FISHERY SURVEY OF LAKES AND STREAMS ON IZEMBEK AND ALASKA PENINSULA NATIONAL WILDLIFE REFUGES, 1985 AND 1986

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pink salmon, sockeye salmon,
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ABSTRACT

During May through September, 1985 and 1986, nine lakes and eight streams on the Izembek National Wildlife Refuge and on the Pavlof Unit of the Alaska Peninsula National Wildlife Refuge (Refuges) were surveyed. The purpose of the survey was to characterize the fish populations and describe the physical and chemical features of the lakes and streams because limited information was previously available. Gill nets, minnow traps, electrofisher, dip nets, carcass recovery, and angling were used to sample the fish populations. Standard hydrological, limnological, and water quality methods were used to sample physical and chemical characteristics.

Anadromous and resident fish were captured including: Arctic char (*Salvelinus alpinus*); Dolly Varden (*S. malma*); chum salmon (*Oncorhynchus keta*); coho salmon (*O. kisutch*); pink salmon (*O. gorbuscha*); sockeye salmon (*O. nerka*); coastrange sculpin (*Cottus aleuticus*); fourhorn sculpin (*Myoxocephalus quadricornis*); threespine stickleback (*Gasterosteus aculeatus*); ninespine stickleback (*Pungitius pungitius*); starry flounder (*Platichthys stellatus*); and Arctic lamprey (*Lampetra japonica*). The occurrence of these species generally reflects the geographic range reported in the literature. However, the presence of fourhorn sculpin and ninespine stickleback within the study area represents a southern range extension for each of these species.

Length, weight, and age characteristics of chum, coho, and sockeye salmon, and Arctic char from the Refuges generally exhibit similar characteristics to other Alaska populations. The typical ages of adult pink salmon and Dolly Varden differed from other Alaska populations. Age 0.1 pink salmon were captured in Swan Lake, which was not a typical age for returning adults of this species. The oldest Dolly Varden captured in this study was age 6 years, which is considerably younger than the maximum age reported for other Alaskan populations.

Open lakes exhibited greater species diversity than closed lakes. Tundra streams exhibited greater species diversity than upland streams. Mean lengths and weights of juvenile coho salmon and Dolly Varden sampled in the lakes were greater than from the streams. Mean lengths at age of juvenile coho salmon captured in the tundra streams were greater than those captured in the upland streams.

Shoreline development was similar for open and closed lakes, but the closed lakes were significantly deeper. Conductivity and pH were greater for the open lakes. Discharge was greater in the upland streams, although the tundra streams exhibited greater conductivity, alkalinity, and pH. Bathymetry indicated that the lakes were glacially formed kettle lakes.

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INTRODUCTION

The King Salmon Fishery Assistance Office conducted a survey of selected lakes and streams on the Izembek National Wildlife Refuge and the Pavlof Unit of the Alaska Peninsula National Wildlife Refuge (Refuges). The goal of the survey was to provide information for development of a management strategy for fish resources and prioritize management objectives.

The U.S. Fish and Wildlife Service (1985b), Morrow (1980), and Alaska Department of Fish and Game (1978) previously documented the existence of 13 species of fish from freshwater habitats (Table 1). Salmonids comprised the majority of species recorded, with the remaining species belonging to four families.

Specific information concerning fish resources in the area is generally limited to aerial salmon escapement surveys by the Alaska Department of Fish and Game, Division of Commercial Fisheries (Alaska Department of Fish and Game 1987). While these surveys supply estimates on the numbers of returning salmon, they provide little information concerning the population characteristics of any species or the distribution of non-commercial species. Also, data concerning the limnology, hydrology, and water quality of the Refuges' lakes and streams are practically nonexistent (U.S. Fish and Wildlife Service 1985a, 1985b).

Objectives of the survey were to: (1) determine fish species composition and distribution; (2) estimate the ages and average lengths and weights of juvenile and adult salmonids; (3) obtain descriptive data concerning the limnology, hydrology, and water quality of the area's waters; and (4) determine the bathymetry of the selected lakes.

STUDY AREA

Izembek National Wildlife Refuge and the Pavlof Unit of the Alaska Peninsula National Wildlife Refuge are located on the southwestern tip of the Alaska Peninsula (Figure 1). The Refuges are near the community of Cold Bay, approximately 1,050 km southwest of Anchorage. Izembek National Wildlife Refuge encompasses 1,270 km^2 (U.S. Fish and Wildlife Service 1985a) and shares a common boundary with the Pavlof Unit. The Pavlof Unit contains approximately 6,212 km^2 (U.S. Fish and Wildlife Service 1985b) and is administered by the Izembek National Wildlife Refuge staff.

The climate is characterized by high winds, moderate temperatures, protracted cloud cover, and frequent precipitation (U.S. Fish and Wildlife Service 1985a, 1985b). Extreme minimum and maximum air temperatures are -25 ^{o}C and 25 ^{o}C, with an average annual precipitation of 90 cm. Average August daily minimum and maximum air temperatures are 7.6 ^{o}C and 16.7 ^{o}C (National Oceanic and Atmospheric Administration 1983).

Table 1.-Fish species documented in the freshwater habitats on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge.

Family Name Scientific Name	Common Name	Source[a]
Petromyzontidae		
Lampetra japonica	Arctic lamprey	B
Salmonidae		
Salvelinus namaycush	Lake trout	B
Salvelinus alpinus	Arctic char	A,B,C
Salvelinus malma	Dolly Varden	A,B,C
Oncorhynchus mykiss	Steelhead trout	A,C
Oncorhynchus gorbuscha	Pink salmon	A,B
Oncorhynchus nerka	Sockeye salmon	A,B
Oncorhynchus tshawytscha	Chinook salmon	A,B
Oncorhynchus kisutch	Coho salmon	A,B
Oncorhynchus keta	Chum salmon	A,B
Gasterosteidae		
Gasterosteus aculeatus	Threespine stickleback	A,B
Cottidae		
Cottus aleuticus	Coastrange sculpin	B
Pleuronectidae		
Platichthys stellatus	Starry flounder	A,B

[a] A = U.S. Fish and Wildlife Service (1985b); B = Morrow (1980); and C = Alaska Department of Fish and Game (1978).

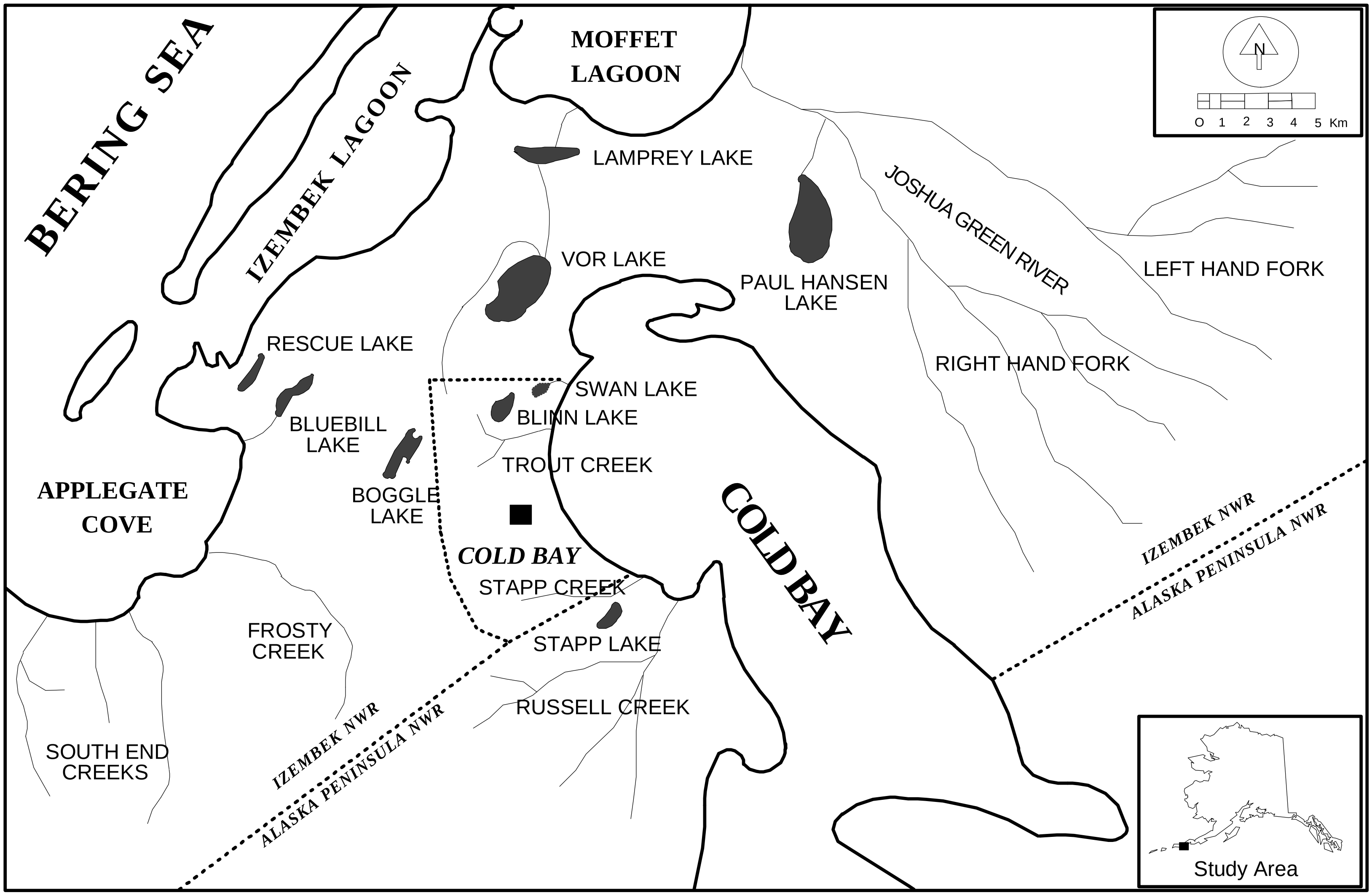

Figure 1.-Lakes and streams sampled on Izembek National Wildlife Refuge and on the Pavlof Unit of the Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

METHODS

Nine lakes and eight streams were surveyed on the Refuges. Stream and lake names were predominantly local and are used for identification purposes only. Lakes and streams to be surveyed were chosen due to their proximity to the road system. A fixed wing aircraft was used to access Paul Hansen Lake and Joshua Green River. Sampling occurred from 10 May to 18 July and from 5 to 22 August, 1985. Sampling during 1986 was conducted from 12 August to 12 September.

The nine lakes sampled were classified as open or closed (Table 2). Open lakes were identified as having stream connections to salt water with closed lakes being landlocked. The eight streams sampled were classified as tundra or upland. Tundra streams were defined as originating from lakes or springs in low coastal wetlands. These streams generally had a lower gradient, more stable banks, and exhibited less fluctuation in flows than the upland streams, which originate on the steep slopes of the Aleutian Range.

Fish Species Composition and Distribution

Lakes were sampled using experimental gill nets, electrofishing, minnow traps, dipnets, and angling. An experimental gill net (45.7 x 1.8 m with 3.8, 5.1, 6.4, 7.7, 9.0, and 10.3 cm stretched mesh) was fished overnight on the bottom of the lake in the area of greatest depth change. Inlet and outlet areas along the shoreline were sampled with a Smith-Root Model 15A backpack electrofisher. Four minnow traps were baited with preserved salmon eggs and set overnight along the shoreline in depths of 0.5-1.0 m. Dipnetting and angling were conducted opportunistically. Salmon carcasses were examined when available. All fish were identified to species by external characteristics except Arctic char and Dolly Varden, which were distinguished by comparisons of gill raker and pyloric caeca counts (Scott and Crossman 1973, Morrow 1980).

In streams, electrofishing, dipnetting, angling, and carcass recovery were used to determine fish species composition and distribution. Three to thirty meter sections of the streams were sampled with the backpack electrofisher. Electrofisher failure prevented effective sampling of the Joshua Green River. Dipnetting and angling were conducted opportunistically. Salmon carcasses were sampled when available.

