27.5	-13.2	-2.0	-28.5
21-28 Feb.	Water	1.7	2.5	1.5	-0.1	0.5	-0.5
	Air	-11.2	6.0	-31.5	-11.1	4.5	-30.5
1-10 Mar.	Water	1.5	2.0	1.5	-0.5	0.0	-0.5
	Air	-7.8	3.5	-16.0	-8.8	4.0	-14.5

Table 2. Maximum, minimum, and average stream and air temperatures (°C) and ranges for test streams in the vicinity of Nelson Island during 10-day intervals, 10 September 1990 through 4 April 1991.

		Ikalugtulik River			Urumangnak River		
Date		Mean	Max	Min	Mean	Max	Min
11-20 Sep.	Water	4.3	7.5	2.0	4.2	9.5	1.5
	Air	6.0	18.0	-4.0	5.5	17.0	-4.0
21-30 Sep.	Water	2.8	6.0	1.0	2.7	7.5	-0.5
	Air	2.9	13.0	-7.5	2.2	16.5	-9.0
1-10 Oct.	Water	3.0	6.0	1.5	3.1	6.0	1.0
	Air	4.2	14.5	-4.0	3.7	10.5	-4.0
11-20 Oct.	Water	1.5	4.5	-0.5	1.0	5.0	-0.5
	Air	1.0	12.0	-11.5	-0.1	8.0	-11.5
21-31 Oct.	Water	0.3	3.0	-0.5	0.1	3.0	-0.5
	Air	-2.5	6.0	-14.0	-3.6	4.0	-12.0
1-10 Nov.	Water	0.0	1.0	-0.5	-0.3	1.0	-0.5
	Air	-5.9	5.5	-23.5	-8.0	4.5	-24.0
11-20 Nov.	Water	0.0	0.5	0.0	0.0	1.0	-0.5
	Air	-1.5	4.0	-16.0	-2.6	2.5	-19.5
21-30 Nov.	Water	-0.2	0.5	-0.5	-0.4	0.5	-0.5
	Air	-9.2	2.5	-33.0	-11.8	2.0	-35.5
1-10 Dec.	Water	-0.1	0.5	-0.5	-0.2	0.0	-0.5
	Air	-17.9	-7.0	-31.5	-21.6	-14.5	-32.5
11-20 Dec.	Water	0.0	0.5	0.0	-0.2	0.5	-0.5
	Air	-10.7	1.0	-28.0	-13.1	1.5	-29.0
21-31 Dec.	Water	0.0	0.5	-0.5	-0.1	-0.5	-0.5
	Air	-4.3	2.5	-18.0	-5.7	2.0	-21.0
1-10 Jan.	Water	0.2	0.5	0.0	-0.1	0.5	-0.5
	Air	-9.0	3.0	-24.0	-13.7	-1.0	-25.0
11-20 Jan.	Water	0.4	0.0	0.0	-0.1	0.5	-0.5
	Air	-23.9	-0.5	-34.5	-23.1	0.0	-39.5
21-31 Jan.	Water	0.0	0.5	0.0	-0.1	0.5	-0.5
	Air	-4.6	2.5	-23.5	-6.8	1.5	-25.5
1-10 Feb.	Water	0.0	0.5	0.0	-0.1	0.5	-0.5
	Air	-23.1	-11.5	-34.0	-24.5	-4.5	-36.0
11-20 Feb.	Water	0.0	0.5	0.0	-0.2	0.5	-0.5
	Air	-9.7	3.0	-26.0	-13.0	-1.5	-27.5
21-28 Feb.	Water	-0.1	0.5	-0.5	-0.3	0.5	-0.5
	Air	-13.9	5.5	-32.0	-11.8	11.5	-30.0
1-10 Mar.	Water	0.0	0.5	0.0	-0.3	1.0	-1.0
	Air	-3.8	17.0	-17.5	-7.0	8.5	-24.0
11-20 Mar.	Water	0.1	0.5	0.0	-0.3	0.5	-1.0

enhancement site. Water temperature at the Volcano Cone site ranged between 32.0 and 45.5°F (0.0 and 7.5°C) and averaged 35.4°F (1.9°C) throughout the study period. Fluctuations of 1.8-3.6°F (2-3°C) during a 24-hour period were not uncommon in this small, spring-fed stream during September and October. There were no extended periods of 32.0°F (0.0°C) water temperatures. Average winter temperatures were 33.8-35.6°F (1-2°C).

