HRSEP 99-NCC-ST-025
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HRSEP 1999/2000 Final Report

Category (Check one)	___	RWS	(Resource & Watershed Stewardship)
	___	HR	(Habitat Restoration)
	X	ST	(Stock Rebuilding)
Area (Check One)	___	VI	(Vancouver Island & South Coast)
	X	NCC	(North & Central Coasts)
	___	FRB	(Fraser River Basin)
	___	YT	(Yukon Territory)

Proponent Information

Organization Name :	Fisheries and Oceans Canada, Science Branch
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Did you receive DFO input on this project? X Yes/No

Name of DFO Contact(s): Sandie MacLaurin

Project Information

Project Title :	Atnarko sockeye enhancement feasibility study: phase 2
Start Date :	June 1999
End Date :	April 2000
Project Rationale (Problem being addressed)	Assess the feasibility of creating and managing a large harvestable surplus of sockeye salmon by outplanting sockeye fry from Atnarko River broodstock into Charlotte Lake, a large, clear lake at the headwaters of the Atnarko River on the Chilcotin Plateau. This style of enhancement has been successful in the Stikine River (Tuya Lake) and in other Alaskan lakes. Part A addresses issues of production and manageability of fisheries within the Bella Coola valley; Part B is a stock ID program to address the manageability of marine fisheries on the central coast.

Was a feasibility study or pre-assessment done for this project? Yes

If yes, please describe.

Charlotte Lake is inaccessible to adult sockeye, but offers excellent rearing habitat for juvenile sockeye that is unutilized by other limnetic fishes. It is almost one third the size of Chilko Lake, is situated at the same elevation, and is comparable in terms of primary productivity. Thus, outplanting to Charlotte Lake appears to provide a cost-effective, large-scale enhancement opportunity.

The main results from phase 1 of this feasibility study (1996-1997) are as follows:

1) Lake-type sockeye were available as potential broodstock in sufficient numbers at spawning sites just upstream of Lonesome Lake in the Atnarko River in both 1996 and 1997. All 53 fish tested in 1997 were free of viruses detectable by tissue culture assay (including the IHN virus), and free of significant bacterial pathogens, with the exception of two fish that tested positive for BKD. Incubation at the nearby Snootli hatchery facility appears feasible, although logistical constraints and policy issues regarding the incubation of sockeye require further consideration.

2) Limnological survey data indicate that Charlotte Lake could produce 10 million smolts if seeded to capacity with an estimated 25 million fry. These estimates were obtained from the PR model (Shortreed et al. 2000. p. 505-521 *In* Knudsen et al. (ed.) Sustainable Fisheries Management: Pacific Salmon, CRC Press) using measurements of lake size and primary productivity, and are similar to levels of production achieved in Chilko Lake, after adjusting for lake surface area. The paucity of limnetic fish, together with the large size and relatively high abundance of preferred zooplankton (e.g., *Daphnia*) confirm that Charlotte Lake would provide an ideal rearing area for juvenile sockeye.

3) Reconnaissance of the Atnarko River below Charlotte Lake indicated only one waterfall large enough to prevent access upstream by adult sockeye, but this did not present any obvious threat to smolts moving downstream. Although no single section of the river would be problematic for smolt migration, the gradient was consistently steep (5.75%) for about 9 km, so it is possible (but unlikely?) that smolts would be adversely affected by the turbulence of the overall descent.

4) Sockeye also spawn in numerous locations below Lonesome Lake. Based on samples collected from two of these sites, most are sea-type sockeye that constitute another stock, distinct from the lake-type sockeye spawning above Lonesome Lake. Sea-type sockeye should be avoided as broodstock for outplanting to Charlotte Lake. Moreover, the need to constrain harvest rate on the sea-type sockeye stock may limit harvesting opportunities on enhanced lake-type sockeye, unless differences in run-timing can be identified. A sampling program to address this possibility was initiated by non-DFO partners in 1997 but too few samples were obtained to be useful. This must be addressed again in Phase 2.

Activity Type

Check all that apply

Inventory & Mapping		*Stock Assessment*	X
Public Awareness		*Habitat Restoration*	
Stock Enhancement	X	*Stewardship/Community Planning*	
Other		*Specify*	

Project Objectives (from your proposal and/or agreement)

Objective # 1 :	**Part A1):** Investigate the current limitations to sockeye production in the Atnarko River by conducting limnological and fry surveys of Lonesome Lake to confirm that its rearing potential is already fully utilized.
	Part A2) Obtain sufficient sockeye samples from the Bella Coola sockeye fishery, and perform stock composition analyses, to determine the run timing of sea-type and lake-type stocks of Atnarko sockeye. This information is needed to assess whether an enhanced lake-type sockeye run could be harvested selectively and intensively without overfishing the wild sea-type sockeye stock. (To be contracted to partners.)
Was it achieved?: Yes/No + Details	Part A1) Yes, see trip reports (Appendices 1 and 2)
	Part A2) No scales or data were received from Nuxalk partners despite pre-season planning and agreement. However, a sample of 108 ageable scales was provided by Wally Weber (DFO office in Bella Coola) (Appendix 3).
Objective # 2 :	Part B1) Collect tissue samples and biological data from at least 5 coastal sockeye populations that might be harvested in marine fisheries targetting on enhanced Atnarko sockeye. (This work could be contracted out to partners.)
	Part B2) Assay tissue samples for genetic variation (including microsatellite DNA variation) and assemble baseline data for stock identification. This research will complement recent studies of DNA variation in sockeye from Long and Owikeno lakes supported by HRSEP in 1997/98 and will help to complete the coastwide B.C. microsatellite DNA baseline.
Was it achieved? : Yes/No + Details	Part B1) No samples were provided by Nuxalk partners despite preseason planning and agreement. However, samples were collected opportunistically by the Kitasoo Band (Mary's Cove and Lagoon lakes), the Rivers Inlet Restoration Society (Wannock River), and a DFO crew from Prince Rupert (Devon and Mikado lakes).
	Part B2) Yes; also analyzed archived tissue samples because fewer samples were collected in 1999 than expected (Appendix 4).

Partnerships

List and describe the personnel involved in the project.

Objectives and procedures for activities to be conducted by Nuxalk partners (Parts A2 and B1) were discussed with Nelson Tallio by telephone and e-mail in late June-early July and in person in Bella Coola, 21 July 1999. To my knowledge, nothing useful (with respect to this proposal) was achieved. Note that funding for these components of the proposal was not provided directly by HRSEP, but by an AFS contribution specifically for this activity. Apparently, HRSEP reduced funding to the DFO coordinator (C. Wood) accordingly.

# of persons trained ______
# of persons employed ______
person-days of employment created ______
# of volunteers involved ______
# of volunteer hours ______

Is the local community involved in this project? List and describe the partnerships involved.

Local assistance was provided by:
1) Kitasoo Band (contact Larry Greba)
2) DFO offices in Bella Coola (Wally Weber, Lyle Enderud, Russ Hilland, Sandie MacLaurin)
3) DFO office in Prince Rupert (contact Brian Spilsted)

Project Location
Complete as fully as possible.

	(Details – name, code or other)
Water body / System(s)	Bella Coola/Atnarko rivers; also small coastal sockeye lakes in Areas 5-8
Watershed(s)	See above
Nearest Community	Bella Coola
Other Geographic Information	

Latitude/Longitude ______ *UTM Coordinates* ______

Results/Quantifiable Measures

Species Addressed (Check as many as applicable)

____ *Coho* ____ *Pink*
____ *Chum* ____ *Chinook*

X *Sockeye* ______ *Other*

Habitat Addressed (Check as many as applicable)

______	*In-channel*	______	*Off-channel*
______	*Riparian*	______	*Estuarine/Marine*
	X *Lake*	______	*Other*

For Mapping & Inventory Projects:

Was your data collected according to the DFO-HEB Info Mgmt. guidelines? (ref. Brad Mason) *Yes/No*

If yes, was it submitted in digital format? ______

Linear metres of area mapped: ______

Other: ______

For Stock Rebuilding Projects:

 # Adult Salmon Enumerated: ______

 # Juvenile Salmon Enumerated: *120000*

 # Salmon marked/Tagged or released: ______

collected/aged scales from 108 fish caught in Bella Coola River fishery

collected DNA tissues from 309 fish

assayed microsatellite DNA in 1519 specimens (including archived specimens)

surveyed 3 or 4 nursery lakes for physical/chemical status, zooplankton, primary producitivity

collected length and weight data for 25 juvenile sockeye caught by trawl in Lonesome Lake

For Stewardship/Community Planning Projects:

 # Public Presentations/Media Releases: ______

 # Landowners Contacted: ______

Other: ______

For Habitat Restoration Projects:

Fencing:	*Stream length protected*	______	*km*
	Stream area (fence to bank) protected	______	*sq. meters*
Riparian replanting:	*Area replanted*	______	*sq. meters*
	# trees/plants	______	
In-channel habitat:	*Stream area restored*	______	*sq. meters*
Off-channel habitat:	*Stream area created/restored*	______	*sq. meters*
Estuarine habitat:	*Area created/restored*	______	*sq. meters*
Lake habitat:	*Area created/restored*	______	*sq. meters*
Fish Access:	*Length of stream made available*	______	*km*
	Area of habitat made available	______	*sq. meters*

Other: __________________

Project Description

Please enter a general project description below. Please include an overview of the methods and techniques used. If required, you may attach an additional sheet.

Part A1) A complete limnological survey of 3 sockeye nursery lakes in the Atnarko Valley (Lonesome, Rainbow and Elbow lakes) was conducted to determine their physical and chemical characteristics and to estimate their current trophic status and potential rearing capacity. This work was "subcontracted" to experts at the DFO Cultus Lake Laboratory (see trip report by Ken Morton and Ken Shortreed in Appendix 1). A hydroacoustic and trawl survey of Lonesome Lake was conducted within the same month to estimate juvenile sockeye abundance, distribution, density, size and age composition. These data, taken together with the limnological survey data, can be used to infer whether rearing habitat in Lonesome Lake is being fully utilized by juvenile sockeye or other species at current seeding (escapement) levels (see Appendix 2).

Part A2) Freshwater age composition determined from scales and the prevalence of the *Philonema* parasite can be used to distinguish the sea-type and lake-type subpopulations that spawn below and above Lonesome Lake, respectively. Nuxalk partners (contact Nelson Tallio) agreed to sample weekly catches from the First Nations sockeye fishery in the Bella Coola River for scales and the presence/absence of the roundworm parasite *Philonema*. The DFO office in Bella Coola (contact Wally Weber) offered to provide backup support.