Length, Weight, and Age

Fork length (mm) was measured on Arctic char, Dolly Varden, and juvenile salmon; mid-eye to fork length (mm) was measured on adult salmon. Weight (g) was measured from a subsample of individuals captured. All juveniles were anesthetized with tricaine methanesulfonate (MS-222) to facilitate handling. For juvenile salmon and released adult pink and sockeye salmon, scales were collected from the mid to posterior region above the lateral line (Jearld 1983). Otoliths were obtained from

Table 2.-Names and types of streams and lakes sampled on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

Name	Type
Bluebill Lake outlet	Tundra Stream
Lamprey Lake outlet	Tundra Stream
Stapp Creek	Tundra Stream
Trout Creek	Tundra Stream
Frosty Creek	Upland Stream
Joshua Green River	Upland Stream
Russell Creek	Upland Stream
South End Creek	Upland Stream
Bluebill Lake	Open Lake
Lamprey Lake	Open Lake
Paul Hansen Lake	Open Lake
Swan Lake	Open Lake
VOR Lake	Open Lake
Blinn Lake	Closed Lake
Boggle Lake	Closed Lake
Rescue Lake	Closed Lake
Stapp Lake	Closed Lake

subsamples of Arctic char and Dolly Varden, as well as from subsamples of live salmon and salmon carcasses.

Ages of scales and otoliths were interpreted by two readers, with a third reader resolving disagreements. Regenerated or damaged scales were discarded. Otoliths were cleared with xylene, and age was estimated by examination of the external surface (Barber and McFarlane 1987). The ages of resident fish and juvenile salmonids were denoted as a single digit. The ages of adult salmon were denoted by the two digit European method (Koo 1962). No attempt was made to compare otolith and scale ages.

Based on McCart (1980) and Armstrong and Morrow (1980), Arctic char and Dolly Varden younger than age 4 were considered to be juveniles. To maximize sample sizes for length and weight analyses, Arctic char and Dolly Varden with no assigned ages were considered to be juveniles if they were smaller than the smallest age 4 Arctic char or Dolly Varden captured from the study area.

Salmon were considered to be juveniles if their scales or otoliths did not exhibit saltwater checks. To maximize sample sizes for length and weight analyses, salmon with no assigned ages were considered to be juveniles if they were smaller than the largest aged juvenile of the same species.

Two sample t-tests ("=0.05) were used to compare mean lengths and weights of fish sampled from lakes and streams (Freund 1984). Significant differences were also tested between open and closed lakes and between tundra and upland streams. To maximize sample sizes for adults and juveniles, catch for all gear types was combined.

Limnology, Hydrology, and Water Quality

Lakes

Maps of each lake were constructed, to scale, from aerial photographs. Lake morphological characteristics were calculated using the methods in Lind (1974). Depth of light penetration was measured with a Secchi disk. Surface area and shoreline length were calculated with a planimeter. Shoreline development (D) reflects the degree of shoreline irregularity and was calculated by:

$$D = \frac{s}{\sqrt{\mathrm{B}a}}$$

where: s = shoreline length (m)
a = lake surface area (m^2) (Cole 1979).

A Yellow Springs Instruments Model 33 conductivity meter was used to measure conductivity (*u*S/cm). A Hach Model AL-36DT portable water chemistry kit was used to measure total alkalinity (mg/L $CaCO_3$) and pH.

All water quality parameters were measured approximately 0.3 m below the surface. Significant differences in mean shoreline development and mean depth between the open and closed lakes were tested with a two sample t-test ("=0.05) (Freund 1984).

Streams

All streams were sampled for hydrological and water quality characteristics except Bluebill Lake outlet, South End Creeks, and Joshua Green River. Discharge measurements were obtained with a Marsh-McBirney flow meter, top setting wading rod, and meter tape. Velocity measurements were taken at 0.6 of the water column depth, and stream discharges were calculated according to Rantz (1982). Sites for discharge measurements were chosen according to the following criteria: (1) parallel flow; (2) minimal obstructions (boulders or large debris); and (3) moderate water depth.

Total alkalinity, pH, and conductivity were measured slightly below the stream surface at all discharge measurement sites. The same equipment used for water quality sampling in the lakes was used for water sampling in the streams.

Lake Bathymetry

Lake perimeters of the bathymetric maps were constructed by enlargement of the lake outlines from scale topographic maps. Depths were determined using a Humminbird portable depth finder in Blinn, Lamprey, Stapp, and VOR lakes. An Eagle Mach 1 graph recording echo sounder was used in Bluebill, Boggle, Paul Hansen, Rescue, and Swan lakes. Depth contours were determined by connecting points of similar depth along predetermined transects.

RESULTS

Fish Species Composition and Distribution

Twelve fish species were captured in the nine lakes and eight streams (Tables 3 and 4). Salmonids were the most common fish, occurring in all four types of water bodies. Dolly Varden and coho salmon were the most widespread species, occurring in 13 of the 17 sampled water bodies. Fourhorn sculpin (*Myoxocephalus quadricornis*), starry flounder, and Arctic lamprey were each captured in only one water body. Because no saltwater checks were observed in otoliths of Dolly Varden and Arctic char, these species were considered to be residents.

Ten fish species were collected from the open lakes, and four species were collected from the closed lakes (Table 3). Arctic char, Dolly Varden, coastrange sculpin, and threespine stickleback were captured in both lake types. Dolly Varden, coho salmon, sockeye salmon, ninespine stickleback (*Pungitius pungitius*), and threespine stickleback were captured in all five open lakes. Fourhorn sculpin were captured in only one open lake. No species was common to all the closed lakes, but coastrange sculpin and threespine stickleback were captured in three of the four closed lakes.

Ten species of fish were captured in the tundra streams and seven were captured in the upland streams (Table 4). Several species were present in both stream types, although the upland streams exhibited less species diversity than the tundra streams. Coastrange sculpin, starry flounder, and Arctic lamprey were present only in tundra streams. Dolly Varden, chum salmon, and coho salmon were captured in all the upland streams. Coho salmon and threespine stickleback were the only species captured in all tundra streams.

Length, Weight, and Age

Lengths were measured from six salmonid species captured in the lakes (Table 5) and five salmonid species captured in the streams (Table 6). The length frequency distribution for the six salmonid species, by water body type, are presented in Figures 2-7. Mean lengths of juvenile coho salmon and juvenile Dolly Varden from the tundra streams were significantly greater than the mean lengths of the same species from the upland streams ($P<0.01$). Dolly Varden mean length was not significantly different between open or closed lakes ($P>0.30$). The mean lengths of juvenile Dolly Varden and juvenile coho salmon captured in the lakes were significantly greater than the mean lengths of similar fish in tundra ($P<0.01$) and upland ($P<0.01$) streams.

Weights were measured from five species in lakes and two species from streams (Tables 5 and 6). The mean weight of juvenile coho salmon from the lakes was significantly greater than the mean weight of juvenile coho salmon in tundra ($P<0.01$) and upland ($P<0.01$) streams. No

Table 3.-Fish distribution in open and closed lakes on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986 (A = adult, J = juvenile, and P = present-maturity not determined).

	Species[a]									
Lake	CS	SS	PS	RS	AC	DV	CR	FS	NS	TS
Open Lakes										
VOR		J		J	J, A	J, A			P	P
Lamprey	A	J	A	J, A		J, A			P	P
Bluebill		J		J		J	P		P	P
Swan	A	J	A	A		J, A		P	P	P
Paul Hansen	A	J		J, A		J	P		P	P
Closed Lakes										
Stapp						A				
Blinn					J, A		P			P
Boggle					J, A		P			P
Rescue							P			P

[a] CS = chum salmon; SS = coho salmon; PS = pink salmon; RS = sockeye salmon; AC = Arctic char; DV = Dolly Varden; CR = coastrange sculpin; FS = fourhorn sculpin; NS = ninespine stickleback; TS = threespine stickleback.

Table 4.-Fish distribution in tundra and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986 (A = adult, J = juvenile, and P = present).

	Species[a]									
Stream Type	CS	SS	PS	RS	DV	CR	NS	TS	SF	AL
Tundra										
Bluebill Lake area		J		J	J	P	P	P	P	
Lamprey Lake area		J		J	J	P	P	P		P
Stapp Creek		J						P		
Trout Creek	A	J, A	A	J	J	P	P	P		
Upland										
Frosty Creek	A	J	A	A	J					
Joshua Green River	J, A	J	A	J, A	J					
Russell Creek	J	J			J		P	P		
South End Creeks	A	J	A	J, A	J					

[a] CS = chum salmon; SS = coho salmon; PS = pink salmon; RS = sockeye salmon; DV = Dolly Varden; CR = coastrange sculpin; NS = ninespine stickleback; TS = threespine stickleback; SF = starry flounder; and AL = Arctic lamprey.

Table 5.-Length (mm) and weight (g) data for salmonids captured in open and closed lakes on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

	Lake Type							
	Open				Closed			
Species	*N*	$\bar{X}$	*SD*	Range	*N*	$\bar{X}$	*SD*	Range
LENGTHS								
ADULTS								
Chum salmon	4	575.0	37.8	515-600				
Pink salmon	43	296.8	49.6	220-455				
Sockeye salmon	72	497.4	67.5	315-610				
Arctic char	1	-	-	670	24	281.2	32.5	248-360
Dolly Varden	16	375.1	25.3	329-433				
JUVENILES								
Coho salmon	48	101.4	69.1	32-289				
Sockeye salmon	67	39.5	19.6	28-145				
Arctic char	1	-	-	144	41	169.4	36.5	119-244
Dolly Varden	57	185.0	96.9	68-350	9	219.0	42.4	130-277
WEIGHTS								
ADULTS								
Pink salmon	33	442.0	98.7	275-625				
Sockeye salmon	42	2,107.1	748.8	1,000-4,000				
Arctic char	1	-	-	5,400	19	210.5	86.3	150-425
Dolly Varden	10	720.0	185.7	370-950				
JUVENILES								
Coho salmon	15	76.2	73.9	3-270				
Arctic char	1	-	-	241	39	63.6	53.6	13-232
Dolly Varden	25	253.3	213.2	4-750	7	171.4	78.4	1-275

Table 6.-Length (mm) and weight (g) data for salmonids captured in tundra and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

	Stream Type							
	Tundra				Upland			
Species	*N*	$\overline{X}$	*SD*	Range	*N*	$\overline{X}$	*SD*	Range
LENGTHS								
ADULT								
Chum salmon	20	592.0	42.3	515-655	366	578.1	37.9	450-700
Coho salmon	12	603.3	53.8	461-669				
Pink salmon	59	439.4	33.6	369-544	51	443.0	31.7	386-518
Sockeye salmon					151	497.3	72.0	346-624
Dolly Varden	2	335.0	5.0	330-340				
JUVENILES								
Chum salmon					11	39.2	2.4	36-45
Coho salmon	335	64.2	33.3	26-176	437	47.1	15.8	28-118
Sockeye salmon	14	49.8	22.0	31-89	43	49.9	6.0	38-68
Dolly Varden	212	99.3	38.1	22-260	408	68.3	36.8	26-260
WEIGHTS								
JUVENILES								
Coho salmon	69	5.7	5.7	1-33	46	6.2	4.6	3-21
Dolly Varden	86	16.0	12.3	2-63	126	14.1	15.0	2-86