It was not possible to obtain an accurate picture of egg development using temperature units because stream temperatures were 32.0°F (0.0°C) for extended periods in Nelson Island streams. At 32.0°F (0.0°C), some development occurs in the egg but at a much reduced rate. Temperature data suggests that fall chum salmon eggs incubated at the Volcano Cone site would not reach the eyed-egg stage (300 ATUs) until at least mid-February using straight, cumulative temperature units. Peter Rob[1] (personal communication) reports that chum salmon eggs must reach 300-400 temperature units before October if hatching is expected to occur by spring. This may be possible, however, if a summer chum salmon donor stock was used.

Water quality was suitable for the culture of salmon at all locations, though there were slightly elevated levels of iron ions at the Pike Stream site (Tables 3 and 4).

The Chevak city wells have excessive levels of iron and manganese ions; otherwise, the water chemistry is acceptable for salmon culture. It may be possible to use local wells as a source of water for incubation in Chevak; however, it may be costly to operate pumps continuously if a flow-through design were incorporated. Iron and manganese levels would also have to be reduced with special filters. Water may have to be recirculated to make a well project cost efficient.

Streams at all western Alaska sites had flowing water, except the Pike Stream site. It was not possible to calculate flow for the Urumangnak River during the early spring visit because

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[1] Sikusuilaq Springs Hatchery, P.O. Box 1030, Kotzebue, Alaska 99752-1030.

Table 3. Water-quality parameters and acceptable values for salmon culture.[a/]

Parameter	Source of Information				
	A	B	C	D	E
Alkalinity	20		20-200	120-400	15
Aluminum	0.01	0.01			0.1
Ammonia	0.02	0.0125	0.012	0.0125	.05 N
Cadmium (alk < 100)	0.0005	0.0005		0.0004	0.0003
(alk > 100)	0.005	0.005		0.003	
Calcium	52		52	4-160	
Chromium	0.03	0.03			0.04
Copper (alk < 100)	0.006	0.006	0.006		0.002
(alk > 100)	0.03	0.03	0.03		
Dissolved Oxygen	5	7	5	5	11.2
Iron	0.1	0.1	1	0.5	0.3
Lead	0.02	0.02			0.004
Manganese	0.01	0.01		0.01	0.1
Mercury	0.2			0.002	0.0002
Nitrite	1	0.1	0.55	0.15	.015 N
Nickel	0.01	0.01			0.045
pH	6.7-8.6	6.5-8.0	6.7-9.0	6.5-8.0	7.2-8.5
Potassium	5	5			
Selenium	0.01	0.01			0.05
Silver	0.003	0.003			0.0001
Turbidity					
Zinc	0.005	0.005	0.04	0.03	0.015

A: Daily, J.P. and P. Economon, 1983.
B: Fish Culture Manual, ADF&G, FRED Division, 1983.
C: Wedemeyer and Wood, 1974.
D: Piper, G.P. et. al., 1982.
E: Sigma Environmental Consultants and DFO Canada, 1983.

[a/] Aquaculture Class, Water Quality Laboratory. 1988. Mimeo. Malaspina College. Nanaimo, B.C., Canada.

Table 4. Water-quality parameters and test results for western Alaska test streams, April and September 1990.