Part B1) Tissue samples for DNA analysis (one fin or operculum punch per fish) were collected non-lethally from sockeye spawning in coastal systems outside the Atnarko River. To be useful as a stock ID baseline, sockeye had to be collected from known spawning locations (i.e., present on spawning grounds or known to be migrating to a particular lake system). Tissue samples were stored in labelled vials containing >70% ethanol or propanol. Nuxalk partners (contact Nelson Tallio) agreed to collect samples from sockeye spawning in coastal lakes, with priority to be placed on Kitlope and Kimsquit lakes. The Kitasoo Band (contact Larry Greba) also offered to collect samples from sockeye in lakes in Area 7. Arrangements were also made within DFO (contacts Lyle Enderud and Brian Spilsted) to sample other coastal lakes as opportunity allowed.

Part B2) Tissue samples collected in 1999 (part B1) and additional samples from archived collections were analyzed by Seastar Biotech (under contract) for DNA variation at 10 independent microsatellite loci. A total of 1519 specimens were analyxed (see Appendix 4). These data were used first, to look for possible population structure within complex lake systems (e.g., the Atnarko River and Owikeno Lake), and second, to develop reference (baseline) data for analyzing the stock composition of mixed stock fisheries on the central coast.

Follow-up & Monitoring

Please describe the current status of the project. Has the problem being addressed been solved? (see "project rationale") What are the ongoing issues in the area and your recommendations for future work.

The project was completed successfully despite inadequate participation by Nuxalk partners. The main conclusions are as follows:

1) The rearing capacity for juvenile sockeye in Lonesome Lake is fully utilized at current (e.g., 1998) escapement levels as evidenced by the small size of fall fry (mean 1.6 g) and their restricted distribution within the lake (to areas deeper than 20 m). The area of suitable habitat (deeper than 20m) appears to limit carrying capacity more than total primary productivity. These findings suggest that rearing capacity in Elbow Lake may be greater than in Rainbow or Tenas lakes where the maximum depth < 10 m.
2) Estimates of optimal escapement from the lake productivity (PR) model (adjusted for benthic production) were 2000, 3000, and 5200 spawners to Elbow, Rainbow, and Lonesome lakes, respectively.
3) Observed differences in run timing between the sea-type and lake-type subpopulations may permit selective harvest of an enhanced lake-type run (i.e., originating in Charlotte Lake). However, there appears to be considerable overlap in run timing so that fishing plans would have to be developed carefully. Further study is advised.
4) The lack of persistent differences in neutral DNA traits among spawning sites within the Atnarko River and within Owikeno Lake suggests considerable straying among the spawning sites, and that spawning sites within these systems should be considered as subpopulations rather than distinct populations. It also demonstrates that existing samples from these watersheds are adequate to characterize the respective populations in the coastwide baseline for stock composition analysis.
5) Atnarko sockeye are genetically distinct from all other coastal populations sampled to date. These differences will be adequate to support stock composition analysis of mixed-stock fisheries. However, baseline sample sizes for other coastal lakes still need to be increased to ensure adequate statistical precision in practice.

Supporting Documentation

You may attach additional documentation to illustrate your project's results. (optional)

Documentation Attached (Check as many as applicable)

_______	*Maps*	_______	*Brochure*
_______	*Photos*	_______	*News clippings*
X	*Data report*	_______	*Other*

Financial Summary

Please specify project costs according to the following categories for the total budget received from HRSEP. *You may also attach further financial statements in other formats, as produced by your group's financial systems. It is not necessary to forward copies of individual receipts and invoices. As per the terms of our Agreement, please retain these in your files for a minimum period of three years, as DFO reserves the right to audit all HRSEP projects.*

		Projected Amount	***Actual Amount***	*Details*
Wages / Personnel Costs	$	30000	0	Funding to Nuxalk partners was provided directly by AFS contributions specifically for this activity, and HRSEP funding to C. Wood was reduced accordingly.
Transport / Equipment	$	15000	14670	Field travel for staff from PBS; helicopter
Office / Overhead	$	1000	1430	Computer supplies, books, stationary
Other Costs	$	25000	48900	Contracts for DNA analysis Expenses for lake limnology survey "subcontract" (includes travel and wages)

Total Received from HRSEP $ 65,000

Contributions to the total budget may be from other agencies or in-kind contributions from your own organization, please specify:

	Amount	*Details*
Other Contributors to Total Project $	20000.	AFS contribution to Nuxalk. However, no evidence that this money was spent on activities related to this proposal.
	Est. 10000.	In-kind contributions (sample collections) from: Kitasoo Band and DFO staff in Prince Rupert

Appendix 1
Limnological survey of Elbow, Rainbow, and Lonesome lakes, 8-9 September 1999

Trip report from a September limnological survey of Elbow, Rainbow and Lonesome lakes

Ken Morton
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Ken Shortreed
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On September 8 and 9, 1999, we carried out a limnological survey of Elbow, Rainbow and Lonesome lakes, 3 lakes in the Atnarko watershed that are accessible to anadromous Sockeye salmon (*Oncorhynchus nerka*). The purpose of this survey was to determine the trophic status and rearing capacity of these lakes for juvenile sockeye. There is no road access to the lakes so we chartered a Beaver floatplane from Nimpo Lake (45 km to the east) and used it to sample the lakes. An isolated homestead at the south-eastern end of Lonesome Lake was the only obvious shore development on any of the lakes. We had intended to sample Tenas Lake during the survey, but shallow water and numerous tree stumps made it too hazardous to land. From the air, Tenas Lake appeared to have extensive dense mats of aquatic vegetation.

The 3 surveyed lakes drain from south to north through a narrow, low-gradient valley located at the eastern edge of the Coast Mountains. Steep mountains border both east and west shorelines of the 3 lakes. Although no data are available, observations of surrounding vegetation suggest that the climate is most likely continental, with warm, dry summers and cold winters. Ice cover probably occurs from November to May. Elbow Lake is the southernmost of the survey lakes and is situated at an elevation of 576 m. It is small (surface area=146 ha) and shallow (mean depth=13.7 m) relative to most other B.C. sockeye lakes (Fig. 1; Table 1). Rainbow Lake, located 3 km downstream at an elevation of 569 m, is also relatively small (surface area=170 ha) and shallow (mean depth=3.8 m) (Fig. 2; Table 1). Lonesome Lake is the largest of the study lakes (surface area=408 ha) and has a mean depth of 13.6 m (Fig. 3; Table 1). It lies at 482 m elevation and is 8 km downstream of Rainbow Lake.

Elbow and Lonesome lakes had well-defined thermoclines at 13 m and 14 m respectively, while Rainbow Lake was nearly isothermal (Fig. 4). All 3 lakes were clear, with no visible glacial or organic stain, but euphotic zone depth in Lonesome Lake (11.7 m) was substantially higher than that in Elbow Lake (7.9 m) (Table 2). In Rainbow Lake the entire water column was within the euphotic zone. The lakes were well-oxygenated, with surface DO concentrations of 10.4-10.7 mg/L (Table 2). Hypolimnetic DO declined only slightly to 7.9 mg/L in Elbow Lake and 9.8 mg/L in Lonesome Lake. In Rainbow Lake, DO concentrations were >10 mg/L throughout the water column. The lakes were slightly acidic (pH ranged from 6.7-6.8) and had low (<28 mg/L) total dissolved solids and low alkalinity (range=12.6-14.4 mg $CaCO_3$/L). Epilimnetic silicon concentrations in Elbow and Lonesome lakes were substantially lower than hypolimnetic concentrations, suggesting that the lakes support a substantial diatom community.

Total P concentrations ranged from 4.4-6.1 µg/L, indicating the lakes are oligotrophic (Table 2). However, the TP concentrations were higher than in many coastal sockeye nursery lakes and higher than seen in some interior sockeye lakes such as Adams and Chilko. Soluble reactive phosphorus concentrations ranged from 1.1 µg/L in Lonesome Lake to 2.1 µg/L in Rainbow Lake. Epilimnetic nitrate concentrations were <5 µg N/L in Elbow and Rainbow lakes, with substantially higher hypolimnetic nitrate concentrations of 54 µg N/L in Elbow Lake and 31 µg N/L in Lonesome Lake (Table 2, Fig. 5). Ammonia concentrations increased from 2.9 µg N/L in Elbow Lake to 7.6 in Lonesome Lake. Epilimnetic chlorophyll concentrations were low, ranging from 0.60 µg/L in Lonesome Lake to 0.75 µg/L in Elbow Lake, providing further evidence for the lakes' oligotrophic status. Photosynthetic rates (PR) were 54, 78, and 55 mg $C \cdot m^{-2} \cdot d^{-1}$ in Elbow, Rainbow, and Lonesome lakes, respectively. Only Rainbow Lake had PR rates as high as those seen in other oligotrophic Chilcotin lakes such as Charlotte and Chilko. When corrected for lake volume, PR was substantially lower (24-29 mg $C \cdot m^{-2} \cdot d^{-1}$). Maximum PR occurred at a depth of 2-3 m in Elbow and Rainbow lakes and at the surface in Lonesome Lake.

Macrozooplankton biomass was highest in Lonesome Lake (1,982 mg dry wt/m^2) and lowest (674 mg dry wt/m^2) in Rainbow Lake (Table 2). *Daphnia galeata* made up >80% of total macrozooplankton biomass in both these lakes (Fig. 7). Macrozooplankton biomass was 1,089 mg dry wt/m^2 in Elbow Lake and the cyclopoid copepod *Diacyclops thomasi* made up 60% of total macrozooplankton biomass. *Daphnia* made up only 25% of the total which may indicate some degree of grazing pressure. Although utilized by juvenile sockeye, *Diacyclops* is a poorer, more predation-resistant food source than *Daphnia*. Other common macrozooplankton were *Acanthodiaptomus denticornis* and *Diacyclops thomasi* in Lonesome Lake and *Eubosmina coregoni* in Elbow Lake.

