FRED Reports

Fisheries Habitat Evaluation and Limnological Investigations of Neck Lake, Whale Pass, Prince of Wales Island, Alaska

by
T. P. Zadina and M. H. Haddix

Number 128

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

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

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Abstract

Neck Lake has been under scrutiny as a viable system for development of a significant run of salmon since the late 1950's. In 1991, the U.S. Forest Service, Thorne Bay Ranger District, contracted the Alaska Department of Fish and Game, FRED Division to assess the potential of the Neck Lake system. This evaluation assessed the potential of the system, above the barrier, to rear sockeye salmon (*Oncorhynchus nerka*) and coho salmon (*Oncorhynchus kisutch*). This evaluation included past studies of Neck Lake. Limnological studies in 1987, 1988, and 1991 indicate Neck Lake nutrient supplies were low for Southeast Alaska oligotrophic lakes. Neck Lake is also distinctive because it is one of the only stained oligotrophic lakes in Southeast Alaska that is slightly alkaline. Zooplankton biomass in Neck Lake is also very low. Based on these zooplankton densities and the physical characteristics of Neck Lake, it can potentially produce 96,600-224,216 threshold (2.2 g) size sockeye smolt. Neck Lake has a littoral area encompassing 33.9% of the total lake area. This littoral area could potentially produce a maximum of 31,663 coho smolt.

Introduction

The U.S. Forest Service, Thorne Bay Ranger District contracted the Alaska Department of Fish and Game, F.R.E.D. Division to assess the potential of the lentic habitat, above the barrier, to rear sockeye salmon (*Oncorhynchus nerka*) and coho salmon (*Oncorhynchus kisutch*) and develop a bioenhancement program from these findings through a Sikes Act Contract. This is the final report to the U.S. Forest Service, fulfilling contract obligations for Sykes Act Contract number 43-0109-1-0785, Item #03. This report includes information obtained from the U.S. Forest Service (Sikes Act funded) studies of 1991 and ADF&G, FRED Division (US / Canada Treaty Mitigation funds) studies of 1987-1988.

Study Site Description -- Neck Lake (133°10'W, 56°06'N) located ~130 km northwest of Ketchikan on the East Coast of Prince of Wales Island in Whale Pass lies within the Tongass National Forest at an elevation of 26.5 m (Figure 1). Neck Lake has a surface area of
377.6 ha (933 acres), a mean lake depth of 14.7 m, a maximum depth of 58 m, and a total volume of $55.58 \bullet 10^6$ m^3 (Table 1, Figure 2).

Methods and Materials

Lake Design

A bathymetric map was created from depth transects taken with a Simrad EY-M scientific echosounder and fathometer. Transects were recorded on lake outlines drawn from aerial photos and a hard copy of each transect was made for later analysis.