Parameter	Chevak				Nelson Island	
	Volcano Cone	Pike Stream	Chevak Well 1	Chevak Well 2	Ikalugtulik River	Urumangnak River
Alkalinity	59	36	87	86	32	26
Aluminum	0.027	0.11	0.0014	0.0014	0.02	0.019
Ammonia	0.0036	0.0058			0.0041	0.0058
Cadmium (alk < 100)	0.00025	0.00025	0.00022	0.00022	0.00025	0.00025
(alk > 100)						
Calcium	13	6.4	22	22	9.8	7.5
Chromium	0.00057	0.00057	0.00064	0.00064	0.00057	0.00057
Copper (alk < 100)	0.00041	0.0023	0.00024	0.00024	0.0012	0.00098
(alk > 100)						
Dissolved Oxygen	11.8	14.8			12.2	18.3
Iron	0.26	0.81	3.2	3.1	0.086	0.041
Lead	0.00008	0.00019	0.00043	0.00037	0.00008	0.00008
Manganese	0.014	0.017	0.51	0.5	0.0083	0.008
Mercury	0.00019	0.00019	0.00019	0.00034	0.00017	0.00017
Nitrite	0.004	0.002			0.0007	0.0001
Nickel	0.0022	0.00083	0.00043	0.00043	0.0021	0.0011
pH	7.2	7	7	7	7.2	7.1
Potassium	6.2	3	2	1.9	1	1.4
Selenium	0.0043	0.0011	0.0024	0.00052	0.0052	0.0053
Silver	0.00004	0.00004	0.00009	0.00007	0.0001	0.00004
Turbidity	1.2	2.2	9	7	5	0.3
Zinc	0.0034	0.0056	0.0013	0.00035	0.0082	0.0017

of snow depth and stream width, but minimum flows were used to estimate site egg-incubation capacities (Table 5).

One of the Chevak area streams was frozen and the other may have enough water to incubate 750,000 eggs. Nelson Island streams may have more potential for egg incubation, but they experience 6 months of 32.0°F (0.0°C) water temperature. The Ikalugtulik River stream has enough flow to incubate 4 million salmon eggs. Minimal flows were not calculated for the Urumangnak River, thus no egg capacity estimates could be made.

Streamside-incubation sites require at least 3 ft (1 m) of head from headbox to incubator to deliver enough flow through the eggs (Ken Roberson[2], personal communication, 1990). The terrain in western Alaska is generally flat with some rolling hills. All sites had approximately a 5% grade, indicating that it would take long runs (approximately 60 ft [18 m]) of pipe to get water from a headbox intake to an incubator to achieve this amount of head. Nelson Island sites were surrounded by beaver dams that altered actual stream gradient. It was not possible to check the experimental headboxes that had been placed in each stream because of snow cover over the streams.

Western Alaska has severe weather during the winter months. It is not uncommon for the area to experience constant high wind and low temperature conditions. Blowing snow results in poor visibility and dangerous traveling conditions when using a snowmachine. Tundra travel is also difficult during warmer overcast days when terrain seems to blend with the sky, making it difficult to follow existing trails. It would be difficult to access these sites during the breakup period at the time alevins emerge because trail conditions become impassable to snowmachines. The only site that was reasonably accessible was the Ikalugtulik site near Toksook Bay.

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[2] ADF&G, FRED Division, P.O. Box 47, Glennallen, Alaska 99588-0047.

Table 5. Stream flows (gal/min) and incubation capacity for Chevak and Nelson Island test locations.

	Chevak			
	Volcano Cone		Pike Stream	
Date	Flow	Capacity	Flow	Capacity
20 March 1990			7,950	
11 September 1990	160		10,700	
02 March 1991	75	750,000	0	0

	Nelson Island			
	Ikalugtulik River		Urumangnak River	
Date	Flow	Capacity	Flow	Capacity
16 March 1990	1,140			
12 September 1990	1,300		2,900	29,000,000
04 April 1991	400	4,000,000		

All of these study streams were ice-free in the winter, except for the Pike Stream site, which was frozen. All streams were covered with 3 to 5 ft (1-1.5 m) of snow. Some streams had large, exposed sections where snow had collapsed into the water. All sites also appeared to have stable flow. There is water in these systems year round, except the Pike Stream site, which froze. Some minor flooding may occur during the spring as a result of melting snow runoff.

Juvenile fish were caught at only one site, the Ikalugtulik River site. Fish caught included 67 Arctic char, *Salvelinus alpinis*, between 1.95- and 5.9-in long (50 and 150 mm) and 3 coho salmon, *Oncorhynchus kisutch*, 100-mm long. All juvenile fish were fat and appeared healthy. Pink and chum salmon, *O. gorbuscha and O. keta*, are also reported from the mainstem Ikalugtulik River as well as the Urumangnak River.