Since, sockeye graze selectively on larger *Daphnia*, the length-frequency distribution of a *Daphnia* population can provide insight into grazing pressure. We constructed length-frequency plots of *Daphnia* in the surveyed Atnarko lakes and compared them to plots of Charlotte Lake *Daphnia* (no grazing pressure) and Quesnel Lake *Daphnia* in both dominant and non-dominant brood years (high and low grazing pressure) (Fig. 8, 9). Despite species related differences in maximum length, length-frequency distributions of *Daphnia* in Lonesome and Rainbow lakes were roughly similar to those in Charlotte Lake, while *Daphnia* in Elbow Lake tended to be smaller. The high numbers of large *Daphnia* in the Lonesome and Rainbow lakes despite low productivity is strongly suggestive of extremely low grazing pressure. The lower relative abundance of *Daphnia* in Elbow Lake along with high numbers of predator-resistant *Diacyclops* could indicate higher grazing pressure.

To estimate lake rearing capacity utilizing the PR model, seasonal average photosynthetic rates (PR) must be available. To use the PR model with Atnarko lake data, we made the assumption that our one-time PR measurements were representative of seasonal averages. Since the lakes are small, shallow and have large littoral zones relative to their surface areas, we corrected PR for lake volume and also for benthic production within the littoral zone (Table 2). We corrected for benthic production by assuming it to be equivalent to PR in the overlying water column. With these assumptions and adjustments, annual carbon production in Elbow, Rainbow, and Lonesome lakes was 10.8, 16.4, and 27.8 tonnes C/yr, respectively (Table 3). This results in a predicted optimum escapement to the 3 lakes of 2.0, 3.1, and 5.2 thousand spawners. Estimated optimum spring fry recruitment to the lakes is 262, 396, and 674 thousand.

Available physical and biological data indicate that of the 3 lakes, Lonesome Lake would provide the best rearing environment for juvenile sockeye. This lake has a favourable thermal regime and an under-exploited population of large *Daphnia*. Although Rainbow Lake also has an under-exploited *Daphnia* population, it is shallower and isothermal and so may not be as suitable a rearing habitat for sockeye. Elbow Lake has a favourable thermal regime and a substantial *Daphnia* population, but higher copepod numbers than in the other lakes. The apparent low productivity of the 3 surveyed lakes suggests that while they can currently sustain a high cladoceran biomass, they would be highly vulnerable to overgrazing. This is particularly true in Elbow Lake where a predation-resistant copepod is already dominant.

Table 1. Salient morphometric and bathymetric data for the Atnarko lakes. Data are from the MELP lake survey data base. Littoral zone is based on the EZD.

	Lake		
Variable	Elbow	Rainbow	Lonesome
Latitude (°N)	52°05'	52°07'	52°14'
Longitude (°W)	125°42'	125°43'	125°43'
Elevation (m)	576	569	482
Surface area (ha)	146	170	408
6 m contour (ha)	88	27	214
Percentage of lake within the littoral zone	44	100	56
Shoreline length (km)	9.9	1.2	20.5
Mean depth (m)	13.7	3.8	13.6
Maximum depth (m)	34	9	41

Table 2. Physical, chemical, and biological data from the September, 1999 survey of the Atnarko lakes. Data are mean epilimnetic values unless otherwise specified. Data from a September, 1997 survey of Charlotte Lake are included for comparative purposes.

	Lake			
Variable	Elbow	Rainbow	Lonesome	Charlotte
Surface temperature (°C)	13.2	15.5	14.8	14.9
Thermocline depth (m)	13.0	isothermal	14.0	15.2
Secchi depth (m)	5.0	6.5	7.5	12.8
Euphotic zone depth (m)	7.9	9.6	11.7	22.1
Dissolved oxygen (mg/L)	10.3	10.7	10.7	
Hypolimnetic DO (mg/L)	7.6		9.8	
Conductivity (µS/cm at 25°C)	24	25	27	47
pH	6.67	6.82	6.80	7.55
Total alkalinity (mg $CaCO_3$/L)	12.6	13.4	14.4	12.2
Dissolved inorganic carbon (mg/L)	4.57	4.37	4.75	3.54
Total dissolved solids (mg/L)	28	21	28	22
Soluble reactive silicon (mg Si/L)	1.20	1.28	0.49	1.25
Hypolimnetic SRS (mg Si/L)	2.27		1.98	
Total P (µg/L)	4.6	4.4	6.1	3.8
Hypolimnetic total P(µg/L)	4.8		5.3	3.7
Particulate P (µg/L)	2.5	3.0	2.6	1.9
Soluble reactive P (µg/L)	1.6	2.1	1.1	
Hypolimnetic SRP (µg/L)	2.4		4.3	
Total dissolved P (µg/L)	3.0	2.7	2.5	
Hypolimnetic TDP (µg/L)	3.0		4.2	
Nitrate (µg N/L)	4.8	2.4	2.1	1.7
Hypolimnetic nitrate (µg N/L)	54.1		30.9	10.8
Ammonia (µg N/L)	2.9	4.8	7.6	
Hypolimnetic ammonia (µg N/L)	6.8		1.8	
Chlorophyll (µg/L)	0.75	0.63	0.60	0.47
Daily PR (mg $C \cdot m^{-2} \cdot d^{-1}$)	53.7	78.2	55.2	76.4
- corrected for bathymetry	28.7	26.8	24.3	
- corrected for bathymetry and benthic PR	41.2	53.5	37.9	
Macrozooplankton biomass (mg dry wt/m^2)	1,089	674	1,982	1,459
Daphnia biomass (mg dry wt/m^2)	276	644	1,572	666

Table 3. PR model predictions based on PR data collected during the September survey. These predictions assume that PR on survey dates was equal to seasonal average PR, which may not be valid. PR was adjusted for lake volume and then further adjusted for benthic production in the littoral zone.

		PR model predictions			
Lake	Total PR (t C/lake/yr)	Escapement (thousands)	Smolt biomass (tonnes)	Smolt numbers (thousands)	Fry recruitment (thousands)
Elbow	10.8	2.0	0.49	110	262
Rainbow	16.4	3.1	0.75	166	396
Lonesome	27.8	5.2	1.27	282	674

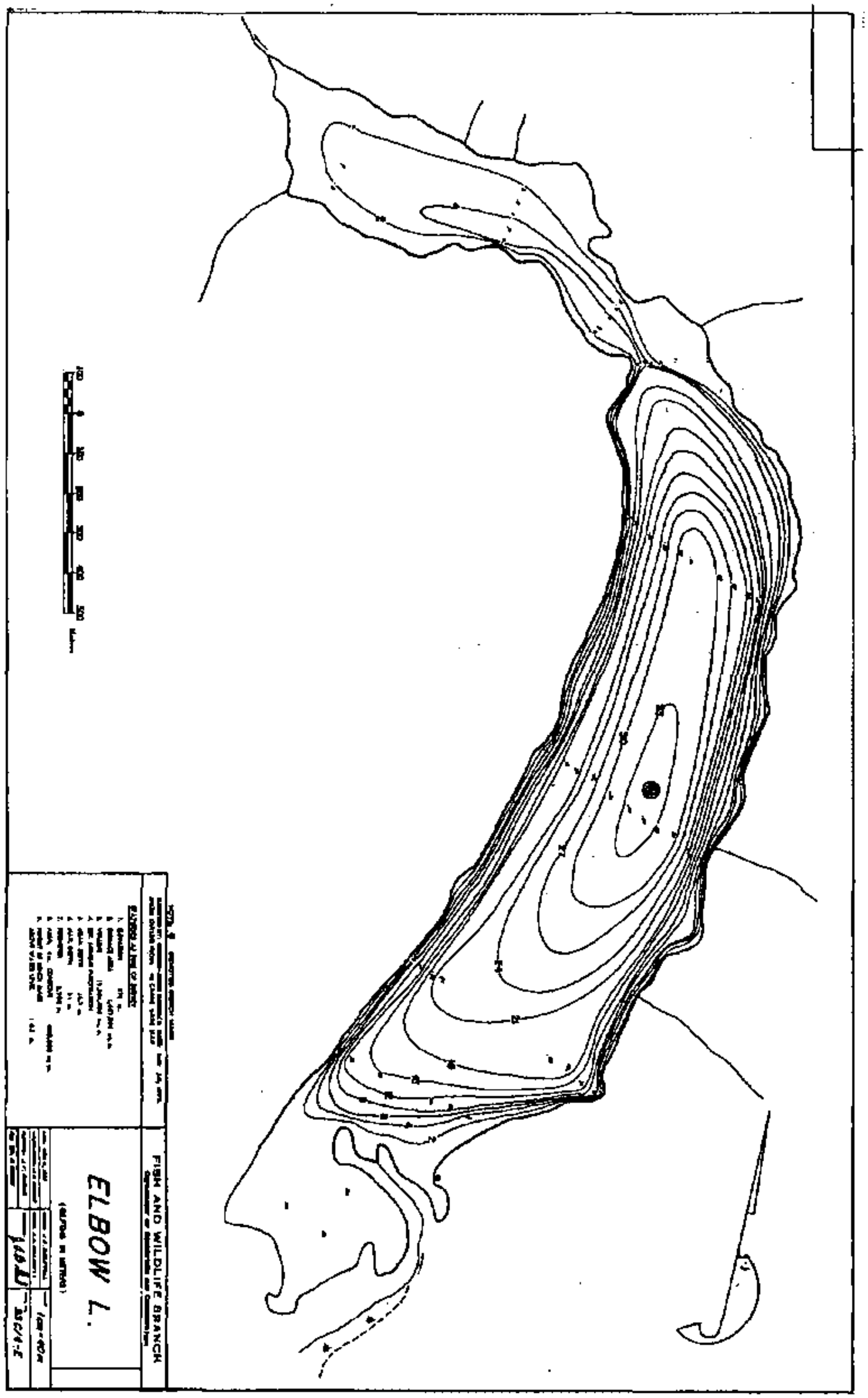

Fig. 1. Map of Elbow Lake with dot indicating sampling location.