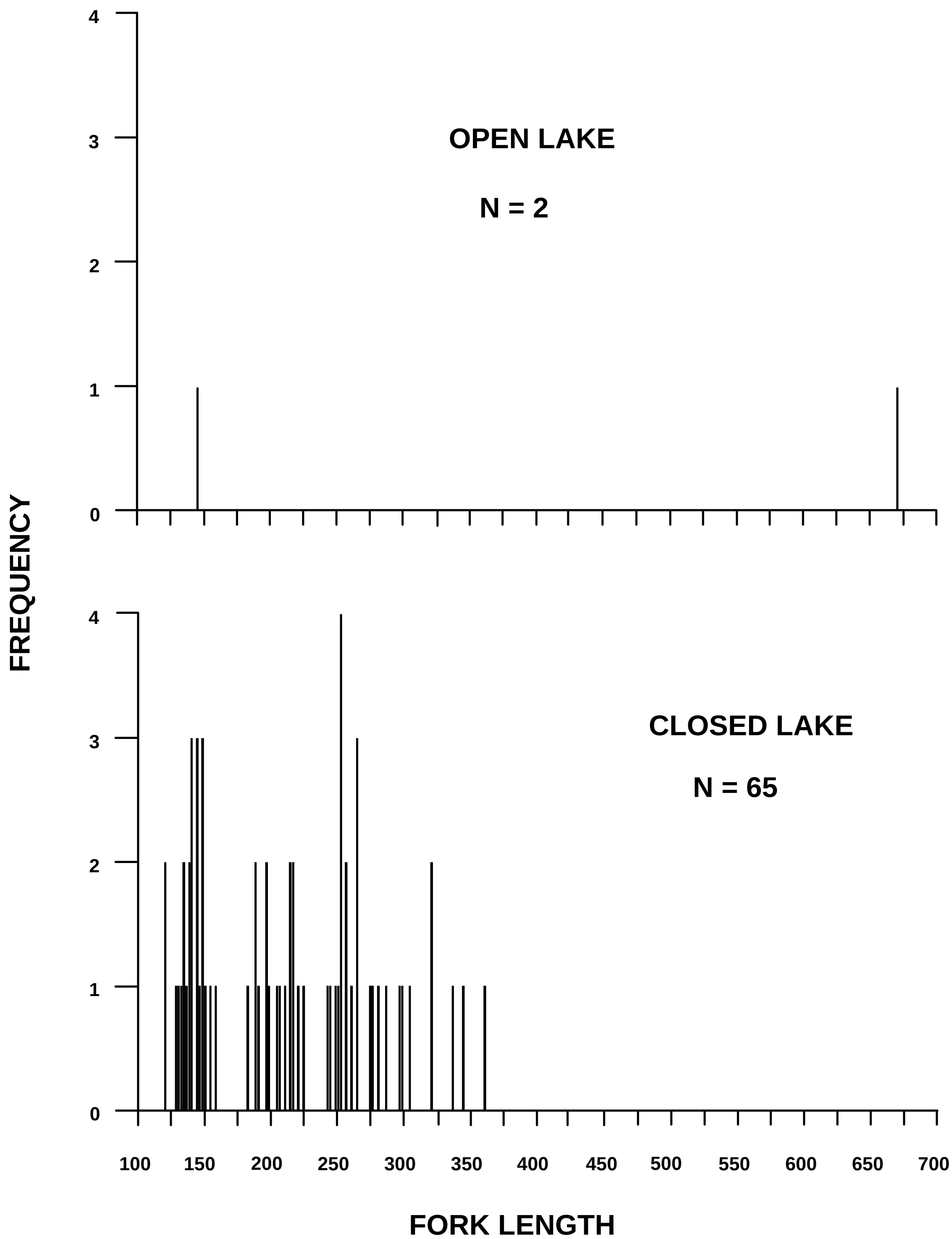

Figure 2.-Length frequency (2 mm increments) of Arctic char captured in open and closed lakes on izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

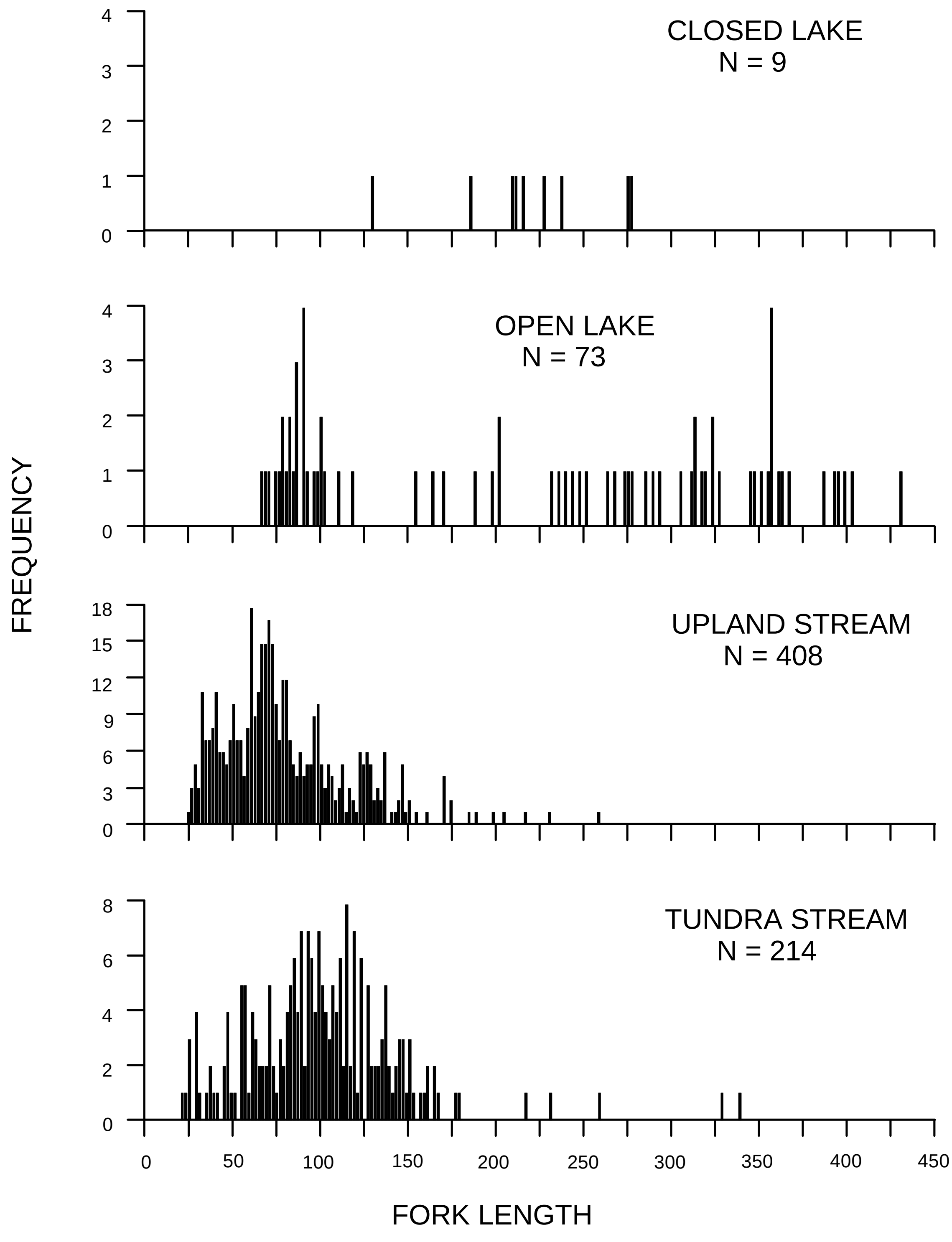

Figure 3.-Length frequency (2mm increments) of dolly Varden captured in open lakes, closed lakes, tundra streams, and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

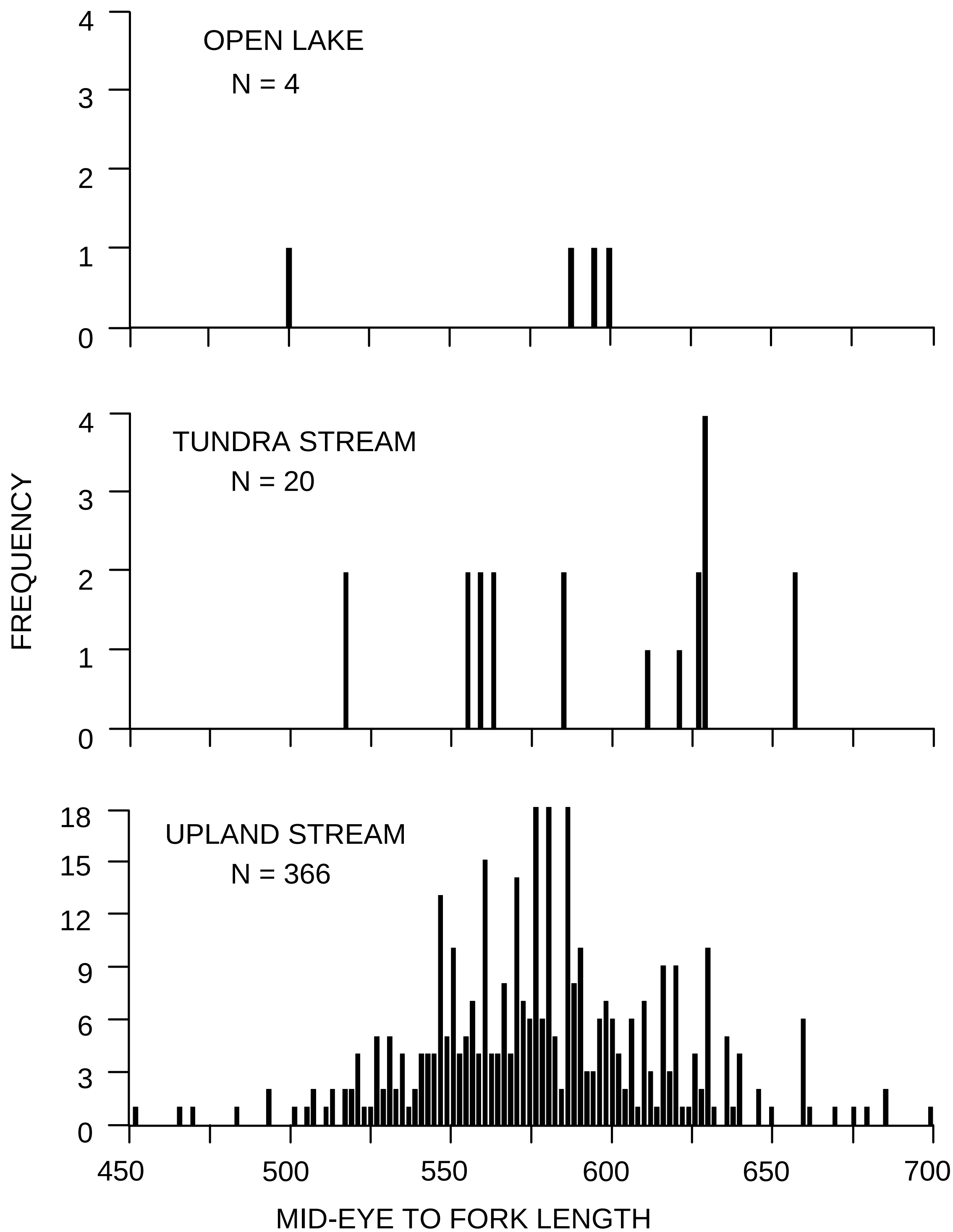

Figure 4.-Length frequency of adult chum salmon captured in open lakes, tundra streams, and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

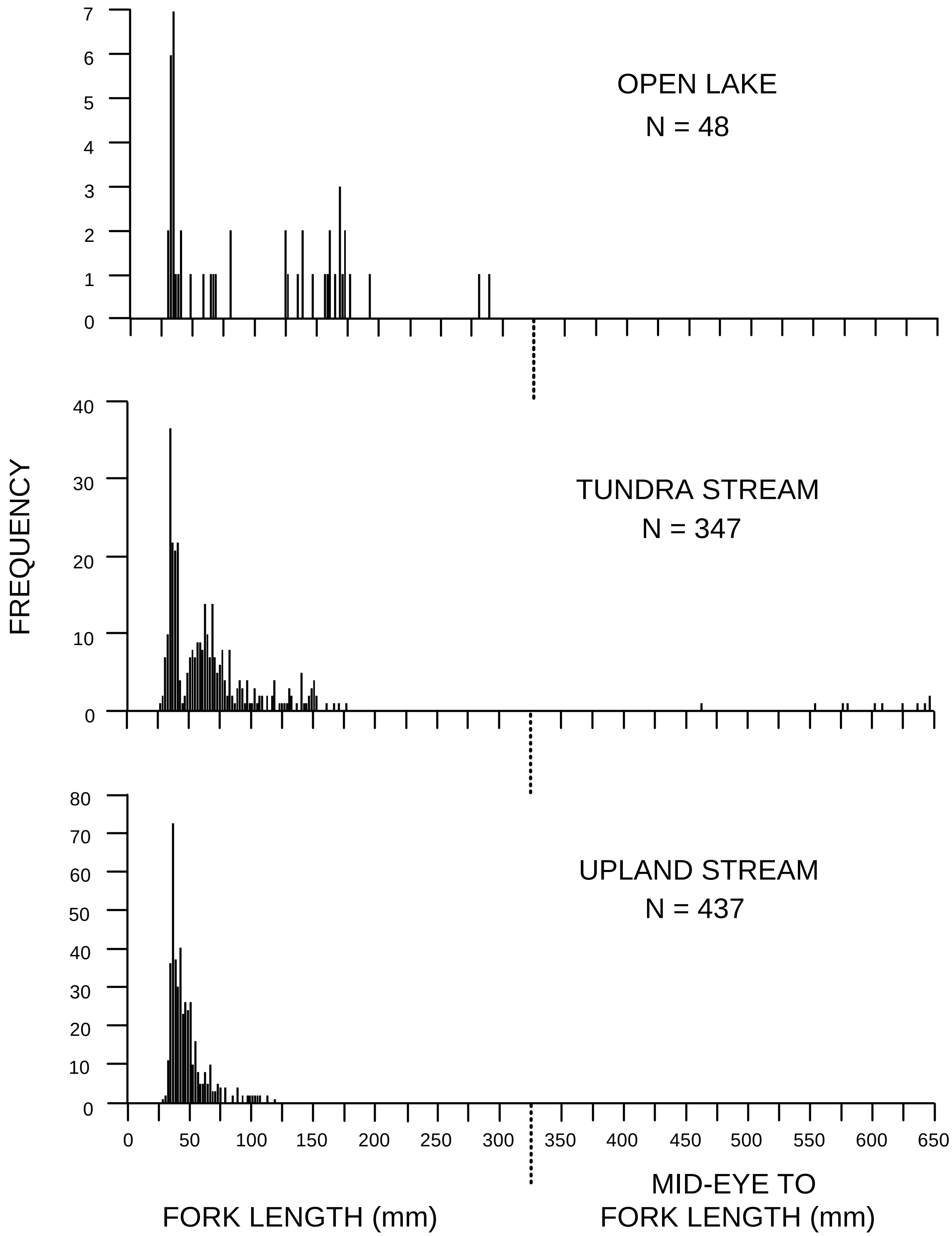

Figure 5.-Length frequency of coho salmon captured in open lakes, tundra streams, and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