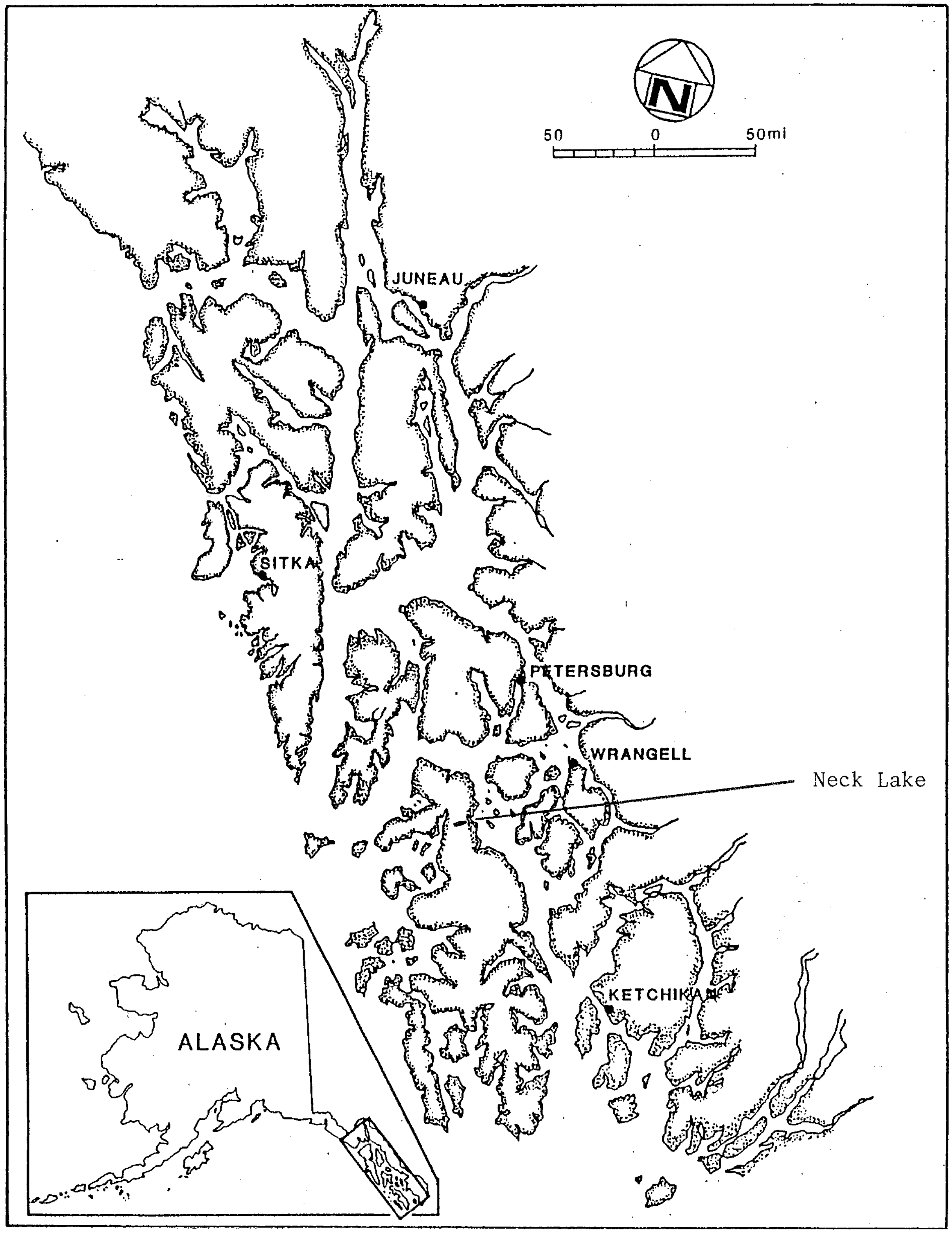

Figure 1. The geographic location of Neck Lake within the State of Alaska, and relative to cities within Southeast Alaska.

Table 1. Summary of the physical characteristics and morphometry of Neck Lake.

Area by Depth Zone

Depth zone (m)	**Area (m^2)**	**Percent of surface area**
0	3,775,686	100.0
5	2,493,714	66.1
10	1,950,296	51.7
20	1,349,866	35.8
30	451,165	12.0
40	158,853	4.2
50	52,606	1.4

Volume by Depth Zone

Depth Zone (m)	**Volume (m^3)**	**Percent of total volume**
0 - 5	15,563,109	28.0
5 - 10	11,082,233	19.9
10 - 20	16,409,009	29.5
20 - 30	8,604,745	15.5
30 - 40	2,925,762	5.3
40 - 50	1,009,579	1.8

Lake Area:	377.6 ha (933 acres)
Maximum depth:	58.0 m
Lake volume:	$55.59 \bullet 10^6 m^3$
Shoreline length:	23.2 km
Lake elevation:	26.5 m
Mean depth:	14.7 m
Volume development	0.76
Shoreline development	3.36