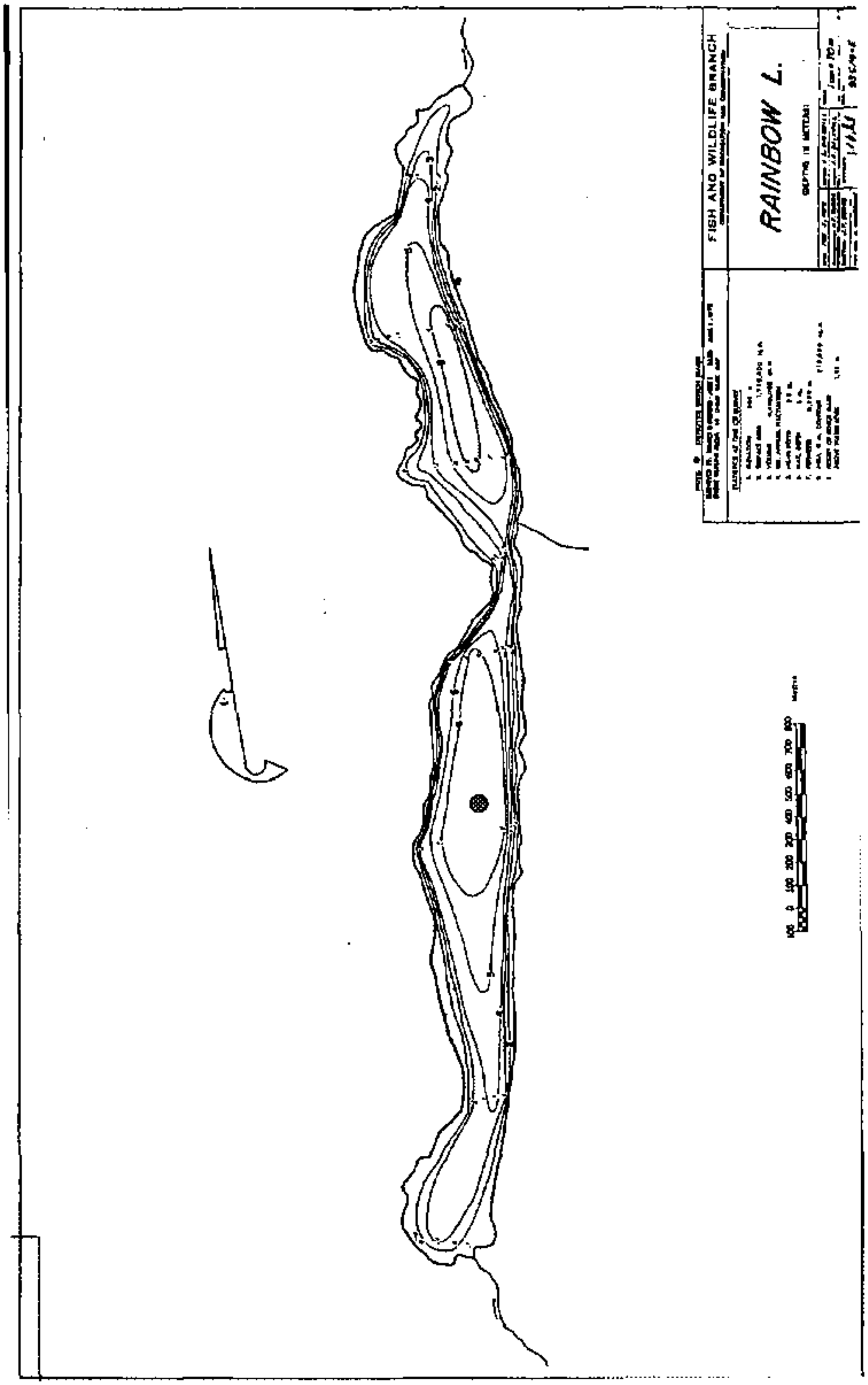

Fig. 2. Map of Rainbow Lake with dot indicating sampling location.

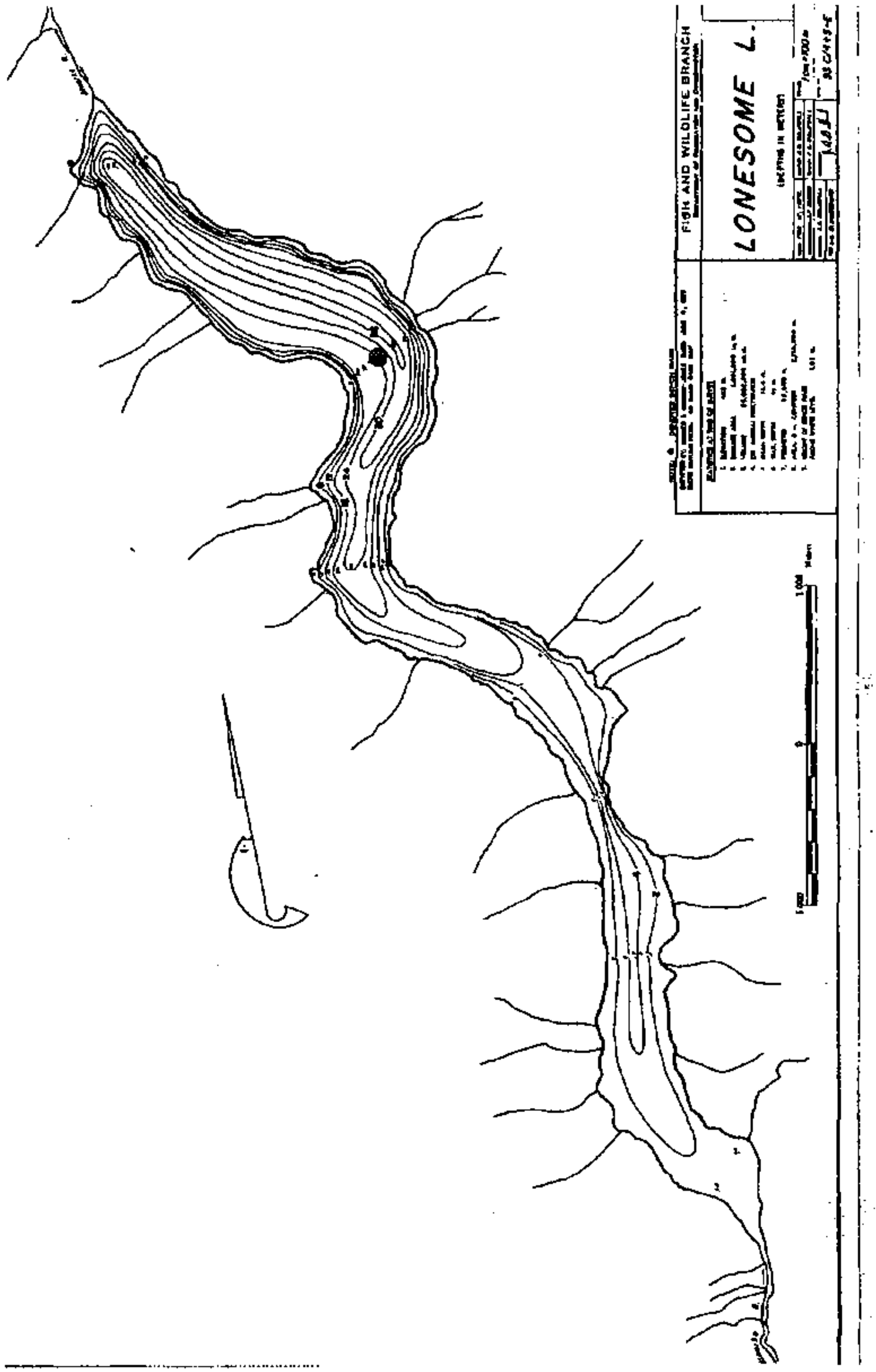

Fig. 3. Map of Lonesome Lake with dot indicating sampling location.

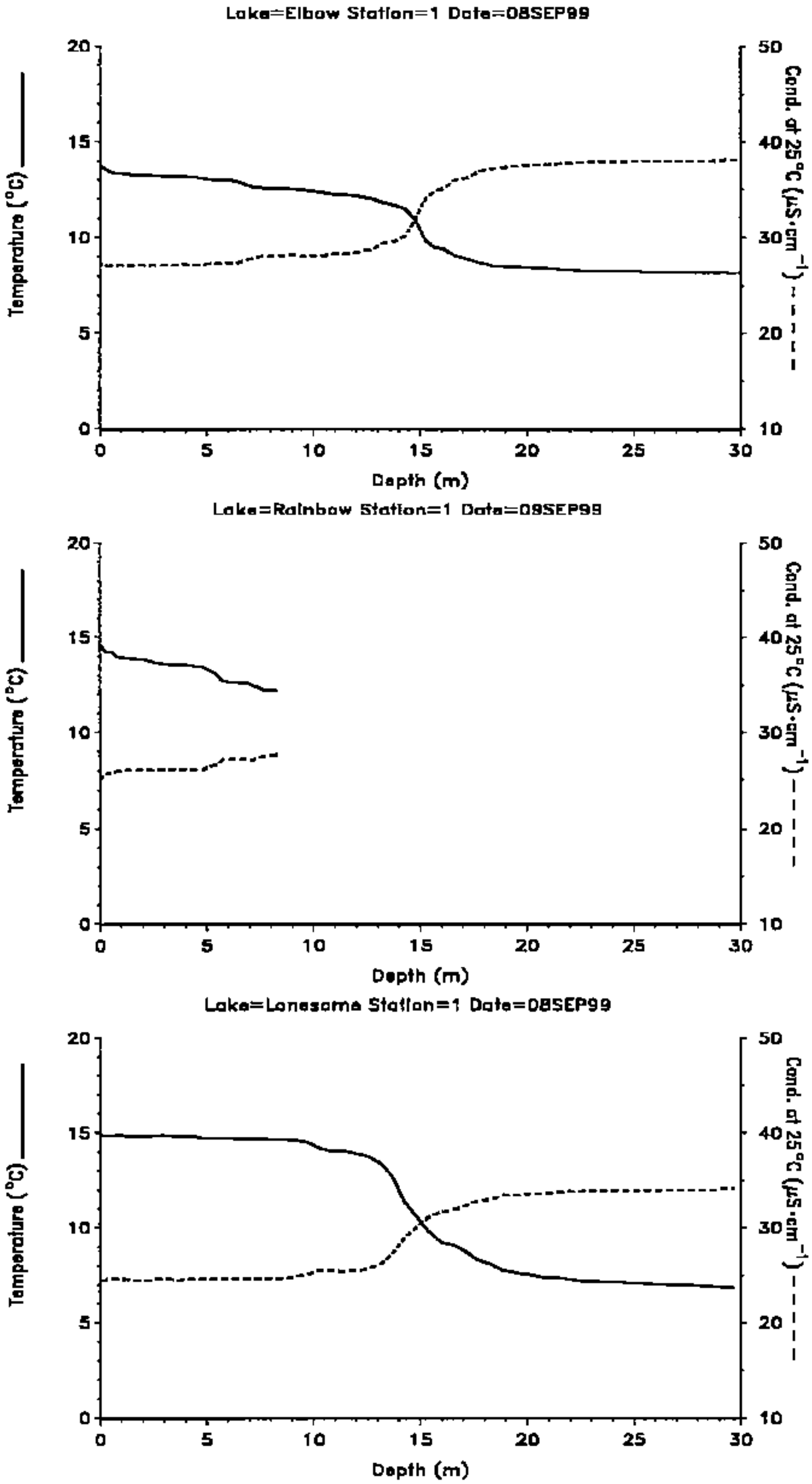

Fig. 4. Temperature and conductivity profiles from the 3 surveyed lakes.