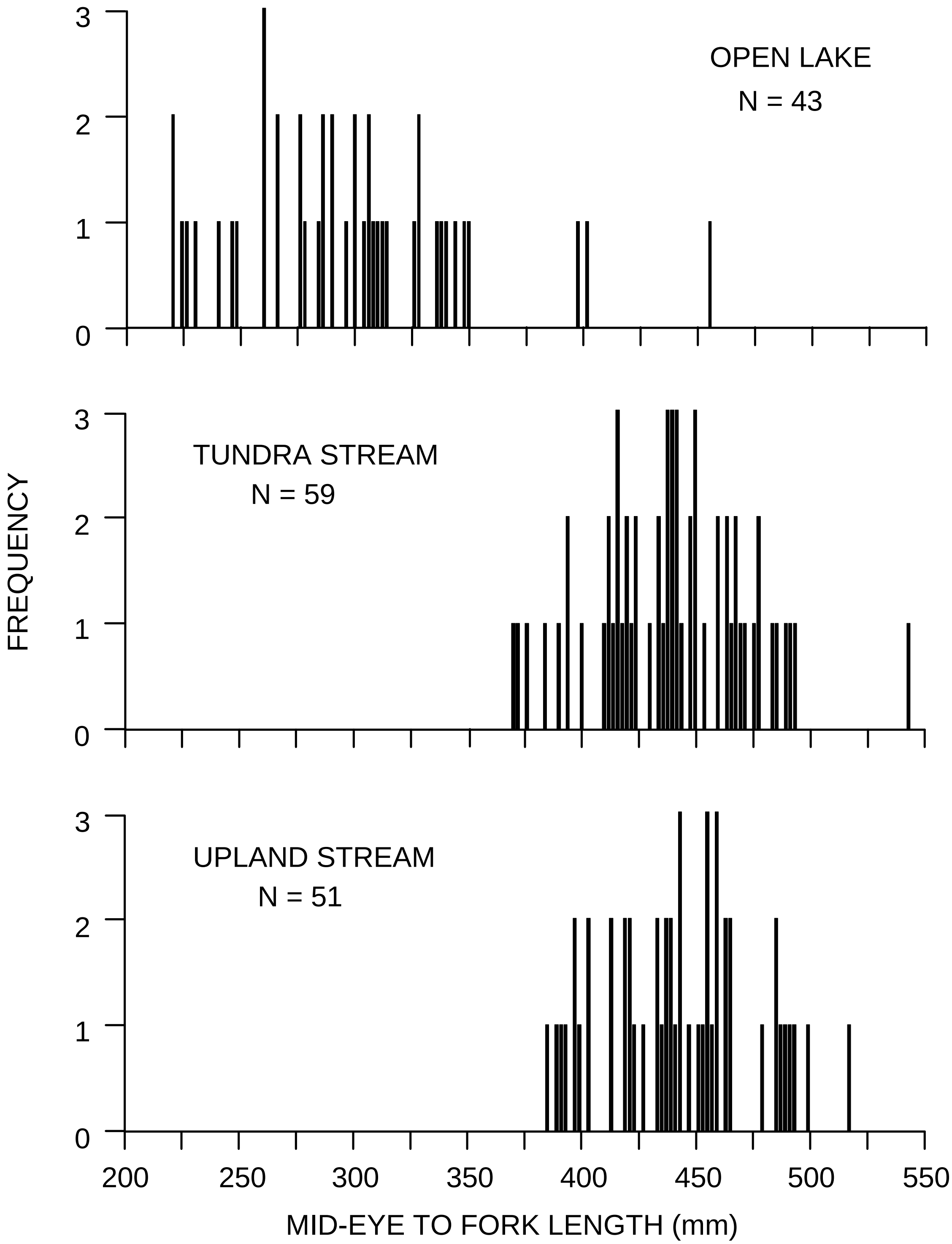

Figure 6.-Length frequency of adult pink salmon captured in open lakes, tundra streams, and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986

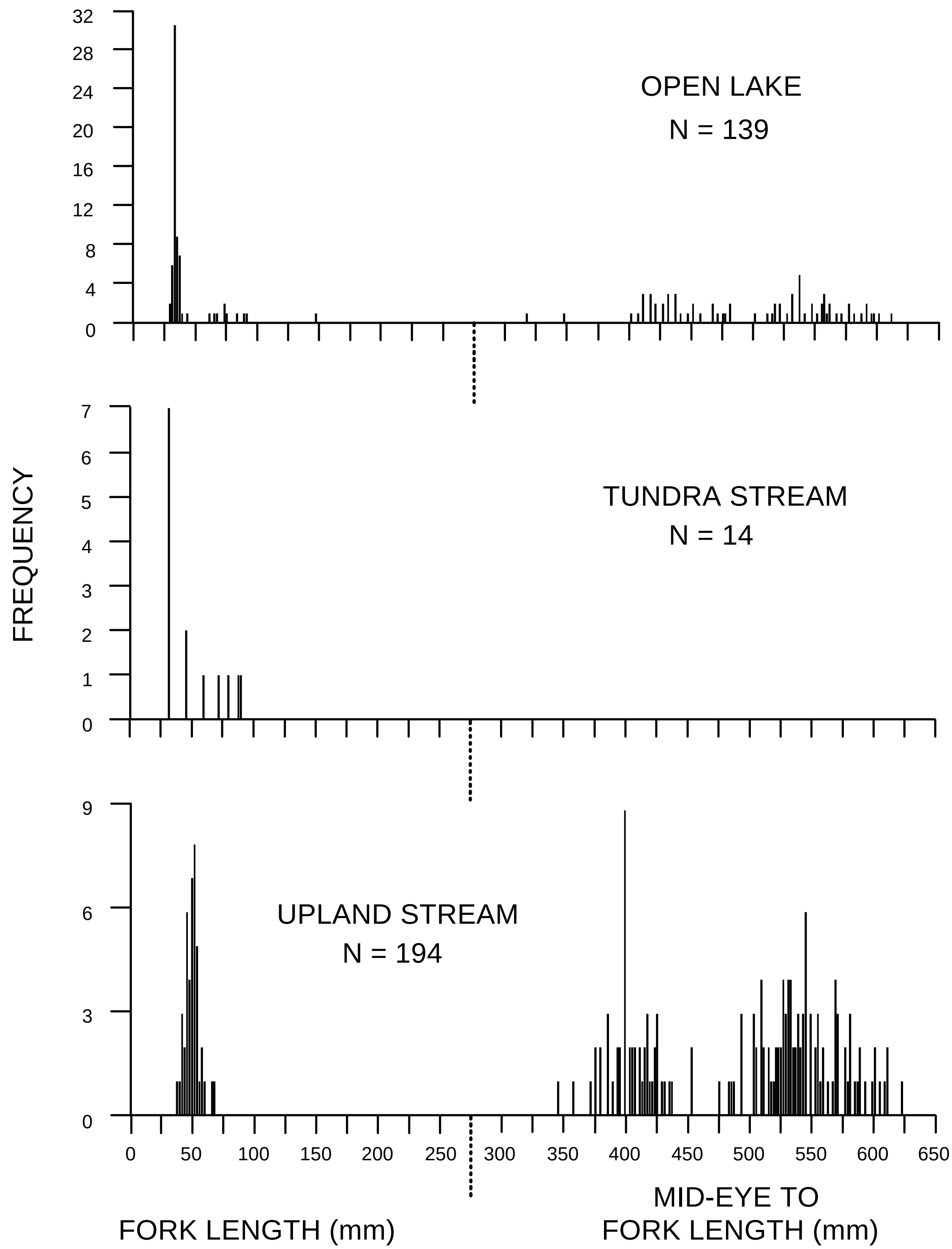

Figure 7.-Length frequency of sockeye salmon captured in open lakes, tundra streams, and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

significant difference for mean weight existed for Dolly Varden captured in the open or closed lakes ($P>0.30$).

Estimated ages of fish captured in the lakes and streams ranged from young-of-year Dolly Varden and chum, coho, and sockeye salmon to age 6 Dolly Varden and age 4.2 coho salmon (Tables 7 and 8). Adult sockeye and coho salmon spanned four age classes, whereas adult pink and chum salmon only comprised two and three ages, respectively. At all corresponding ages, mean lengths at age of juvenile Dolly Varden, juvenile coho salmon, and adult chum salmon from tundra streams were greater than upland streams (Table 8). Adult pink salmon captured in the tundra and upland streams exhibited near identical mean lengths at age.

Limnology, Hydrology, and Water Quality

All nine lakes and five of the eight streams were sampled for limnological, hydrological and water quality characteristics (Tables 9 and 10). Equipment failure prevented sampling on Bluebill Lake outlet, South End Creeks, and Joshua Green River.

Conductivity of the lakes was generally higher than conductivity of the streams. The alkalinity of the streams exhibited a narrower range of values than exhibited in the lakes. The pH was generally the same for both types of water bodies.

Conductivity from four of the five open lakes was higher than in closed lakes (Table 9). Alkalinity from the open lakes exhibited a wider range of values than the closed lakes. The pH in the open lakes was slightly more alkaline than the pH in the closed lakes. Secchi disk readings were generally higher in the closed lakes.

Conductivity and alkalinity were greater in the tundra streams than in the upland streams (Table 10). The pH in the tundra streams exhibited a wider range of values than pH in the upland streams. Discharge in the upland streams (1.6 - 6.4 m^3/s) was greater than tundra streams (0.1 - 0.7 m^3/s).

Lake Bathymetry

The surface areas of the lakes ranged from 5 to 192 hectares, and surface areas of the open lakes were generally larger than closed lakes (Table 9 and Appendix A). Perimeters of all the lakes were irregular, although shoreline development did not differ significantly between the lake types ($P>0.10$). Maximum depth was generally greater and mean depth was significantly greater in the closed lakes ($P<0.05$).