Production Alternatives

The following are strategies that may be available to increase fish production:

Strategy	Method	Advantages	Disadvantages
Local hatchery	- Facility developed from local water source	- May control developmental rate of fry - Access to brood stock	- Limited by amount of water - Remote - Expensive
Incubation boxes	- Install boxes in free-flowing waters	- Simple operation - Inexpensive	- Small-scale - Remote from brood stock
Central Incubation Facility (CIF)	- One large facility with many stocks for outplanting	- Support many locations - Share costs - Design new fisheries	- May require new fisheries - Remote from brood stocks - Transport for fry releases
Net-pen rearing	- Rear fry in estuarine net pens	- Increased survival rate after release - Design new fisheries - Accessibility - Good combination with CIF	- Transport fry to pens - Donor stock selection

Another consideration that must be discussed entails developing a new water source, such as pumped well water. This may provide an excellent source of water for a fish hatchery, but could be very expensive.

The next step in the planning process must also include identification of one or more reliable brood stocks. In addition, a crucial part of the planning process must include a harvest and marketing plan that is developed in association with an enhancement plan. A special harvest area must be identified through a regional planning process that will not interfere with wild stock management strategies. Planning assumptions that may be useful are included in the appendix.

RECOMMENDATIONS

1. The Volcano Cone area may be suitable for small-scale salmon egg-incubation projects.
2. Nelson Island test streams experience long periods (6 months) of 32.0°F (0.0°C) water temperature which would slow salmon egg development.
3. The idea of using the Chevak city wells as an incubation water supply should be investigated. It may be possible to use the well water if excessive iron and manganese concentrations could be reduced by a filtration system cost-efficiently.
4. In the Chevak area, other streams or rivers should be investigated, particularly those closer to the village, including the Ninglikfak River. The lower reaches of this river are subject to tidal influence; however, there may be potential streamside-incubator sites upstream if this system does not exhibit the same temperature patterns found in other area streams.
5. The Ikalugtulik River stream holds the most potential of all the streams visited; however, the problem of a 6-month, 32.0°F (0.0°C) regime needs to be addressed.
6. None of the sites visited could sustain production hatchery facilities.

Other items not included in this report that must also be considered prior to commencement of any salmon enhancement program include:

1. Identification of species, project goal, and affected user groups.
2. Fisheries management implications and concerns.
3. A method of evaluating project results.
4. Land ownership and potential conflicts.
5. Site-specific management problems; e.g., beavers, muskox, snow, access, etc.
6. Brood stock acquisition and logistics. (Wild brood stock appears to be limited in the Kuskokwim River Delta region).

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REFERENCES

McLean, R. and J. Raymond. 1983. Lower Yukon River hatchery site investigation. Volume 1. Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development Division. Fairbanks, AK.

APPENDIX

Tentative chum salmon planning assumptions for an egg incubation project designed for 10,000,000 eggs (approximate data).

Assumptions

Age:	2	3	4	5
% return:	0.0	0.1	0.6	0.3

Survival rate; green egg to fry release: 0.5

Survival rate; release to return: 0.01

Fecundity: 2500 eggs per female

Number of fish available: 10,000

Number of ripe females: 4000

First egg take: 1993

Calculations:

Number of eggs	Number of fry	Number of returning adults 1997	1998	1999	total
10,000,000	5,000,000	5,000	30,000	15,000	50,000

Tentative chum salmon planning assumptions for a typical fish hatchery with 10,000,000 design egg capacity (approximate data).

Assumptions

Age:	2	3	4	5
% return:	0.0	0.1	0.6	0.3

Survival rate; green egg to fry release: 0.75

Survival rate; release to return: 0.01

Fecundity: 2500 eggs per female

Number of fish available: 10,000

Number of ripe females: 4000

First egg take: 1993

Calculations:

Number of eggs	Number of fry	Number of returning adults 1997	1998	1999	total
10,000,000	7,500,000	7,500	45,000	22,500	75,000

If fry are fed in net pens in the estuary for 20 - 40 days the survival rate will probably double.
Total number of returning adults would equal 150,000