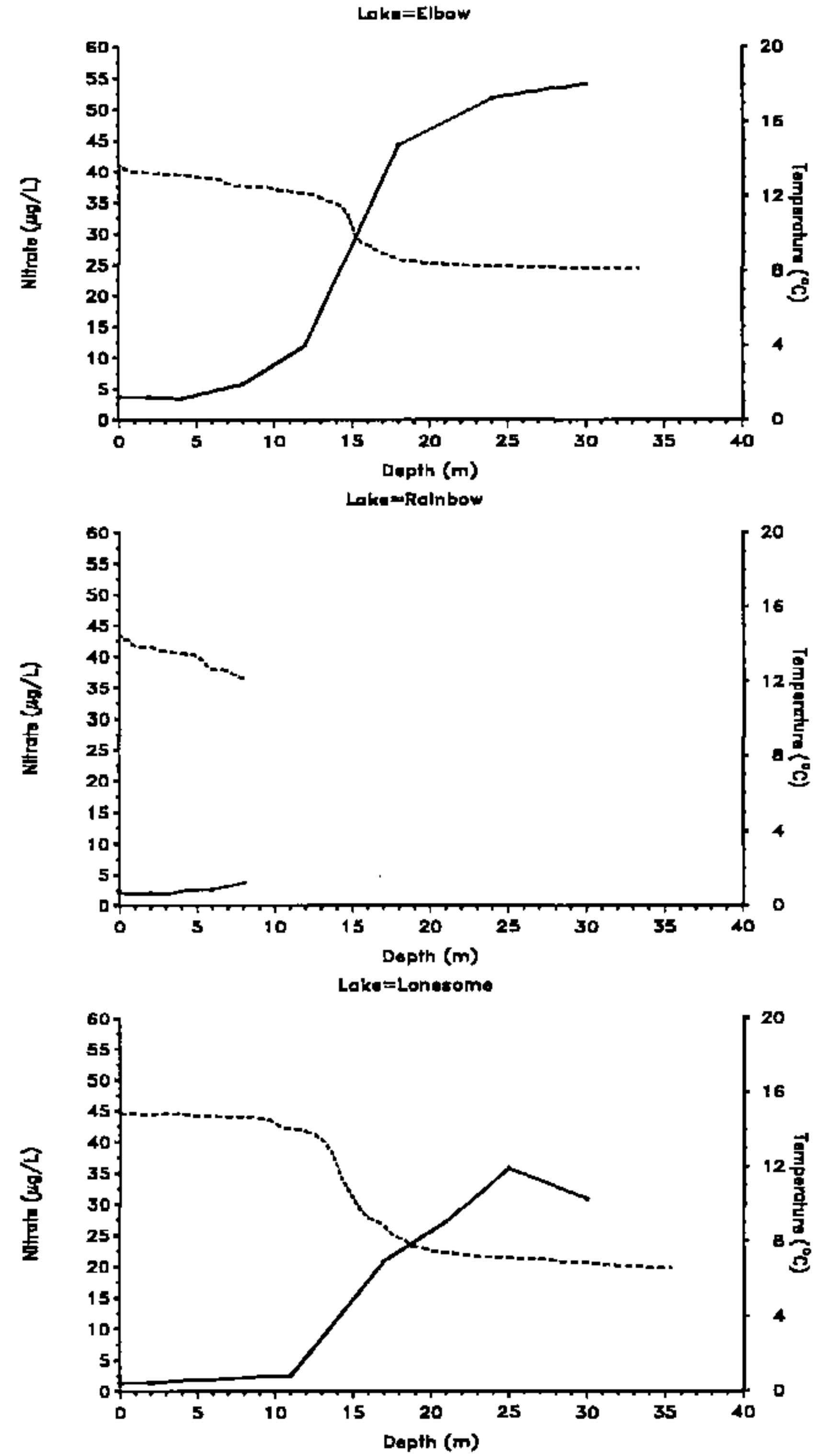

Fig. 5. Nitrate (as nitrogen) and temperature profiles from the 3 surveyed lakes.

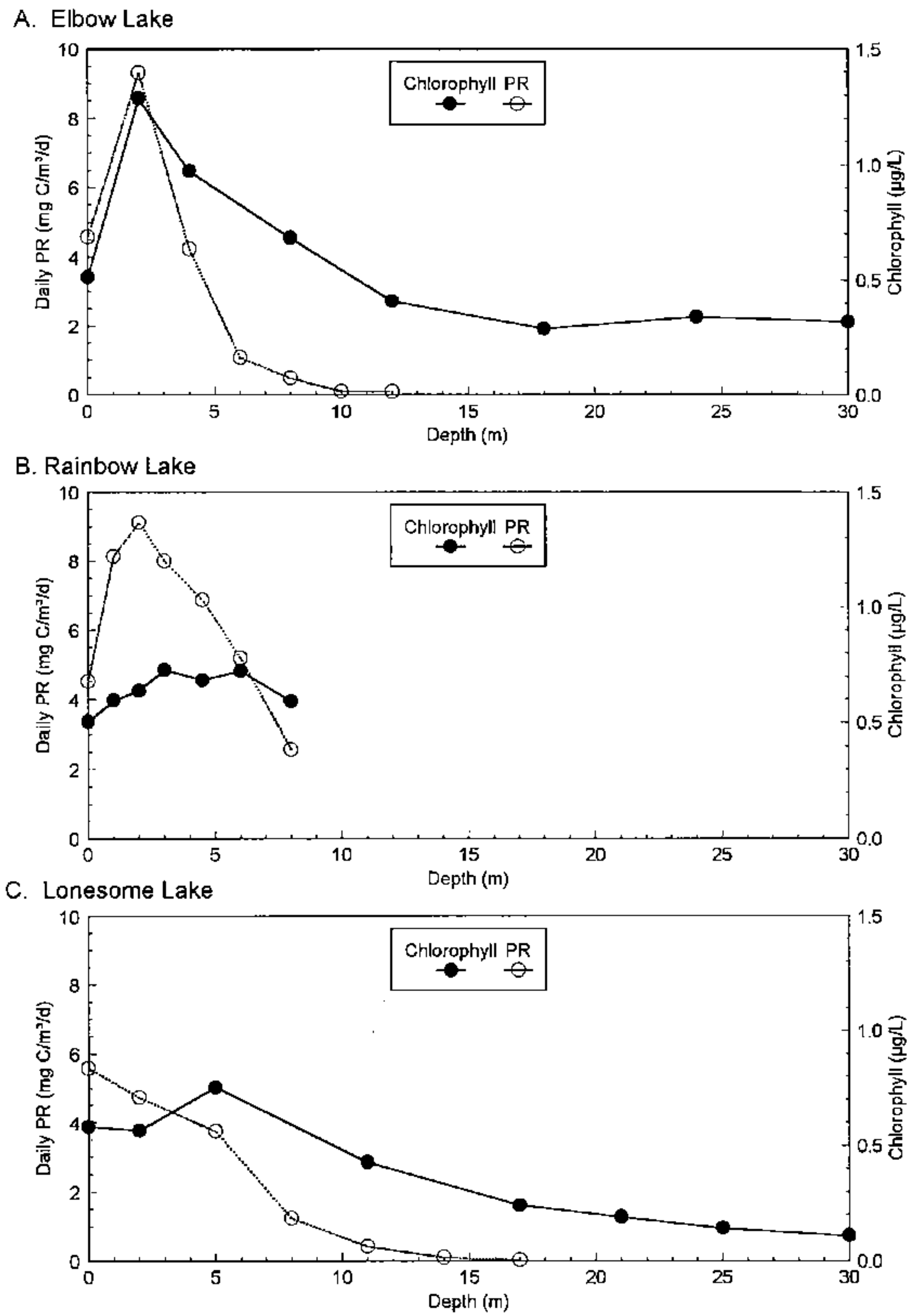

Fig. 6. Vertical profiles of chlorophyll concentration and photosynthetic rates from the 3 surveyed lakes.

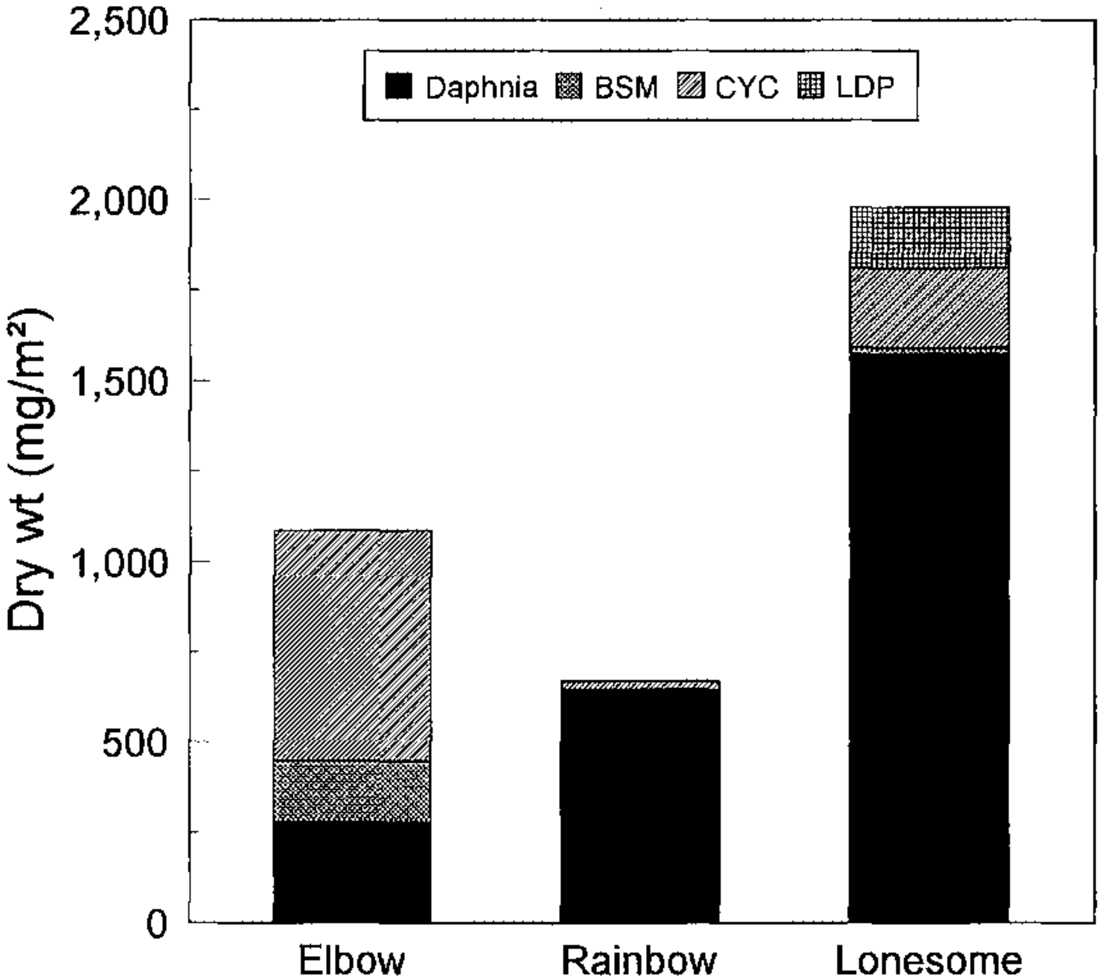

Fig. 7. Biomass of major zooplankton groups in the 3 surveyed lakes.