Table 7.-Mean length (mm) at age for salmonids captured in open and closed lakes on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

		Open Lakes				Closed Lakes			
Species	Age	*N*	$\overline{X}$	*SD*	Range	*N*	$\overline{X}$	*SD*	Range
ADULTS									
Chum salmon	0.3	2	597.5	2.5	595-600				
	0.4	1	-	-	515				
Pink salmon	0.1	9	239.8	20.2	220-275				
	0.2	25	311.2	47.3	220-455				
Sockeye salmon	2.1	2	330.0	15.0	315-345				
	2.2	14	509.6	35.7	445-560				
	3.1	1	-	-	555				
	3.2	16	562.2	32.4	480-610				
Arctic char	4					3	137.2	19.6	248-295
	5					2	319.0	0	319
Dolly Varden	5	8	356.8	11.4	329-369				
	6	5	403.6	15.2	390-433				
JUVENILES									
Coho salmon	0	23	39.9	10.3	32-67				
	1	2	131.5	3.5	128-135				
	2	17	159.4	18.1	125-194				
	3	3	248.3	52.6	174-289				
Sockeye salmon	0	57	32.3	2.3	28-42				
	1	9	73.3	10.0	59-89				
Arctic char	2					1	-	-	130
Dolly Varden	3	5	185.2	32.0	155-245				
	4	17	293.4	28.8	238-350				

Table 8.-Mean length (mm) at age for salmonids captured in tundra and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

		Tundra Streams				Upland Streams			
Species	Age	*N*	$\overline{X}$	*SD*	Range	*N*	$\overline{X}$	*SD*	Range
ADULTS									
Chum salmon	0.2					29	534.3	41.6	450-620
	0.3	20	592.0	42.3	515-655	217	573.9	32.6	491-685
	0.4					113	595.9	35.1	510-700
Coho salmon	2.1	1	-	-	461				
	3.1	2	598.0	44.0	554-642				
	3.2	5	606.4	26.0	576-645				
	4.2	3	635.0	27.8	601-669				
Pink salmon	0.2	52	439.7	34.8	369-544	50	443.0	32.1	386-518
Sockeye salmon	2.1					7	394.6	21.4	375-431
	2.2					47	442.6	57.0	372-580
	3.1					18	526.7	46.7	421-589
	3.2					59	546.3	31.7	484-624
Dolly Varden	5	2	335.0	5.0	330-340				
JUVENILES									
Chum salmon	0					11	39.2	2.4	36-45
Coho salmon	0	12	86.8	17.9	46-118	36	82.3	16.7	59-118
	1	66	70.4	17.4	48-129	13	61.9	6.5	50-72
	2	35	114.2	29.0	55-176	3	97.3	9.5	84-105
	3	2	132.0	9.0	123-141				
Sockeye salmon	1	1	-	-	46	2	67.0	1.0	66-68
Dolly Varden	0					2	71.5	0.5	71-72
	1	3	110.7	8.1	104-122	46	80.5	12.1	60-108
	2	1	-	-	140	37	123.2	18.4	93-161
	3	3	182.3	27.4	150-217	6	173.7	19.5	136-200
	4	2	246.0	14.0	232-260	1	-	-	190

Table 9.-Chemical and physical parameters of open and closed lakes on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

	Open Lakes					Closed Lakes			
Parameter	VOR	Lamprey	Bluebill	Swan	Paul Hansen	Stapp	Blinn	Boggle	Rescue
Surface area (ha)	31	20	80	76	192	27	43	5	62
Maximum depth (m)	2.4	1.4	0.8	0.9	1.8	1.7	13.1	4.9	9.7
Mean depth (m)	1.4	1.0	0.4	0.4	1.2	1.2	4.6	1.2	2.4
Shoreline development	1.5	1.6	2.1	1.5	1.9	1.4	1.6	1.7	1.5
Conductivity (*u*S/cm)	73	75	74	138	52	45	50	60	61
Alkalinity (mg/L)	13.5	23.6	34.0	0.1	59.0	5.4	1.7	8.0	24.5
pH	7.3	7.5	7.0	8.0	7.0	7.0	7.3	6.5	7.0
Secchi disk (m)	2.4	1.3	-	0.5	1.2	1.7	1.5	4.1	6.1
DO (mg/L)	-	-	12.0	9.7	11.2	-	-	11.5	11.1

Table 10.-Conductivity, alkalinity, pH, and discharge measurements of tundra and upland streams on Izembek National Wildlife Refuge and on the Pavlof Unit of Alaska Peninsula National Wildlife Refuge, 1985 and 1986.

Stream	Conductivity (μS/cm)	Alkalinity (mg/L)	pH	Discharge (m^3/s)
TUNDRA				
Lamprey Lake outlet	75	19.2	7.7	0.1
Stapp Creek	55	29.1	6.9	0.2
Trout Creek	56	17.8	6.7	0.7
UPLAND				
Frosty Creek	27	14.7	6.9	1.6
Russell Creek	28	6.8	7.0	6.4

DISCUSSION

Fish Species Composition and Distribution

The fish species found on the Refuges generally reflect the geographic range reported in the literature (Hart 1973; Morrow 1980; and Scott and Crossman 1973). However, the presence of fourhorn sculpin and ninespine stickleback within the study area represents a range extension for each of these species. Tack (1970) did not capture either of these species in Izembek Lagoon during July. Morrow (1980) reports the range of fourhorn sculpin extended only as far south as Pastol Bay, north of the Yukon River delta. Morrow (1980) also states that ninespine stickleback had been reported only as far south as the Port Heiden area. Whether these species exhibit seasonal movements, had recently moved into the study area, or simply were not previously collected is not known.

Three fish species have been reported to occur within the study area but were not captured during sampling: chinook salmon (U.S. Fish and Wildlife Service 1985b, Morrow 1980); lake trout (Morrow 1980); and steelhead trout (U.S. Fish and Wildlife Service 1985b, Alaska Department of Fish and Game 1978). Some possible reasons these fish were not captured include: they exist in low numbers; they occur in waters that were not sampled; or the time of sampling did not coincide with the species' availability.

Open lakes exhibited a greater fish species diversity than the closed lakes due to their connections with marine water. The connection made it possible for four species of salmon to enter the open lakes. Swan Lake contained fourhorn sculpin, a brackish water species (Morrow 1980). Since Swan Lake is located very close to the shore of Cold Bay, the tidal influx of salt water probably allowed fourhorn sculpin to survive.

Stapp Lake was unique among the closed lakes because it contained only Dolly Varden. Landlocked Dolly Varden have only been reported from arctic Alaska and Kamchatka, U.S.S.R. (Armstrong and Morrow 1980; Morrow 1980). The presence of Dolly Varden within Stapp Lake provides a significant range extension for landlocked Dolly Varden. Stapp Lake was also the only lake that did not contain threespine stickleback. However, minnow traps were not used to sample the lake which may explain the absence of this species.

Arctic char and Dolly Varden were captured in both the open and closed lakes. Their presence suggests that anadromous and resident forms of each species may occur in the sampled waters. Anadromous and resident forms of these species have been documented in Alaska, although Arctic char are generally considered to be a resident species (Morrow 1980).

Tundra streams exhibited a greater species diversity than the upland streams, although the upland streams exhibited a more consistent species composition. Ten species were captured in the tundra streams, but none of these streams had the same species composition. The upland streams contained only seven species and three of these streams exhibited the same species composition. The characteristics of the tundra streams (i.e., more stable stream banks and less fluctuating discharges) may provide suitable habitat for species adapted to either high or low discharges. Conversely, variable flows and active stream banks of the upland streams may provide suitable habitat only for those species adapted to higher discharges. Species adapted to the lower discharges may not be able to survive in the upland streams, while species adapted to higher discharges are probably able to survive in the tundra streams. Species unique to the tundra streams were not captured in the lower reaches of the upland streams where water velocities were similar. However, conductivity and alkalinity in the tundra streams were greater than in the upland streams which may affect species distribution.

No juvenile pink salmon and only 11 juvenile chum salmon were captured in the tundra and upland streams during the study. Bricker (1982) found 99% of the chum salmon fry in Russell Creek had outmigrated prior to 1 June and 100% of the pink salmon outmigrated prior to 15 May. The earliest stream sampling during this study began on 30 May 1985 and apparently occurred after the majority of these juveniles had outmigrated.

Length, Weight, and Age

Chum, coho, pink, and sockeye salmon, and Dolly Varden from the Refuges generally exhibited length, weight, and age characteristics similar to other Alaska populations (Armstrong and Morrow 1980, Bue 1986, McCullough 1987, and Morrow 1980). However, the age of adult pink salmon and Dolly Varden found on the Refuges differed from other Alaska populations.

Pink salmon usually return to spawn at age 0.2 and do not exhibit much variation in age at return (Scott and Crossman 1973). However, nine (26.5%) of the adult pink salmon captured in Swan Lake were age 0.1. Heard (1991) reported that age 0.1 returning adult pink salmon are considered rare exceptions to the two year cycle. The commercial fishery harvests few age 0.1 pink salmon (Arnie Shaul, Alaska Department of Fish and Game, personal communication). While age 0.1 returning pink salmon do exist, the large proportion found in this sample may be unique to the Swan Lake stock.

The maximum age of Dolly Varden from the Refuges was considerably less than the maximum age of Dolly Varden from other regions of Alaska. Ages of Dolly Varden from the Refuges ranged from 3 to 6 years. Ages of Dolly Varden in arctic Alaska range from 3 to 10 years (Morrow 1980), and from 2 to 11 years in southeast Alaska (Armstrong and Morrow 1980). A small number of older Dolly Varden may have been present. However, limited sampling efforts would reduce the probability of capture.

Length and weight data for both Dolly Varden and coho salmon allowed the lake and stream rearing habitats to be compared assuming greater length and weight indicated better rearing environment. Lakes appeared to provide better rearing habitat than streams. Tundra streams appeared to provide a better rearing environment that the upland streams. Environmental stability, food availability, competition, or habitat preference may explain the differences. Lakes and tundra streams are not subject to extreme temperature, flow, and sediment load fluctuations found in the upland streams. The more stable environment may allow fish to use less energy to maintain position in the water column and use the saved energy for growth. More food may be available in the lakes and tundra streams, which would explain the difference in fish size. Conductivity in the lakes was higher than conductivity from the streams. Higher conductivity may indicate greater productivity (Cole 1979) and better growth conditions. Because larger fish have a competitive advantage, smaller fish may be forced to utilize different habitat types. Conversely, there may be a age/size specific difference in habitat preference.

Limnology, Hydrology, and Water Quality

Lakes

Data from this study indicate that open lakes have greater productivity than closed lakes. Indicators of productivity include conductivity, alkalinity, and pH (Cole 1979), as well as shallow depth and shoreline development (Wetzel 1975). Chemical parameters from the open lakes were generally higher than the closed lakes, and the open lakes exhibited significantly less mean depth. Although shoreline development was not significantly different between the two lake types, it was generally greater in the open lakes.

The stream connections of open lakes may directly influence productivity. In northern areas, poorly drained (closed) lakes may become bogs (Cole 1979), which typically exhibit low pH values and poor productivity (Rutner 1974). Higher pH may indicate higher productivity (Cole 1979), and the open lakes from the study area generally exhibited higher pH than the closed lakes. The stream connections of the open lakes apparently provide a flushing action that prevents them from becoming bog-like. Stream connections in the open lakes also influence the lake productivity by allowing salmon to enter the lake and lake tributaries. The nutrients released from the decomposed salmon carcasses act as fertilizer and stimulate productivity.

The dissolved oxygen values of the sampled lakes exceeded the levels required to support fish populations. At similar temperatures to those found in the sampled waters, the minimum oxygen requirement for adult sockeye salmon was between 5.0 and 6.7 mg/L (Davis 1975). Lake dissolved oxygen exceeded the minimum value by 4 mg/L.

Swan Lake exhibited chemical characteristics that were unusual. The conductivity was higher and the alkalinity was lower than the other lakes in the study. The high conductivity was probably due to the tidal influx of salt water. The low alkalinity may have resulted from the reaction of salt water with the edaphic properties of the lake basin.

Streams

Besides supporting larger Dolly Varden and juvenile coho salmon, chemical characteristics indicated that the tundra streams were more productive than the upland streams. Conductivity and alkalinity were higher in the tundra streams, although no trends in pH were apparent.

Russell Creek was the only sampled water body with a historical record of water quality. Values for conductivity and alkalinity on Russell Creek during December 1975 were 47 *u*S/cm and 10 mg/L (Bricker 1978). These values were slightly higher than the values collected during June-August 1985. The differences could be due to sampling location, discharge fluctuations, or season. The pH of 7.0 for June-August 1985 was within the range previously recorded from the stream.

Lake Bathymetry

The sampled lakes on the Refuges can be categorized as "kettle lakes" which appear to be typical of the small, shallow tundra lakes found on the Alaska Peninsula. These lakes were formed during the retreat of decaying glaciers. Ice blocks broke off of the retreating glaciers and were covered with glacial drift material (Wetzel 1975). The ice block eventually melted leaving behind shallow lake basins that have irregular shorelines and underwater relief.

Lake productivity increases with increasing shoreline development and decreasing depth (Wetzel 1975). Therefore, the sampled lakes would be classified as productive since they are shallow and most of the lake lies within the photic zone. However, the small sizes of the lakes limit the actual fish production. These lakes provide significant rearing habitat for the localized small fish stocks, but the production of large numbers of fish is physically limited.