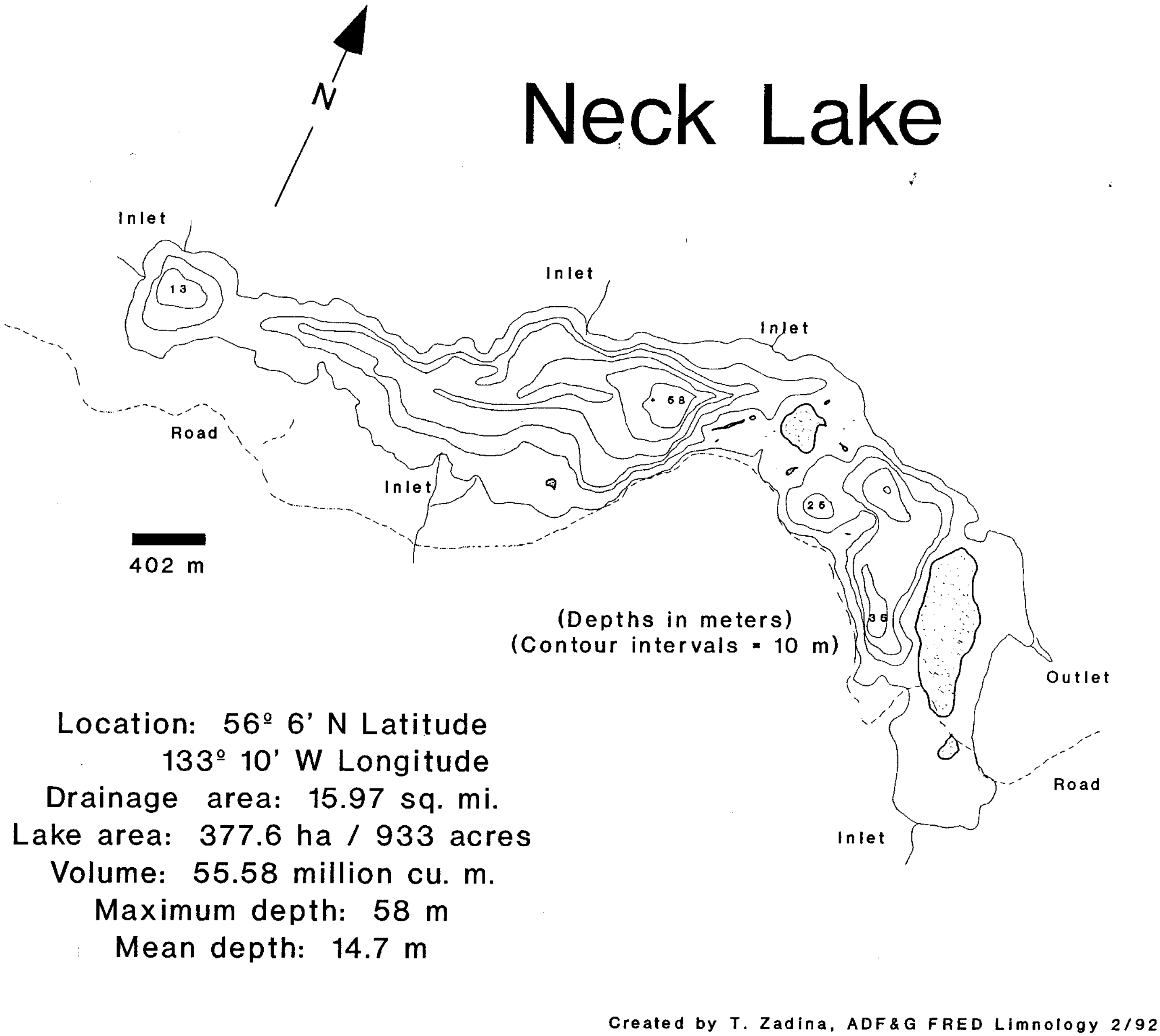

Figure 2. Morphometric map of Neck Lake, Whale Pass, Prince of Wales Island, Southeast Alaska.

Limnological Sampling

Sampling to define lake productivity and juvenile sockeye carrying capacity was conducted in 1987, 1988, and 1991. The 1987 and 1988 limnological parameters were sampled at one station located in the outlet basin of the lake (Station A). The 1991 limnological parameters were sampled at one station located in the deepest basin (58 m) of the lake (Station B). In addition to obtaining physical data (e.g., light penetration, temperature profiles, and dissolved oxygen levels), water quality and biological samples were collected. Chemical and biological samples were analyzed by the ADF&G, FRED Limnology Laboratory in Soldotna, Alaska.

Physical Parameters -- Light penetration (footcandles) was recorded at 0.5 m intervals from the surface to a depth equivalent to one percent of the subsurface light reading using a Protomatic submarine photometer. The euphotic zone depth (EZD), the depth to which 1% of the subsurface light [photosynthetically available radiation (400-700 nm)] penetrates (Schindler 1971), was calculated as the y-intercept derived by regressing depth against the logarithm (ln) of the percent subsurface light. Euphotic volume (EV) is the product of the euphotic zone depth (EZD) and the lake surface area, and represents the volume of water capable of photosynthesis. Secchi disk (SD) transparency was determined by recording the depths at which the disk becomes invisible upon descent and visible upon ascent. Temperatures and dissolved oxygen levels were recorded at 1 m intervals from the lake surface to the bottom using a YSI model 58 meter.

Water Quality -- Water quality samples were collected from the epilimnion at the 1 m depth and the mid-hypolimnion using a Van Dorn sampler. Eight liters of water were collected from each depth, stored in pre-cleaned polyethylene carboys, transported to Ketchikan, and then filtered or preserved for laboratory analysis. Separate subsamples from each carboy were: 1) refrigerated for general tests and metals; 2) frozen for nitrogen and phosphorus analysis; and 3) filtered through a Whatman 4.7 cm GFF glass fiber filter and frozen for analysis of dissolved nutrients (Koenings, et al. 1987).

Phytoplankton -- Samples for the analysis of the algal pigment chlorophyll a (chl a) were prepared by filtering 1-2 ℓ of lake water through a Whatman 4.7 cm GFF glass fiber filter to which 1-2 mℓ of 1N magnesium carbonate were added prior to completion. Filters were stored frozen in individual plexiglas holders until analyzed.

Zooplankton -- Replicate bottom to surface vertical zooplankton tows were taken using a 0.5 m diameter, 153 μm mesh, conical net. The net was pulled at a constant speed (~0.5 m•sec^{-1}), rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings, et al. 1987).

Laboratory Analysis

General Water Quality -- Conductivity (temperature compensated to 25°C) was measured using a YSI model 32 conductance meter, and the pH was measured with an Orion 399A ionanalyzer following standard calibrations. Alkalinity was determined by sulfuric acid (0.02N) titration to a pH of 4.5 (APHA 1985). Turbidity, expressed in nephelometric turbidity units (NTU) was determined using a DRT-100 turbidimeter. Water color was determined on a filtered sample by measuring the spectrophotometric absorbance at 400 nm and converting to equivalent platinum cobalt (Pt) units (Koenings, et al. 1987).

Metals -- Calcium and magnesium were determined from separate EDTA (0.01N) titrations after Golterman (1970). Total iron was determined by reduction of ferric iron with hydroxylamine during hydrochloric acid digestion after Strickland and Parsons (1972).

Nutrients -- Filterable reactive phosphorus (orthophosphate) was determined using the molybdenum-blue method as modified by Eisenreich, et al. (1975). Total and total filterable phosphorus utilized the same procedure following acid-persulfate digestion. Total ammonia (NH_3 + NH^+_4) was determined using the phenolhypochlorite procedure; and nitrate (NO_{-3}) + nitrite (NO^-_2) were determined as nitrite following cadmium reduction and diazotization with sulfanilamide after Stainton, et al (1977). Total Kjeldahl nitrogen (TKN) was determined as ammonia after sulfuric acid block digestion (Crowther, et al. 1980). Total nitrogen was calculated as the sum of TKN and nitrate + nitrite. Reactive silicon was determined using the ascorbic acid reduction to molybdenum-blue methodology after Stainton, et al (1977).