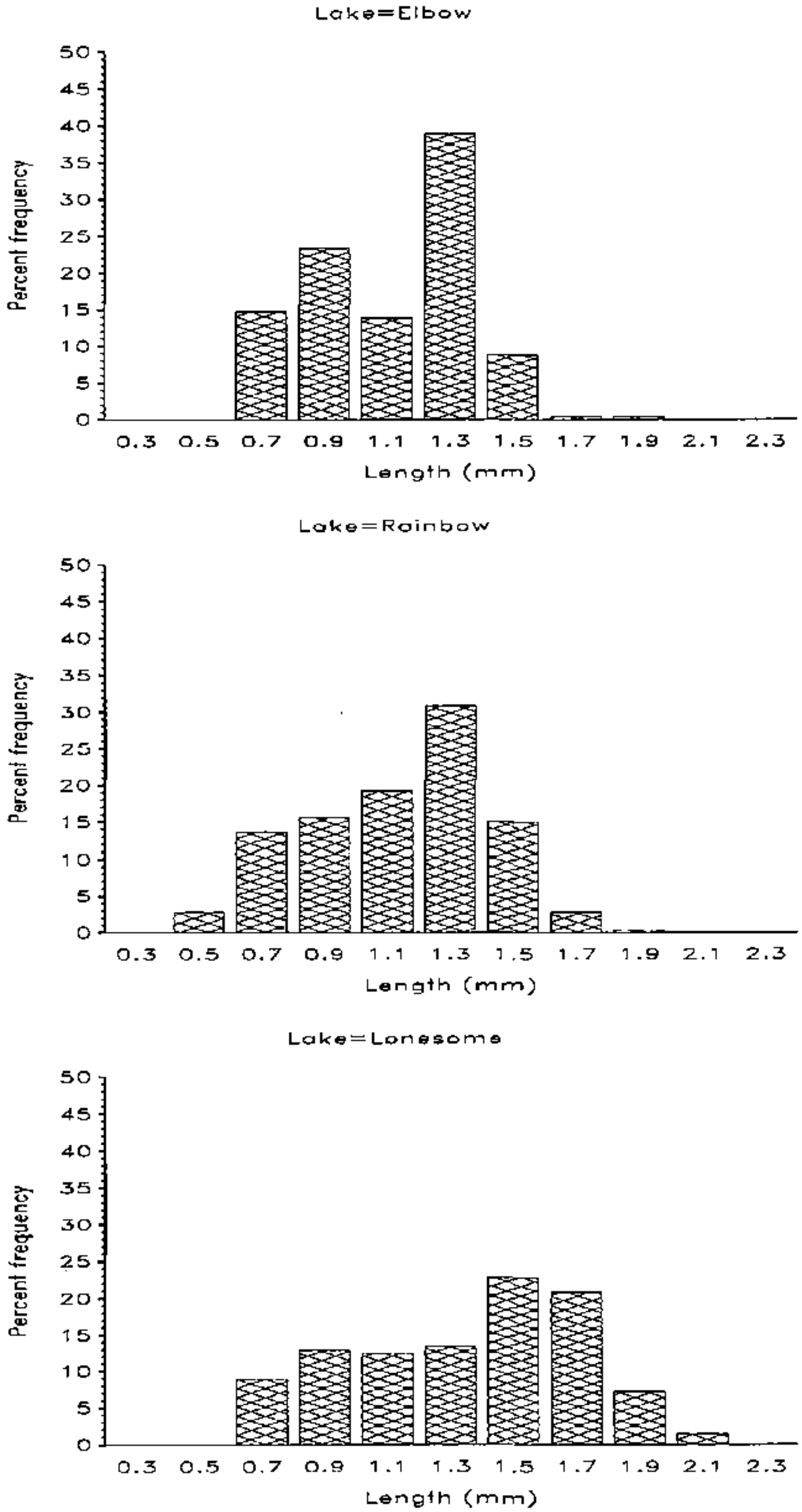

Fig. 8. Length-frequency distribution of Daphnia in the 3 surveyed lakes.

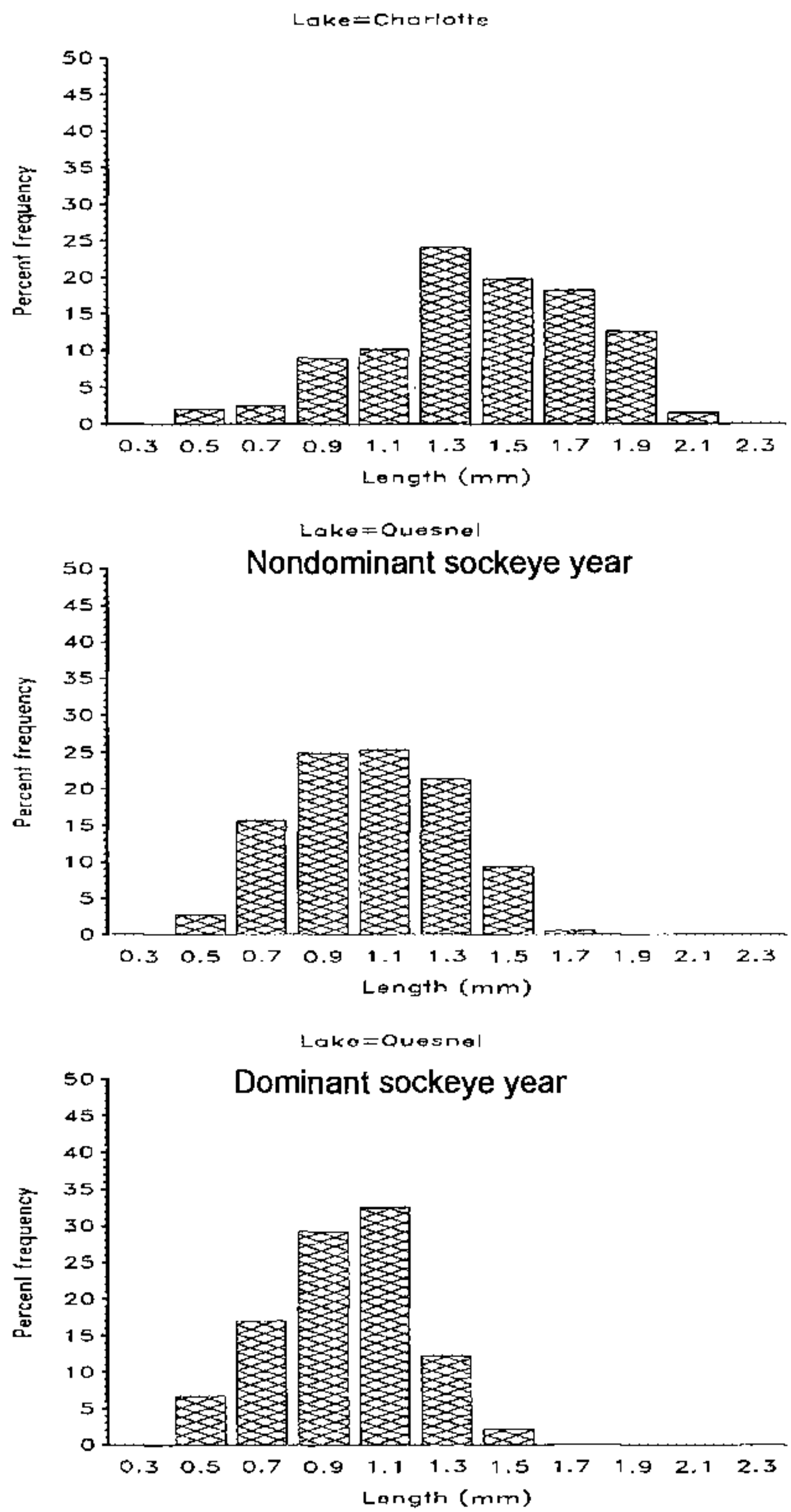

Fig. 9. Length-frequency distribution of Daphnia in Charlotte and Quesnel lakes.

Appendix 2
Hydroacoustic and trawl survey of Lonesome Lake, 28-29 September 1999

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Hydroacoustic assessment techniques were used to estimate the abundance of juvenile sockeye in Lonesome Lake the night of 28-29 September 1999. The hydroacoustic equipment included an uncalibrated 70kHz Simrad EYM echosounder with a time varied gain circuit and a 13-degree transducer suspended 1 m below the surface alongside an inflatable boat. This configuration permitted insonification of all areas of Lonesome Lake below 2 m.

Assessment surveys were conducted during total darkness before moonrise (20:20 to 23:00 h) using standard procedures (Hyatt et al. 1984). A total of 7 transects were completed (Fig. 1), but targets were detected only in the deeper sections of the lake (transects 1-6) (Table 1). Population estimates were determined from echo trace counts using the formula recommended by Hyatt et al. (1988). Sockeye density was highest between 20-30 m, habitat that occurred only in a restricted area near the outlet end of the lake (transects 1-3). In this restricted area, sockeye density was relatively high, averaging 1007 sockeye per hectare; averaged across the entire lake area, density was only 293 sockeye per hectare because most of the lake area is <20 m.