Recommendations

Because the lakes and streams sampled were not randomly selected, the data may not be representative of the fish populations present nor indicative of the physical and chemical characteristics of all the waters on the Refuges. Sampling locations within a water body may have influenced the number and species of fish captured. Constraints on logistics and manpower limited the frequency, timing, and amount of sampling that each water body received. Gear selectivity, the combining of data from all gear types, the opportunistic use of some gear types, and the use of subsamples may have biased the analyses of fish population structures. Small or highly variable sample sizes precluded meaningful comparisons of some of the data. However, this survey of selected waters of Izembek National Wildlife Refuge and the adjacent Pavlof Unit of the Alaska Peninsula National Wildlife Refuge will serve as a cursory baseline for fish resource management on these lands.

Additional studies will complement the collected data and refine the interpretation. Recommendations for future studies include: (1) begin sampling earlier in the year so chum and pink salmon fry will be captured; (2) extend the sampling season to collect more adult coho salmon; (3) investigate the existence of other populations of landlocked Dolly Varden in the area; (4) confirm the existence of age 0.1 adult pink salmon in Swan Lake or other water bodies; and (5) collect time series data for fish abundance and water quality to document seasonal fluctuations. With this additional information, management priorities and strategies can be developed. The additional information would allow implementation of a management plan to proceed more promptly and efficiently.

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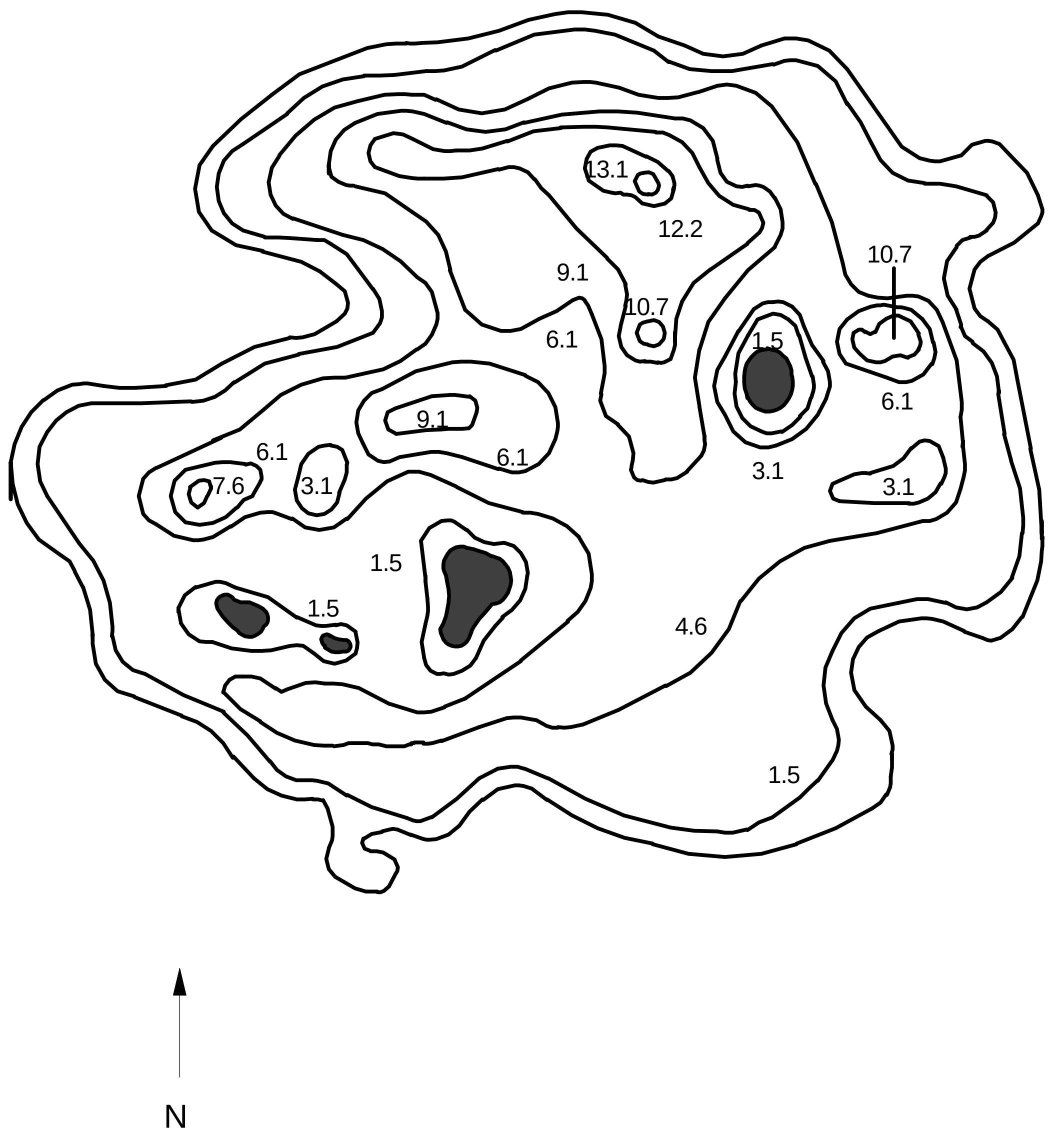
APPENDIX A

Bathymetric maps of lakes on the Izembek National Wildlife Refuge and on the Pavlof Unit of the Alaska Peninsula Refuge, 1985 and 1986.