Phytoplankton -- Phytoplankton biomass (primary production) was estimated from the algal pigment chlorophyll a (chl a). Chl a was extracted from glass fiber filters after homogenizing the filters in 90% acetone (Koenings, et al. 1987). Chl a concentrations (corrected for inactive phaeophytin) were then determined using the direct fluorometric procedure of Strickland and Parsons (1972) with dilute acid (0.02N HCl) addition after Reimann (1978).

Zooplankton -- *Daphnia* sp. were identified according to Brooks (1957) and copepods were identified after Wilson (1959) and Yeatman (1959). Zooplankton were enumerated from three separate 1 mℓ subsamples taken with a Hensen-Stemple pipet and placed in a 1 mℓ Sedgewick-Rafter counting chamber. Zooplankton body sizes from thirty organisms of each species were measured to the nearest 0.01 mm along a transect in each of the 1 mℓ subsamples using a calibrated ocular micrometer. Zooplankton biomass was estimated using species-specific dry weight vs. zooplankter length regression equations (Koenings, et al. 1987).

Fisheries Assessment

Resident fish -- Fish samples were collected on 25-26 September 1985 by the Southern Southeast Regional Aquaculture Association (SSRAA) for pathological analysis. Fish samples were collected on 2-3 September 1987 by ADF&G, FRED Division for pathological analysis. Three 38 m by 1.8 m variable mesh monofilament gill nets with square mesh sizes of 1.3 cm, 1.9 cm, 2.5 cm, 3.2 cm, and 3.8 cm were used. Nets were fished at the three main inlet streams for a minimum of 12 hours overnight. All fish captured were retained for analysis.

Results and Discussion

Limnological Assessment

Light Penetration -- From 1987 to 1991, the euphotic zone depth ranged from 2.5 m to 4.5 m and averaged 3.5 m (Table 2). Based on the average EZD (3.5 m), the euphotic volume (EV) of Neck Lake where depth is greater than 5 m is estimated at $8.6 \cdot 10^6$ m^3 or 8.6 EV units which comprises ~18% of the total lake volume. Secchi disk (SD) transparency ranged from 2.3 m to 4.0 m and averaged 3.17 m.

Temperature and Dissolved Oxygen Regimes -- Neck Lake follows a standard summer stratification with summer surface temperatures (Table 3) reaching 19.7°C in 1987, 16.9°C in 1988, and 17.0°C in 1991. Temperatures cooled rapidly down to 10-15 m to ~6°C and then remained fairly constant to the bottom. Thus during summer stratification, the surface to
~10 m stratum was defined as the epilimnion which comprised 47.9% of the total lake volume. The thermocline extended from ~10-20 m, and the hypolimnion was formed at depths >20 m.

Dissolved oxygen (D.O.) concentrations (Table 4) ranged between 7 and 12 $mg \cdot \ell^{-1}$ (60->100% saturation) within the epilimnion, increased slightly within the thermocline and then decreased slightly within the hypolimnion.

Table 2. Neck Lake light intensity profiles for 1987 to 1991.

Light Intensity Levels by percentage

Depth	1987		1988		1991	
(m)	13 Aug	19 Nov	4 Aug	13 Dec	9 July	13 Sept
+0.5m	205.0	250.0	271.0	522.0	245.5	176.5
5cm	100.0	100.0	100.0	100.0	100.0	100.0
0.5m		21.7	51.6	42.8	52.7	41.2
1.0m	21.3	20.0	23.2	19.4	26.4	17.6
1.5m		7.3	11.3	7.2	14.5	7.5
2.0m	11.1	3.2	6.8	4.0	10.0	3.9
2.5m		1.0	3.0	2.2	6.1	2.1
3.0m	3.9		1.1	1.0	3.7	1.3
3.5m					2.5	0.7
4.0m	1.8				1.6	
4.5m	1.0				1.0	

Table 3. Neck Lake Temperature Profiles 1987 to 1991.

Temperature (°C)

Depth (m)	**1987**		**1988**		**1991**	
	13 Aug	**19 Nov**	**4 Aug**	**13 Dec**	**9 July**	**13 Sept**
1.0	19.8	6.1	16.9	4.0	17.0	13.3
2.0	19.1	6.1	16.5	4.0	16.8	13.2
3.0	18.8	6.1	16.5		16.6	13.0
4.0	17.2	6.1	16.1	4.0	16.6	12.1
5.0	15.3	6.1	14.3		15.6	11.9
6.0	11.8	6.1	12.0		12.7	11.7
7.0	9.5	6.1	10.1		11.6	11.5
8.0	8.6	6.1	8.2	4.0	10.4	11.2
9.0	7.9	6.1	7.5		9.3	10.9
10.0	7.2	6.0	6.5		8.2	10.4
11.0	6.9	6.0			7.2	
12.0	6.5	6.0	5.5	4.0	6.8	8.3
13.0	6.1	6.0				
14.0	5.9	6.0	5.0		6.3	7.1
15.0	5.8					
16.0	5.8	6.0	4.9	4.0	5.8	6.4
18.0	5.6	6.0	4.8		5.8	6.1
20.0	5.6	6.0	4.7	4.0	5.7	5.8
25.0	5.5	5.9	4.6	4.0	5.4	5.6
30.0	5.4	5.9	4.5	4.1	5.2	5.5
35.0					5.1	5.3
40.0					5.0	5.2
45.0					4.9	5.1
50.0					4.8	5.1

Table 4. Neck Lake Dissolved Oxygen Profiles 1987 to 1991.