Surface and midwater trawl gear were deployed using standard procedures (Hyatt et al 1984) to obtain fish samples to determine species and size composition, and to investigate abundance above 2 m. The trawl net measured 2 x 2 x 7.5 m and was constructed of a graded series of meshes ranging from 1.3 cm near the codend to 5.0 cm at the mouth (Gjernes 1979). A 350-micron mesh net in the codend provided a dead-water space to prevent damage to fish specimens.

Two 20-min surface trawls were conducted to verify that no juvenile sockeye were present in the uninsonified surface layer (0-2 m). These trawls were completed in almost total darkness before the moon rose above the surroundings mountains. No fish were caught in either surface trawl. Three midwater trawls were completed after moon rise to obtain fish samples from 20 – 30m depth, near the bottom, where most fish were visible on the echosounder. These trawls were also 20 min in duration, although trawl #4 was terminated early (after only 5 min) because the net hung up on the bottom. A total of 25 sockeye, 2 cottids and 1 catostomid were captured (Table 2). Samples were preserved in 10% formalin for approximately 100 d before measurement. The preserved juvenile sockeye were all underyearlings (age 0+) with a median size of 53 mm and 1.53 g (Fig. 2).

References:

Gjernes, T. 1979. A portable midwater trawling system for use in remote lakes. Fish. Mar. Serv. Tech. Rep. 888: 13 p.

Hyatt, K.D., D. Rutherford, T. Gjernes, P. Rankin and T. Cone. 1984. Lake Enrichment Program: Juvenile Sockeye Unit guidelines. Can MS rep. Fish. Aquat. Sci. 1976: 84 p.

Hyatt, K.D., J. Candy, M. Wright, and D.P. Rankin. 1988. An appraisal of the potential utility of hydroacoustic techniques forroutine estimation of sockeye (*Oncorhynchus nerka*) escapements in British Columbia coastal lakes. Can. J. Fish. Aquat. Sci. 45:

Table 1. Hydroacoustic estimates from Lonesome Lake survey 28-29 Sepember 1999

Depth Stratum	Beam Width (m)	Stratum Area (ha)	Transect Length (m) 1	2	3	4	5	6	7
Surface		408.1	587	737	919	808	358	385	343
0-5	0.93	292	580	716	901	781	295	93	
5-10	1.75	235.3	573	668	864	708	31		
10-15	2.91	178.5	558	636	841	649			
15-20	4.08	135.8	540	605	657	490			
20-25	4.96	93.5	519	394	368				
25-30	6.41	74.4	505	342	230				
30-35	7.58	37	463	280					
35-40	8.74	9	447	199					

Tran#	Strata (m)	Tran lth (m)	Bw (m)	# targets	targ/m^2		# of juv sockeye strata est	SD	Density (fish/ha)	SD
1	3-5	580	0.93	2	0.0037					
2	3-5	716	0.93	4	0.0060					
3	3-5	901	0.93	13	0.0155					
4	3-5	781	0.93	10	0.0138					
5	3-5	295	0.93	0	0.0000					
6	3-5	93	0.93	0	0.0000		**27051**	19658	**92.6**	
1	5-10	573	1.75	1	0.0010					
2	5-10	668	1.75	10	0.0086					
3	5-10	864	1.75	16	0.0106					
4	5-10	708	1.75	15	0.0121					
5	5-10	31	1.75	0	0.0000		**19857**	13145	**84.4**	
1	10-15	558	2.91	1	0.0006					
2	10-15	636	2.91	12	0.0065					
3	10-15	841	2.91	7	0.0029					
4	10-15	649	2.91	9	0.0048		**6628**	14080	**37.1**	
1	15-20	540	4.08	5	0.0023					
2	15-20	605	4.08	81	0.0328					
3	15-20	657	4.08	6	0.0022					
4	15-20	490	4.08	24	0.0120		**16845**	19566	**124.0**	
1	20-25	519	4.96	26	0.0101					
2	20-25	394	4.96	116	0.0594					
3	20-25	368	4.96	57	0.0312		**29284**	23106	**313.2**	
1	25-30	505	6.41	51	0.0158					
2	25-30	342	6.41	60	0.0274					
3	25-30	230	6.41	32	0.0217		**15411**	4321	**207.1**	
1	30-35	463	7.58	34	0.0093					
2	30-35	280	7.58	32	0.0151		**4222**	1515	**114.1**	
1	35-40	447	8.74	14	0.0036					
2	35-40	199	8.74	6	0.0034		**319**	9	**35.4**	
						Total sockeye	**119617**	38951	**293.1**	95

Table 2. Biological data for juvenile sockeye specimens captured from Lonesome Lake on 28-29 September 1999 and preserved in 10% formalin for ~100 days

TRAWL #	DEPTH	DURATION	FISH #	SPECIES	LENGTH	WEIGHT	SCALE #	SCALE BOOK #	COMMENTS
3	20m	20 Min	1	Sockeye	61	2.45			
			2	Sockeye	59	2.35			
			3	Sockeye	55	1.57			
5	30m	20 Min	1	Sockeye	58	2.04			1 Sculpin
			2	Sockeye	52	1.45			
			3	Sockeye	51	1.28			
			4	Sockeye	52	1.62			
			5	Sockeye	57	1.81			
			6	Sockeye	66	2.82			
			7	Sockeye	50	1.13			
			8	Sockeye	49	1.3			
			9	Sockeye	52	1.39			
			10	Sockeye	55	1.67			
			11	Sockeye	53	1.74			
			12	Sockeye	52	1.46			
			13	Sockeye	57	1.96			
			14	Sockeye	49	1.29			
4	30	5 Min	1	Sockeye	57	1.82			Hit Bottom. 1Sculpin
			2	Sockeye	50	1.29			
			3	Sockeye	52	1.48			
			4	Sockeye	53	1.46			
			5	Sockeye	46	1.06			
			6	Sockeye	55	1.72			
			7	Sockeye	47	1.09			
			8	Sockeye	54	1.52			

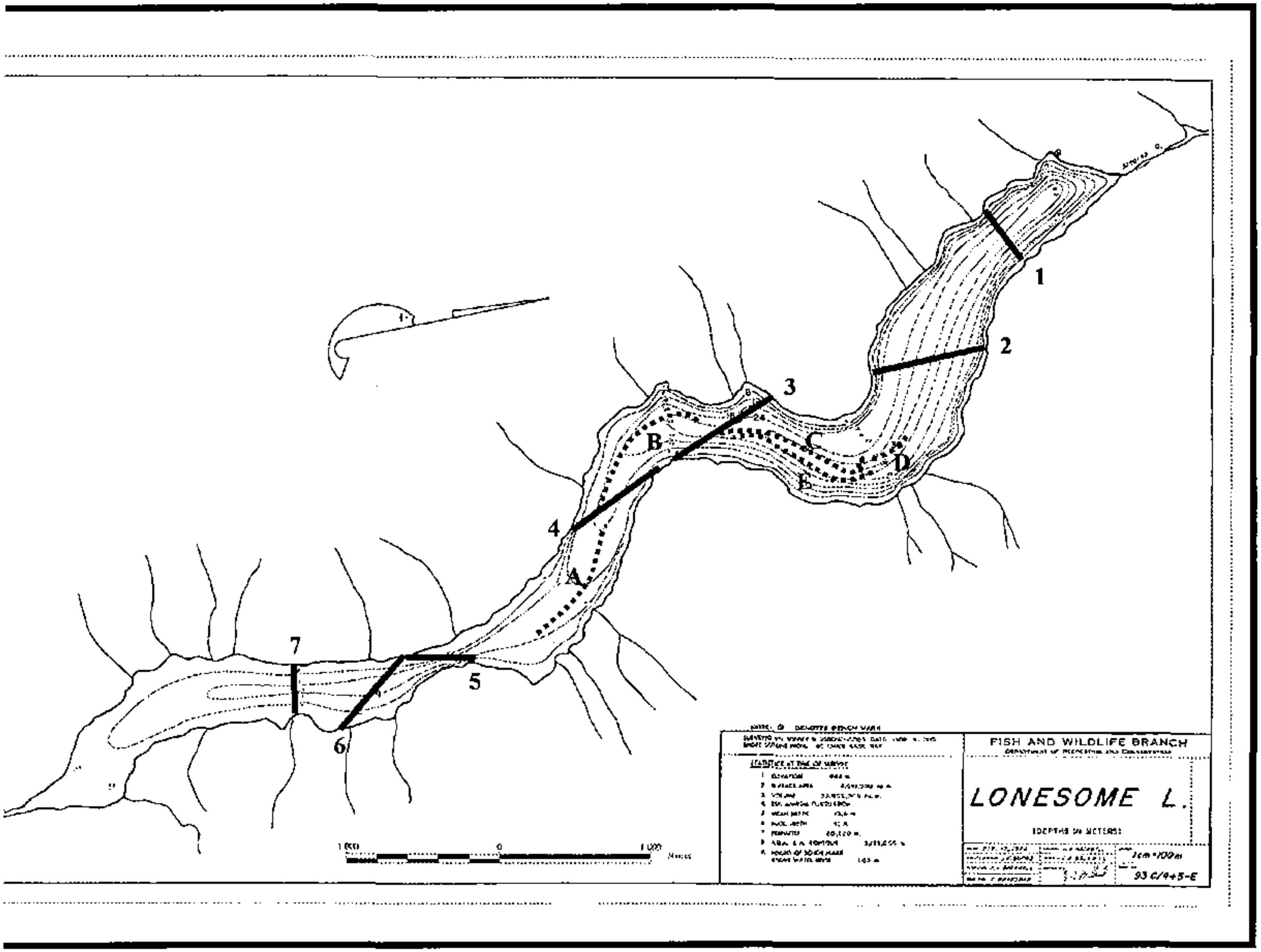

Figure 1 Bathymetric map of Lonesome Lake showing locations of hydroacoustic transects (1-7) and trawls (A-E corresponding to trawls 1-5 in Table 1)

Appendix 3
Run timing of lake-type sockeye in the Bella Coola River in 1999

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Freshwater age was determined for a total of 108 adult sockeye sampled from the First Nations food fishery in the Bella Coola River. These fish were caught by drifting gillnets between 1July and 4 August 1999. This sampling period almost spanned the period of upstream migration for sockeye in 1999. Drift net fishing had begun by 1 May but no sockeye were caught until late June; similarly the last sockeye was caught in mid August although fishing continued until early September (Fig. 1). This run timing distribution appeared to be typical of other years based on unpublished DFO annual reports (Record of Management Strategies series). Age was determined from scales by staff in the ageing lab at the Pacific Biological Station, Nanaimo

Overall, 25% of sockeye were age 3, 59% age 4, and 16% age 5. However, most (64%) were sea-type sockeye (age 0.2 or age 0.3). The proportion of lake-type sockeye declined from 50% in early July, to 45% in late July, to 8% in early August (Fig. 2).