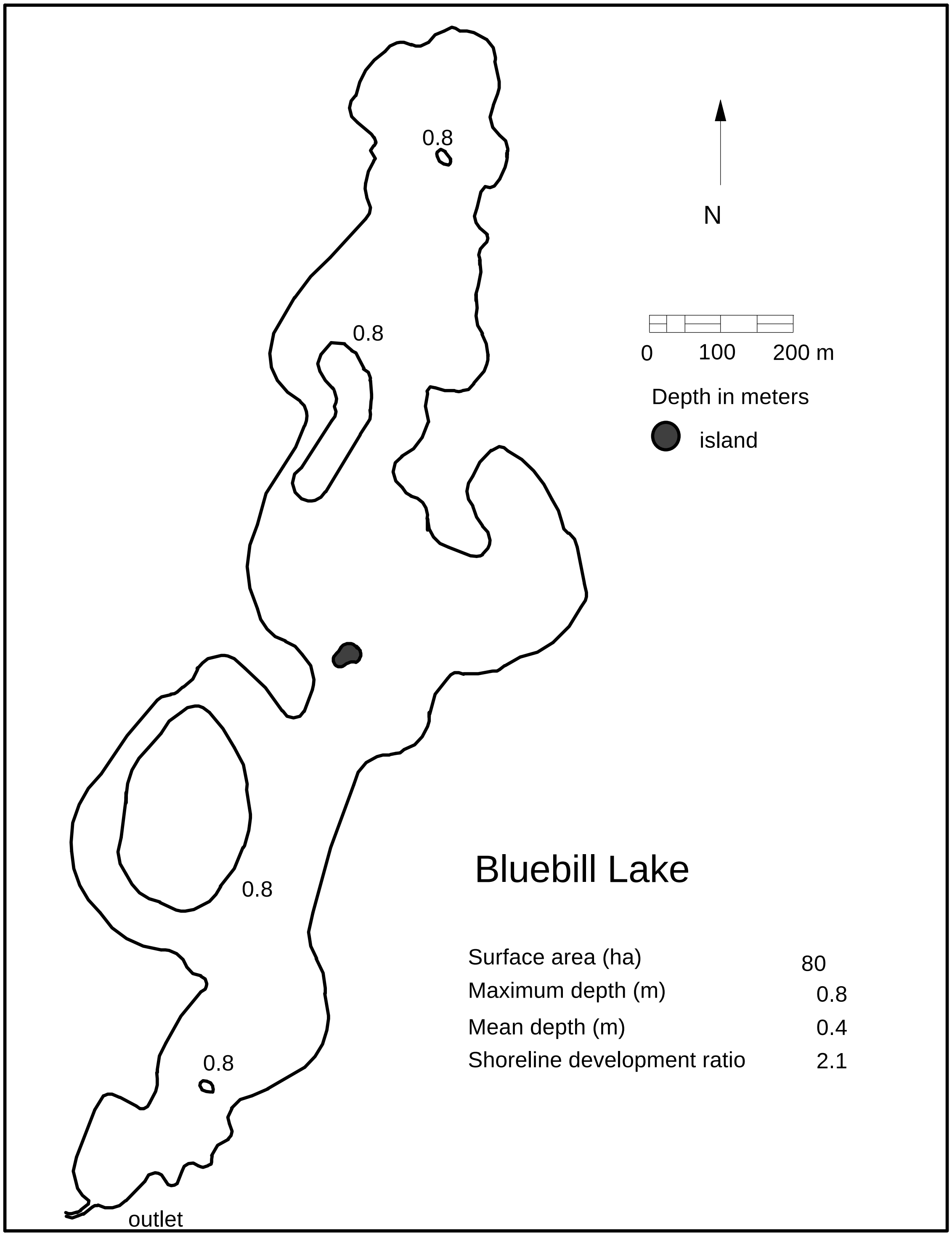
Blinn Lake

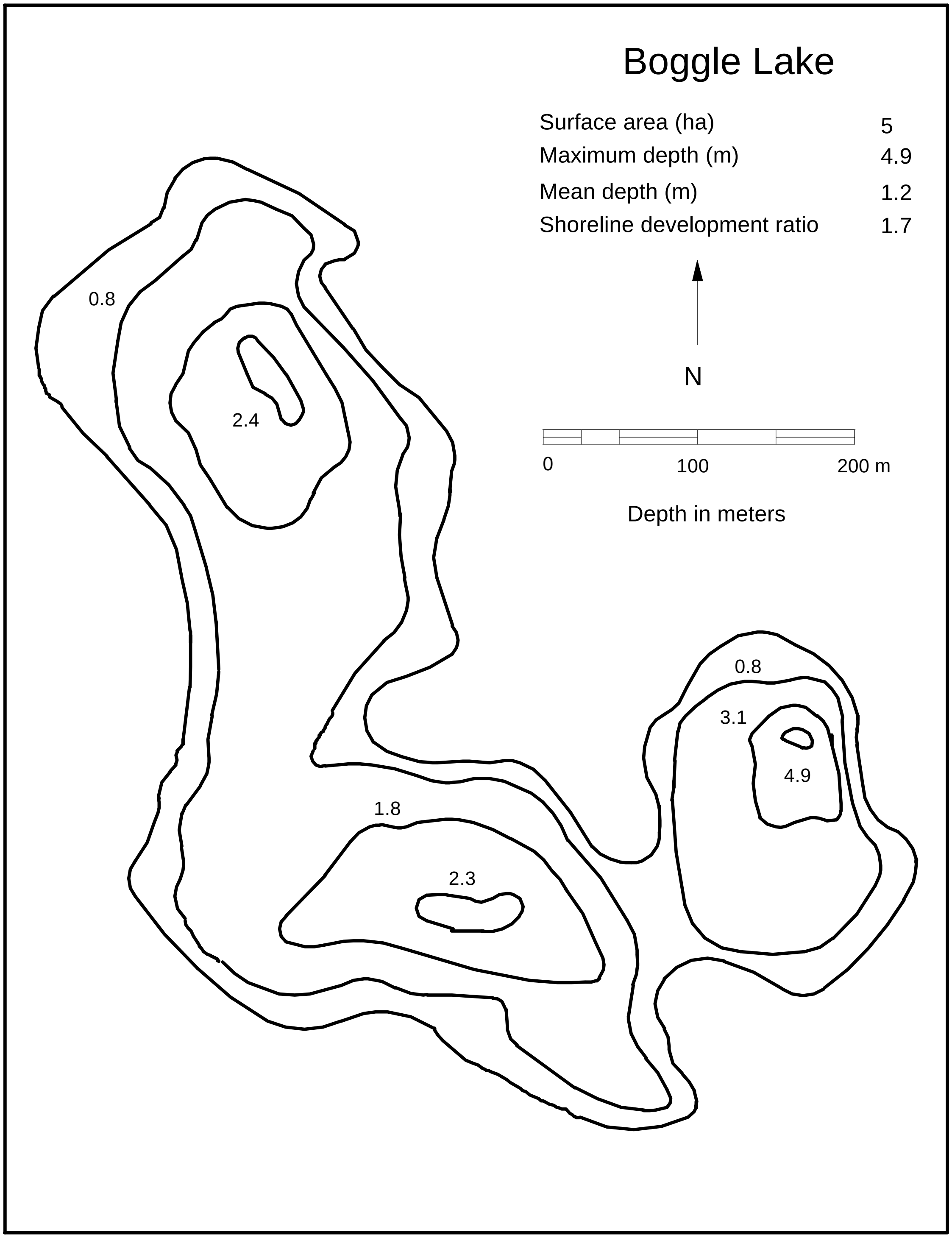
0 100 200 m

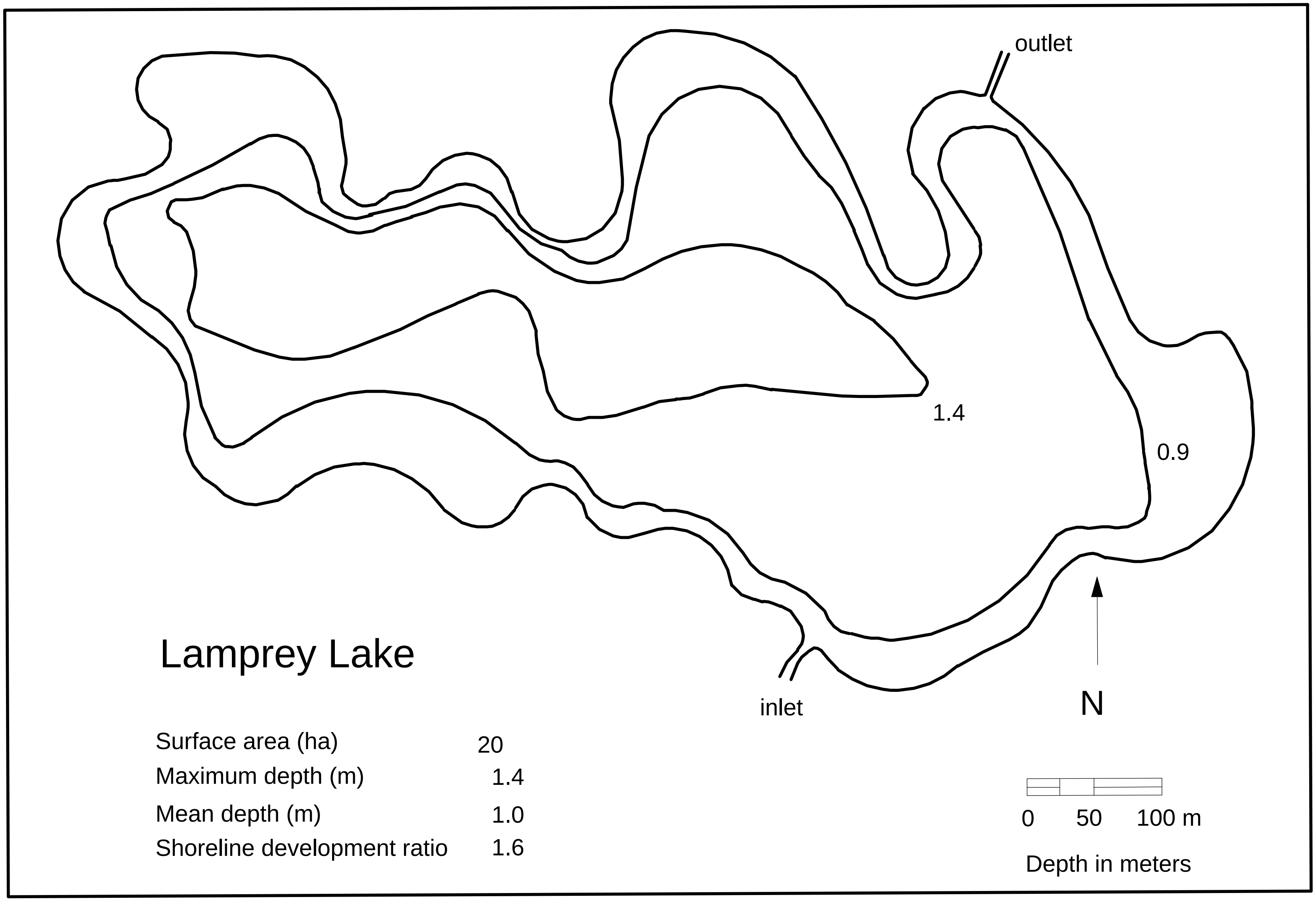
Depth in meters

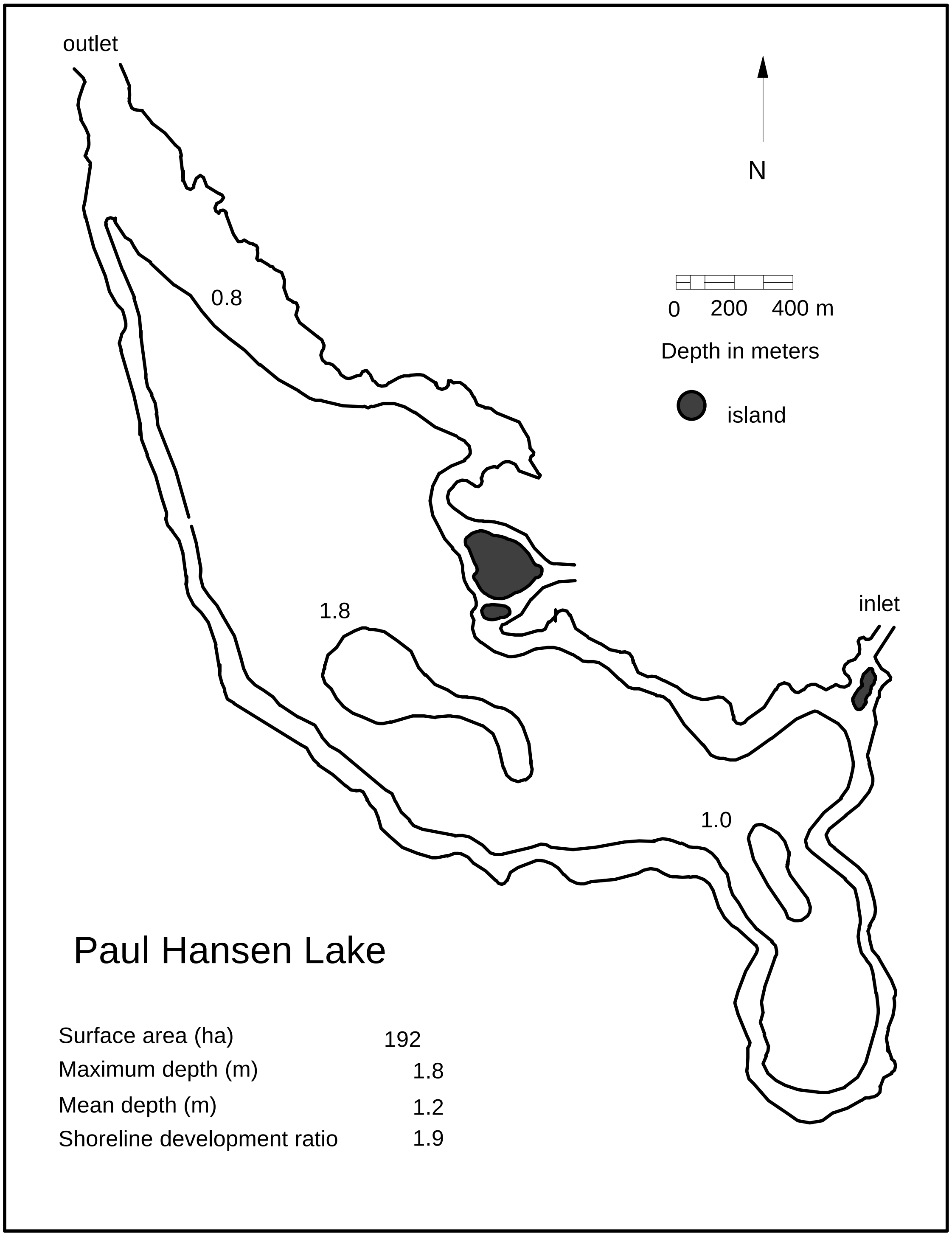
island

Surface area (ha)	43
Maximum depth (m)	13.1
Mean depth (m)	4.6
Shoreline development ratio	1.6


0.8
0.8
0.8
0.8
N
0 100 200 m
Depth in meters
island
Bluebill Lake
Surface area (ha) 80
Maximum depth (m) 0.8
Mean depth (m) 0.4
Shoreline development ratio 2.1
outlet

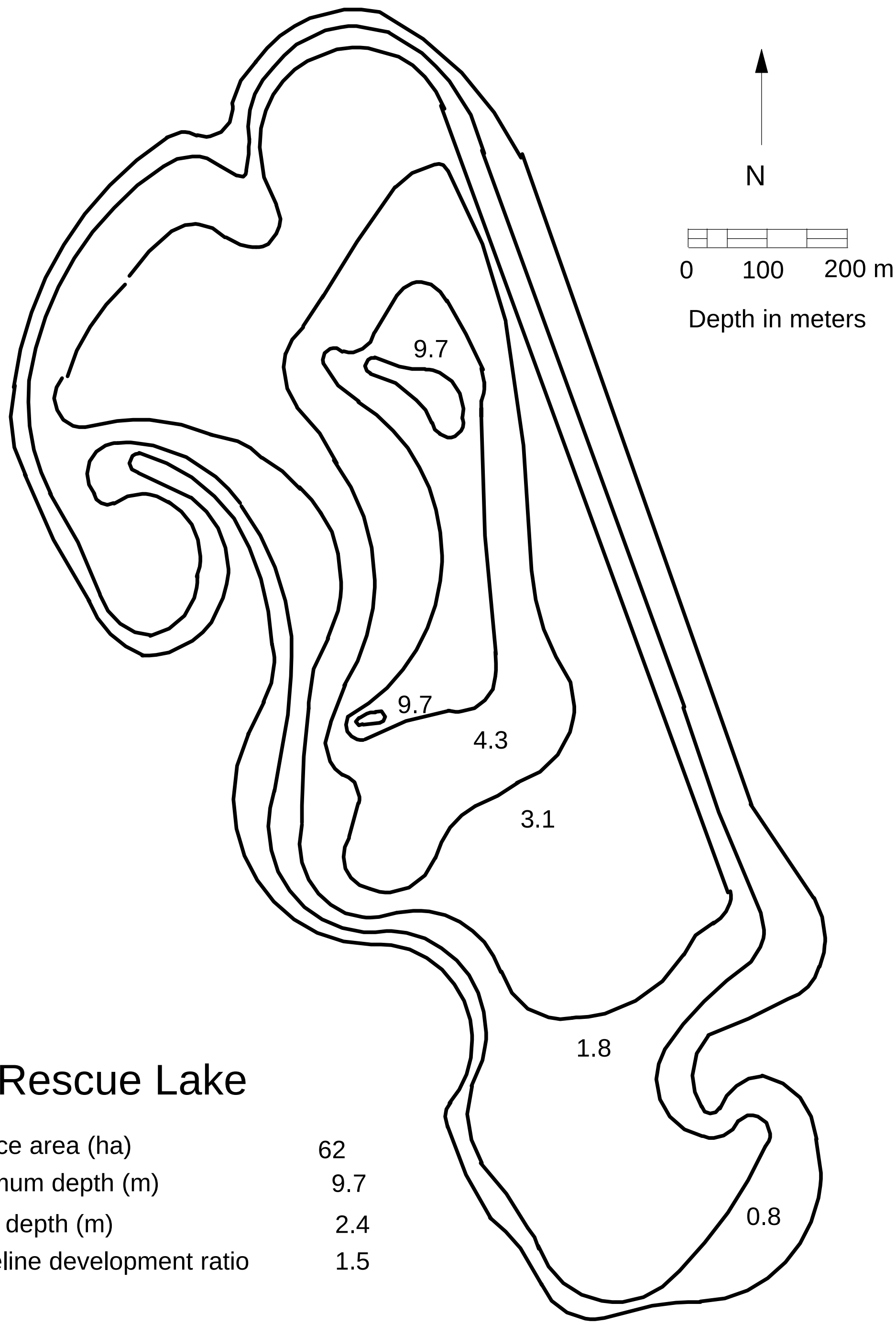

Boggle Lake
Surface area (ha) 5
Maximum depth (m) 4.9
Mean depth (m) 1.2
Shoreline development ratio 1.7
N
0
100
200 m
Depth in meters
0.8
2.4
0.8
3.1
4.9
1.8
2.3


outlet
1.4
0.9
inlet
N
Lamprey Lake
Surface area (ha) 20
Maximum depth (m) 1.4
Mean depth (m) 1.0
Shoreline development ratio 1.6
0 50 100 m
Depth in meters