Dissolved Oxygen (mg•ℓ⁻¹)

Depth (m)	**1987**		**1988**		**1991**	
	13 Aug	**19 Nov**	**4 Aug**	**13 Dec**	**9 July**	**13 Sept**
1.0	9.00	10.45	9.50	11.60	9.57	9.86
2.0	9.15	10.40	9.40		9.78	9.82
3.0	9.20	10.40	9.50		10.01	9.66
4.0	8.90	10.40	9.50	11.60	10.20	9.56
5.0	7.80	10.40	9.40		10.25	9.46
6.0	7.90	10.40	9.30	11.60	10.48	9.57
7.0	7.75	10.40	10.00		10.95	9.84
8.0	7.50	10.40	10.30	11.60	11.32	9.45
9.0	7.40	10.40	10.50		11.53	9.13
10.0	7.45	10.40	10.70	11.65	12.30	9.71
11.0	7.40				12.07	
12.0	7.25	10.40	10.90	11.65	12.30	9.71
13.0	7.20					
14.0	6.90	10.40	11.10	11.65	12.29	9.46
15.0	6.90					
16.0	6.80	10.40	11.10	11.65	12.63	10.16
18.0	6.65	10.40	11.10	11.65	12.55	9.95
20.0	6.55	10.40	11.00	11.65	12.47	9.86
25.0	6.40	10.00	11.00	11.65	12.38	10.21
30.0	6.20	9.50	10.30	11.65	12.15	10.05
35.0					11.95	10.10
40.0					11.60	10.00
45.0					11.00	9.95
50.0					10.42	9.64

General Water Quality -- Neck Lake is a stained, slightly alkaline water system as evidenced by conductivities ranging from 62-102 μmhos•m^{-1} (Tables 5 & 6). Moreover, alkalinities varied from 36-49 mg•ℓ^{-1} (as $CaCO_3$) which indicates moderate levels of inorganic carbon (Wetzel 1975). The pH was slightly alkaline and ranged from 7.1-7.9 units. Turbidities in Neck Lake were very low and ranged from 0.3-1.8 NTU; whereas, color ranged from 29-51 Pt units which characterizes Neck Lake as a stained system (Koenings and Edmundson 1991). This deviation from the normal Southeast Alaska stained, acidic lake can be attributed to the large abundance of limestone located in this area of Prince of Wales Island.

Metals -- Calcium levels in Neck Lake are considered high (14.8-20.0 mg•ℓ^{-1}) for oligotrophic Alaskan lakes (Tables 5 & 6). Magnesium levels were low ranging from <0.2-0.7 mg•ℓ^{-1}. Unlike clearwater lakes, which typically exhibit iron levels <20 μg•ℓ^{-1} (Stumm and Lee 1960), concentrations with the epilimnion and hypolimnion in Neck Lake ranged from 38-93 μg•ℓ^{-1}, and averaged 61 μg•ℓ^{-1} which is characteristic of organically stained lakes (Koenings 1976).

Nutrient Levels -- During 1987 to 1991, total phosphorus (TP) levels in Neck Lake ranged from 2.1-5.9 μg•ℓ^{-1} and averaged 3.8 μg•ℓ^{-1} within the epilimnion (Tables 5 & 6). Total filterable (TFP) and filterable reactive phosphorus (FRP) levels within the epilimnion average 1.9 and
1.7 μg•ℓ^{-1}, respectively (Tables 5 & 6).

Ammonia nitrogen levels (Tables 5 & 6) were relatively low in the epilimnion with concentrations ranging from 1.9-7.8 μg•ℓ^{-1} and averaged 4.5 μg•ℓ^{-1}. The hypolimnion levels were similar with a range of 1.4-8.9 μg•ℓ^{-1} and averaged 5.5 μg•ℓ^{-1}. Nitrate + nitrite levels within the hypolimnion average ~23 μg•ℓ^{-1}, but epilimnetic concentrations decreased to ~3 μg•ℓ^{-1} during the summer which signals a nitrogen deficit. Total Kjeldahl nitrogen (TKN) levels (equivalent to ammonia + organic nitrogen) averaged 93 μg•ℓ^{-1}. Total nitrogen (TN) levels within the epilimnion ranged from 96.8-113.7 μg•ℓ^{-1} and averaged 108 μg•ℓ^{-1}.

Reactive silicon (Si) levels fluctuated immensely throughout all years sampled. Concentrations ranged from 534-948 and averaged 713 μg•ℓ^{-1} in the epilimnion.

Table 5. Summary of General Water Quality parameters including pH, specific conductance, alkalinity, turbidity, color, metal concentrations, nutrient concentrations, an algal pigments within the epilimnion (1m) and hypolimnion of Neck Lake, Station A in 1987 and 1988.

Date	13 August 1987		19 November 1987		4 August 1988		13 December 1988	
Parameter Depth	1 m	Hypolimnion	1 m	Hypolimnion	1 m	Hypolimnion	1 m	Hypolimnion
pH (units)	7.9	7.3	7.7	7.1	7.4	7.1	7.3	7.3
Conductivity (μmhos•cm^{-1})	101	90	62	92	93	98	89	90
Alkalinity (mg•ℓ^{-1})	49.0	42.0	39.0	40.5	41.5	41.0	36.0	37.0
Turbidity (NTU)	0.5	1.0	1.8	0.5	0.4	0.3	1.2	1.2
Color (Pt units)	36	40	49	51	32	36	40	40
Calcium (mg•ℓ^{-1})	17.3	15.5	17.8	17.3	17.6	16.3	16.7	16.7
Magnesium (mg•ℓ^{-1})	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total iron (μg•ℓ^{-1})	43	48	68	73	93	80	66	65
Total-P (μg•ℓ^{-1})	5.9	3.9	4.3	3.6	3.3	2.8	4.2	4.1
TFP (μg•ℓ^{-1})	2.4	1.8	1.7	2.0	1.9	1.4	2.2	2.0
FRP (μg•ℓ^{-1})	2.1	1.6	1.9	2.5	1.4	1.5	1.6	1.7
TKN (μg•ℓ^{-1})	109.5	98.9	92.5	83.7	93.4	75.7	96.2	96.2
Total N (μg•ℓ^{-1})	113.7	123.8	109.2	100.4	96.8	96.8	110.9	110.1
Ammonia (μg•ℓ^{-1})	6.5	8.9	7.8	7.0	2.7	4.0	1.9	1.4
Nitrate + Nitrite (μg•ℓ^{-1})	4.2	24.9	16.7	16.7	<3.4	21.1	14.7	13.9
Reactive silicon (μg•ℓ^{-1})	789	1049	948	966	661	784	534	674
Chl a (μg•ℓ^{-1})	0.90	0.25	0.08	0.07	0.18	<0.01	0.08	0.07
Phaeo a (μg•ℓ^{-1})	0.20	0.90	0.08	0.10	0.17	0.06	0.07	0.07

Table 6. Summary of General Water Quality parameters including pH, specific conductance, alkalinity, turbidity, color, metal concentrations, nutrient concentrations, and algal pigments within the epilimnion (1m) and hypolimnion of Neck Lake, Station B in 1991.

Parameter	Date	9 July 1991		13 September 1991	
	Depth	1 m	Hypolimnion	1 m	Hypolimnion
pH (units)		7.8	7.4	7.5	7.4
Conductivity (μmhos•cm^{-1})		101	102	89	87
Alkalinity (mg•ℓ^{-1})		47.5	46.0	47.0	46.0
Turbidity (NTU)		0.5	0.3	0.7	0.7
Color (Pt units)		30	29	47	30
Calcium (mg•ℓ^{-1})		14.8	14.8	20.0	20.0
Magnesium (mg•ℓ^{-1})		0.7	<0.2	0.5	<0.2
Total iron (μg•ℓ^{-1})		38	52	66	41
Total-P (μg•ℓ^{-1})		2.1	3.0	3.3	2.6
TFP (μg•ℓ^{-1})		1.5	1.8	1.9	1.5
FRP (μg•ℓ^{-1})		1.4	1.5	1.9	1.4
TKN (μg•ℓ^{-1})		NA	NA	NA	NA
Total N (μg•ℓ^{-1})		NA	NA	NA	NA
Ammonia (μg•ℓ^{-1})		4.4	6.4	3.4	5.4
Nitrate + Nitrite (μg•ℓ^{-1})		<3.4	23.5	13.2	29.8
Reactive silicon (μg•ℓ^{-1})		634	794	709	762
Chl a (μg•ℓ^{-1})		0.35	<0.01	0.44	<0.01
Phaeo a (μg•ℓ^{-1})		0.29	0.06	0.14	0.10

NA - indicates not available.

Phytoplankton -- During the growing season Chl a concentrations within the epilimnion ranged from 0.18-0.90 $\mu g \bullet \ell^{-1}$ and averaging 0.47 $\mu g \bullet \ell^{-1}$ (Tables 5 & 6).

Zooplankton Abundance and Body Size -- The total macrozooplankton community in Neck Lake was comprised of three species of copepods and four species of cladocerans (Table 7). The copepod community consisted of *Cyclops* sp., *Epischura* sp., and *Diaptomus* sp. The cladocerans were represented in abundance primarily by *Bosmina* sp., *Daphnia ambigua* sp., *Holopedium* sp., and *Daphnia longiremis*. The total seasonal macrozooplankton densities were 20,908$\bullet m^{-2}$ in 1988, and 98,489$\bullet m^{-2}$ in 1991.

Epischura was the numerically dominant copepod species in 1987. The densities of *Epischura* ranged from 3,693-10,316 in 1987-1991. *Cyclops* was the numerically dominant species in 1988 and 1991. The densities of *Cyclops* ranged from 4,203-17,151$\bullet m^{-2}$ in 1987-1988 to 58,096$\bullet m^{-2}$ in 1991. The weighted mean body sizes of *Cyclops* was 0.69 mm, 0.73 mm, and 0.64 mm respectively for 1987-1991 (Table 7). The weighted mean body sizes for *Epischura* was 1.12 mm, 1.18 mm, and 1.35 mm respectively for 1987-1991 (Table 7). *Diaptomus* densities were present in 1988 and had a high count in 1991 of 3,057$\bullet m^{-2}$. The weighted mean body size was 1.55 mm.