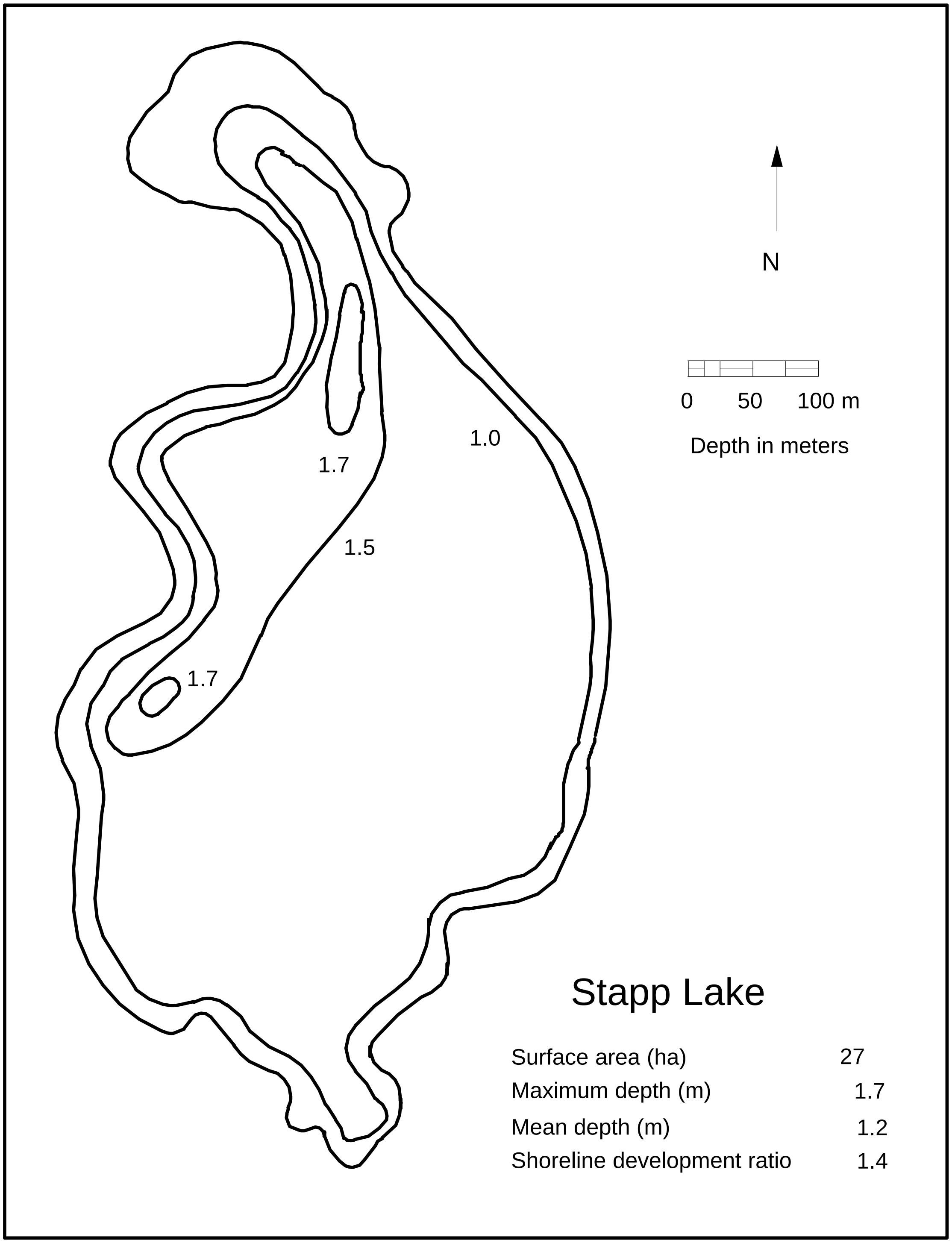
Paul Hansen Lake

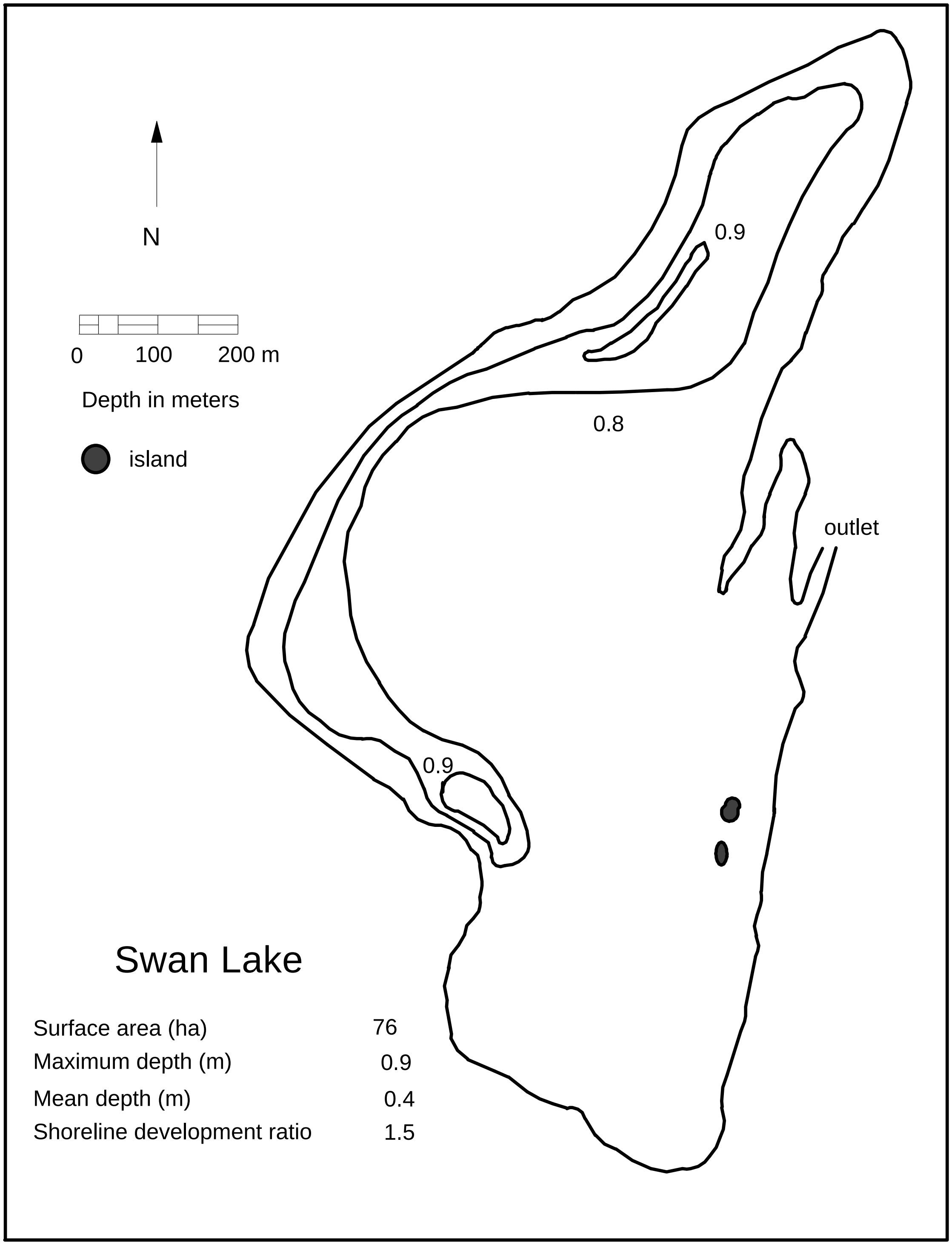
Surface area (ha)	192
Maximum depth (m)	1.8
Mean depth (m)	1.2
Shoreline development ratio	1.9

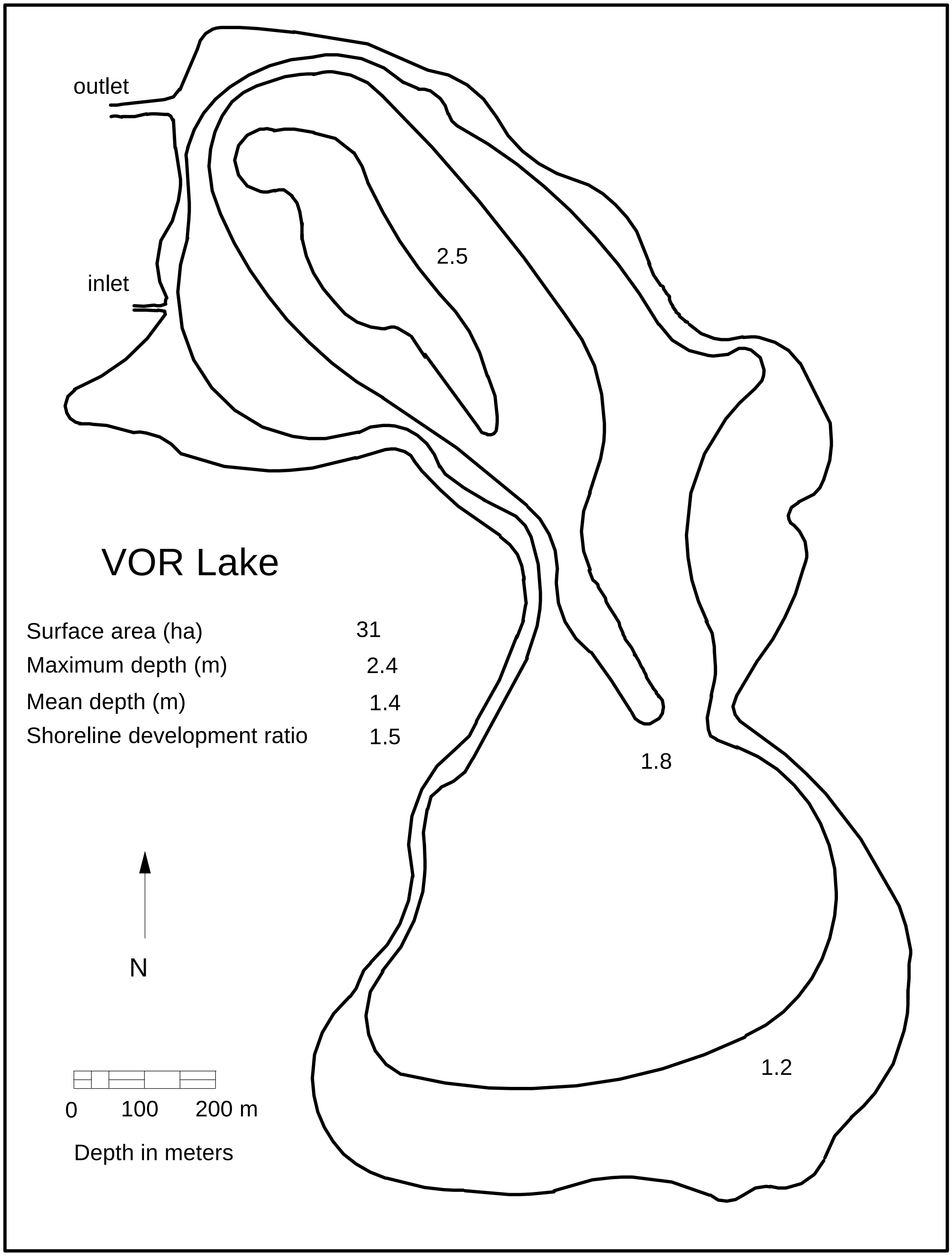


Rescue Lake

Surface area (ha)	62
Maximum depth (m)	9.7
Mean depth (m)	2.4
Shoreline development ratio	1.5


N
0 50 100 m
Depth in meters
1.0
1.7
1.5
1.7
Stapp Lake
Surface area (ha) 27
Maximum depth (m) 1.7
Mean depth (m) 1.2
Shoreline development ratio 1.4


N
0
100
200 m
Depth in meters
island
0.9
0.8
0.9
outlet
Swan Lake
Surface area (ha) 76
Maximum depth (m) 0.9
Mean depth (m) 0.4
Shoreline development ratio 1.5


outlet
inlet
2.5
VOR Lake
Surface area (ha) 31
Maximum depth (m) 2.4
Mean depth (m) 1.4
Shoreline development ratio 1.5
1.8
N
1.2
0 100 200 m
Depth in meters