Within the cladoceran community, *Bosmina* was by far the most abundant species with densities ranging from 8,830-22,245$\bullet m^{-2}$ for 1987-1991. The highest density of *Bosmina* occurred during September 1991. With a mean body size of 0.41-0.45 mm for 1987-1991, they are considered above the 0.40 mm minimum threshold size for elective feeding by sockeye salmon fry (Koenings and McDaniel 1983; Kyle, et al. 1988). *Daphnia ambigua* is the second most abundant cladoceran with densities ranging from 1,274-9,934$\bullet m^{-2}$ for 1987-1991. The weighted mean body size ranged from 0.87-0.92 mm for 1987-1991. *Daphnia longeremis* was identified during all sampling periods. The densities for this species ranged from 340-3,439$\bullet m^{-2}$ and had a weighted mean body size range of 0.65-0.96 mm for 1987-1991. *Holopedium* is the next most abundant with densities ranging from 425-976$\bullet m^{-2}$ for 1987-1991. The mean body size ranged from 0.81-0.87 mm for 1987-1991. This species is only found during mid-summer sampling (Table 7).

Table 7. Macrozooplankton densities and body size from Neck Lake from samples taken at 30 m depth (Station A) in 1987-1988 and at 50 m depth (Station B) in 1991.

Macrozooplankton Density (#•m^{-2})

	1987		1988		1991	
Species	**13 Aug**	**19 Nov**	**4 Aug**	**13 Dec**	**9 July**	**13 Sept**
Cyclops	6,453	4,203	17,151	4,118	57,947	58,224
Epischura	10,316		7,217		3,693	6,623
Diaptomus			present		3,057	present
Bosmina	13,924	127	8,830	1,401	21,523	22,245
Daphnia a.	4,670		1,274	85	9,934	6,962
Daphnia l.	552	594	425	340	3,439	1,698
Holopedium	976		425		764	849
Totals:	36,891	4,924	35,322	5,944	100,357	96,621

Mean Body Size (mm)

	1987		1988		1991	
Species	**13 Aug**	**19 Nov**	**4 Aug**	**13 Dec**	**9 July**	**13 Sept**
Cyclops	0.73	0.63	0.75	0.67	0.62	0.65
Epischura	1.12		1.18		1.17	1.40
Diaptomus					1.55	
Bosmina	0.41	0.49	0.45	0.46	0.41	0.46
Daphnia a.	0.92		0.85	1.14	0.91	0.93
Daphnia l.	0.97	0.86		0.65	0.98	0.93
Holopedium	0.87		0.81		0.83	0.85

Zooplankton Biomass -- The total weighted macrozooplankton biomass in Neck Lake varied significantly between the 1987-1988 and 1991 samples. The 1987, 1988, and 1991 total weighted biomass was 67, 60, and 222 mg•m^{-2} respectively (Table 8). In 1989, *Cyclops* populations comprised ~31% of the total biomass and ~36% of the total biomass in 1991. *Bosmina* remained fairly constant in all years with a range of 16.2-17.4% of the total biomass. *Holopedium* changed significantly from ~17% of the total biomass in 1989 and dropping to less than 3% in 1991.

Table 8. Relative biomass of macrozooplankton from Neck Lake for 1987-1991.

	Weighted Biomass ($mg \bullet m^{-2}$)		
Species	**1987**	**1988**	**1991**
Cyclops	8.68	19.78	79.15
Epischura	32.02	25.98	54.83
Diaptomus	NA	NA	NA
Bosmina	10.96	9.74	38.62
Daphnia a.	8.96	2.30	32.29
Daphnia l.	2.16	0.69	10.90
Holopedium	3.96	1.45	6.02
Totals:	**66.74**	**59.94**	**221.81**

Sockeye Salmon Production

Sockeye Rearing Capacity Evaluation

Potential sockeye salmon smolt production was estimated using both the Euphotic Volume Model (Koenings and Burkett, 1987) and the Zooplankton Biomass Model (Barto and Koenings, 1991) with corresponding data collected at Neck Lake.

Koenings and Burkett (1987) established a relationship between EV and sockeye salmon production. The EV model yields a maximum of 23,000 Age-1 threshold size (2.2 g) smolt per EV unit. The EV model yields an 11,290 Age-1 optimum size (4.5 g) smolt. The EV model for Neck Lake with 8.6 EV units would produce 197,800 threshold size or 97,094 optimum size sockeye smolt (Table 9).

Barto and Koenings (1990) established a biological relationship between zooplankton standing crop and sockeye salmon production. This model uses current biological trends found in each lake where:

$[(ZB) \bullet (LA)] \bullet 0.1375^{-1}$ = number of threshold size (2.2 g) smolt produced.
$[(ZB) \bullet (LA)] \bullet 0.2813^{-1}$ = number of optimum (4.5 g) smolt produced.

where: ZB = zooplankton biomass ($mg \bullet m^{-2}$)
LA = lake surface area, >5 m depth (hectares)

The results of this analysis are presented in Table 9.

Table 9. Estimated potential smolt production of Neck Lake comparing the Euphotic Volume and Zooplankton Biomass Models using mean Euphotic Zone Depth and zooplankton densities from samples taken in 1987-1991.

Year	**Seasonal Mean Zooplankton Density (#•m^{-2})**	**Seasonal Mean Zooplankton Biomass (mg•m^{-2})**	**Potential Threshold Smolt (2.2 g) Production**	**Potential Optimum Smolt (4.5 g) Production**
1987	20,908	67		
1988	20,633	60		
1991	98,489	222		
Mean	**46,677**	**116**	**210,378**	**102,851**
EV Model		**8.6 EV units**	**197,800**	**97,094**

A comparison of the Neck Lake zooplankton biomass relative to other lakes in southern Southeast Alaska indicates that Neck Lake secondary production levels are very low (Table 10).

Table 10. Comparison of seasonal mean macro-zooplankton densities and biomass of Neck Lake to sockeye salmon nursery lakes (*) and other non-anadromous lakes (#) in Southeast Alaska.

	Macro-zooplankton			
Lake	**Years Sampled**	**Density (#•m^{-2})**	**Biomass (mg•m^{-2})**	**comment**
Orchard (#)	89	262,788	821	
Margaret (*)	87 & 89	233,407	643	
Hugh Smith (*)	81-84	304,771	548	Fertilized
Heckman (*)	87-88	322,530	475	
Hugh Smith (*)	85-87	233,570	474	Post-fertilize
Big (Ratz Hbr) (*)	89 & 91	250,907	465	
Woodpecker (#)	86	59,911	431	
McDonald (*)	82-90	108,239	351	Fertilized
Dog Salmon (*)	89	149,855	295	
Mary (#)	89	5,945	263	
Bakewell (*)	84,85,89	163,690	267	
Old Franks (#)	89	18,365	236	
Klawock (*)	86-87	113,262	212	
Patching (#)	87	82,125	212	Pre-stocking
Upper Old Franks (#)	89	36,650	210	
McDonald (*)	81	83,281	186	Pre-fertilize
Badger (*)	85-89	80,549	168	Fry stocked
Patching (#)	88	48,356	166	Fry stocked
Salmon (*) Karta R.	84-89	56,547	161	
Eagle (#)	89	48,311	150	
Ward (*)	89	156,648	136	
Neck (#)	**87,88,91**	**46,677**	**116**	
Virginia (*)	86,88	40,946	111	Pre-stocking
Badger (*)	83-84	55,012	111	Pre-stocking
Virginia (*)	89-90	37,950	93	Fry stocked

Sockeye Adult Production

The estimated potential sockeye smolt production for Neck Lake, based on euphotic volume and estimated seasonal mean zooplankton production from 1987-1991 is 197,800-210,378 threshold size (2.2 g) smolt. Based on standard survival assumptions, this estimated smolt production would result in 23,736-25,245 adults of which 60% would be needed for escapement and 40% would be the harvestable surplus.

Coho Salmon Production

There is 1,281,972 m^2 of lake area less than 5 m deep (littoral) available for rearing habitat of coho. This littoral area is 33.9% of the total Neck Lake area. The stream rearing area above the falls is very limited and not included in this section. The coho production estimate is based on a fry rearing density of 0.247 $fish \bullet m^{-2}$. Neck Lake has the capacity to produce a maximum of 31,663 smolt. Using standard survival assumptions, Neck Lake could produce 3,166 adult coho.

Resident Fish

Neck Lake has an existing cutthroat trout *(Oncorhynchus clarki spp.)*, Dolly Varden char *(Salvelinus malma)*, and kokanee *(Oncorhynchus nerka)* population. However, no population studies have been done. The 1985 sampling captured 84 kokanee adults with an estimated mean length of 150 mm; 54 cutthroat trout with a size range estimated at 150-360 mm; and 58 Dolly Varden char with a size range estimated at 150-200 mm. The 1987 sampling captured 2 kokanee which averaged 181 mm in length; 8 cutthroat with a size range of 160-220 mm; and 12 Dolly Varden char with a size range of 140-200 mm.

Historical Data

Neck Lake has been under scrutiny as a viable system for development of a significant run of salmon since the late 1950's. In 1959-1960, flow records were kept of the lake outflow which had a discharge range of 32-335 cfs. The falls were mapped at this time also to facilitate a fish pass design. However, current steepass designs did not appear feasible and the project was dropped.

In 1970, new developments renewed interest in the Neck Lake project. The ADF&G, Commercial Fish Division, Research section reopened the project again. An electro-shocking sampler was used to evaluate all inlet streams for resident fish. This survey concluded that "a partial eradication using Pro-Nox fish to reduce cutthroat trout and cottids in these major rearing areas" was warranted.[1] The project at this time was primarily interested in coho enhancement with little emphasis on sockeye production. The option to build a fish pass was left open at this time. However, stocking of coho into the system was still the primary objective.

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[1] Marriott, Dick. 1971. Memorandum to Mel Seibel on the Neck Lake Project Proposal. 3p.

In 1990, the ADF&G, Commercial Fish Division conducted a gillnet test fishery for the feasibility of a terminal harvest for cost recovery. The objective of this fishery was to determine conflicts of other wild salmon runs in Whale Pass with future enhanced Neck Lake fish. The primary result was that Whale Pass is too shallow and narrow for any commercial net use.

Recommendations

1. The feasibility of building a fishpass appears to be cost prohibitive. However, there are other scenarios listed below which are feasible.

2. Stock coho into Neck Lake as a put and take procedure where returning adults are caught in existing commercial fisheries. Those adults which bypass the fisheries will be available for either a terminal subsistence / sport harvest or a cost recovery site.

3. Fertilize Neck Lake to bring production for coho to a level similar to the Deer Lake program on Baranof Island. Neck Lake has a small drainage with a high water residence time which would allow maximum usage of the fertilizer applied.

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