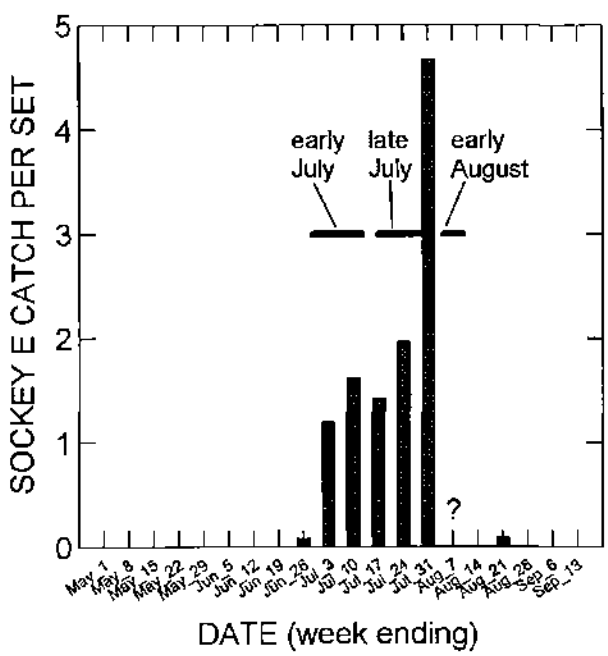

Figure 1. Seasonal trend in the adult sockeye abundance index (catch/driftnet set) for the First Nation fishery in the Bella Coola River in 1999. Horizontal bars define sampling periods; question mark indicates no documented fishing the week ending 7 August.

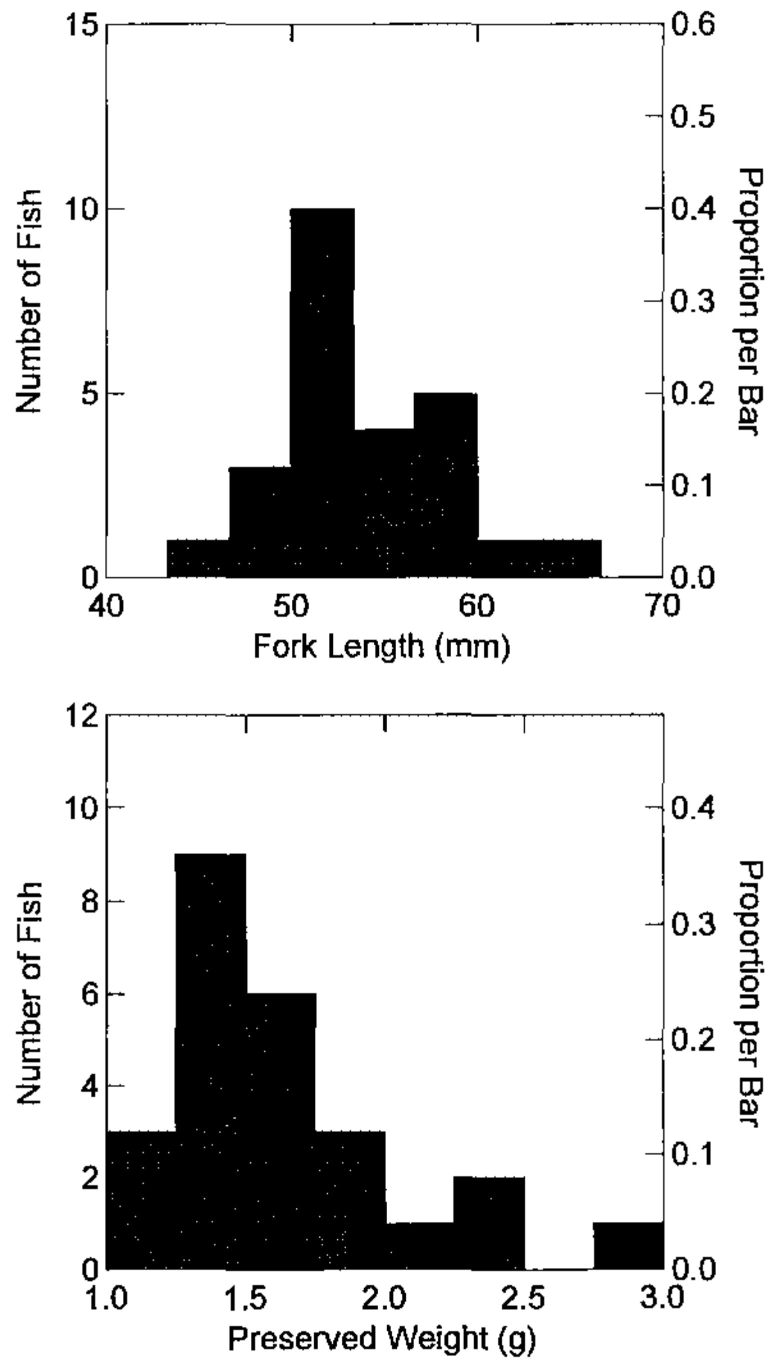

Figure 2 Length and weight distributions of age 0+ sockeye caught by midwater trawl in Lonesome Lake on 28-29 September 1999. Samples were preserved in 10% formalin for approximately 100 d before measurement.

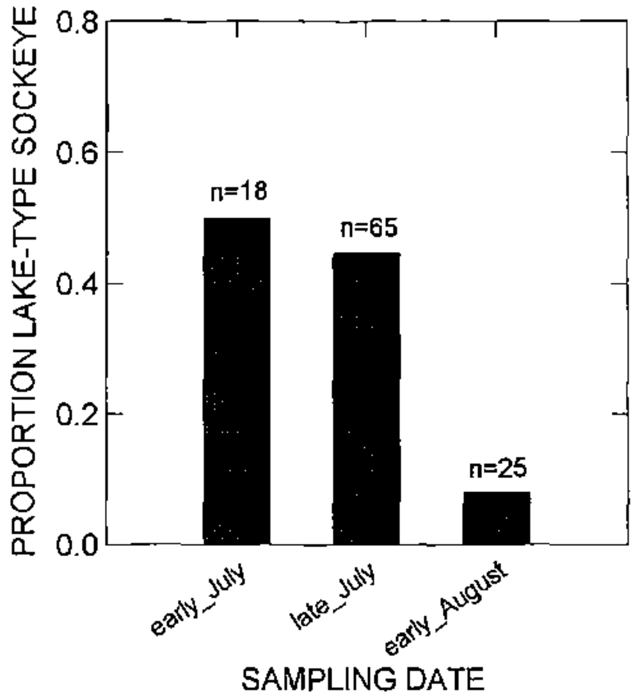

Figure 2. The proportion of lake-type sockeye in scale samples collected from the First Nation fishery in the Bella Coola River in 1999. Sampling periods as defined in Figure 1.

Appendix 4
Surveys of microsatellite DNA variation in central coast sockeye with view towards identifying Atnarko sockeye in mixed-stock fisheries

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Tissue samples collected in 1999 and additional samples from archived collections were analyzed by Seastar Biotech Ltd., Victoria (under contract to DFO) for DNA variation at 10 independent microsatellite loci. A total of 1519 specimens were analyzed (Table 1). These data were used first, to look for possible population structure within complex lake systems (e.g., the Atnarko River and Owikeno Lake), and second, to develop reference (baseline) data for analyzing the stock composition of mixed stock fisheries on the central coast.

The dendrogram in Figure 1 was constructed from pairwise genetic chord distances among samples averaged across 10 loci using the neighbor-joining algorithm (Saitou and Nei 1987). It reveals the most probable genetic relationships among the 27 samples analyzed. Samples that cluster closely together share the same alleles (genes) at a similar frequency whereas those that are widely separated do not. Labels are defined in Table 1. Note that samples within the Atnarko River and Owikeno Lake tend to cluster together by year of sampling rather than by site within each watershed. Failure to detect a persistent spatial structure within each watershed despite detection of a common parental brood year effect is strong evidence that gene flow (straying) among sites within these watersheds is sufficient to prevent genetic differentiation in these non-adaptive DNA traits. This preliminary analysis indicates that the sites examined within each watershed should not be considered as isolated populations, although they appear to exist as partially isolated subpopulations with signficant differences in some adaptive life history traits. A more comprehensive analysis will be prepared for publication in the scientific literature.

References:

Saitou, N., and M. Nei. 1987. The neighbor-joining method: a new method for reconstructing phylogenetic trees. Molecular Biology and Evolution 4:406-425.

Table 1. Summary of tissue samples collected in 1999 (part B1) and additional samples from archived collections that were analyzed for DNA variation.

Area	Population	Site	Abbreviation	number	Year Collected
					New
9	Owikeno	Wannock	Ow_Wann_99	34	1999
6	Mary's Cove		Marys_C_99	78	1999
	Lagoon		LagoonL_99	50	1999
5	Devon		Devon_99	100	1999
	Mikado		Mikado_99	62	1999
					From archives
10	Long	Canoe Creek	Long_Ca_84	51	1997
9	Owikeno	Amback	Ow_Ambk_97	48	1997
		Ashlum	Ow_Ashl_98	50	1998
		Inziana	Ow_Inzi_97	47	1997
		Inziana	Ow_Inzi_98	47	1998
		Neechanz	Ow_Neec_98	50	1998
		Sheemahant	Ow_Shee_96	38	1996
		Sheemahant	Ow_Shee_98	48	1998
		Wannock	Ow_Wann_96	27	1996
		Wannock	Ow_Wann_97	69	1997
		Washwash	Ow_Wash_97	40	1997
		Washwash	Ow_Wash_98	48	1998
8	Koeye		Koeye_86	80	1986
	Atnarko	river (=sea-type)	AtnarkR_96	20	1996
		river (=sea-type)	AtnarkR_97	42	1997
		Lonesome	AtnarkL_96	28	1996
		Lonesome	AtnarkL_97	52	1997
		Tenas	AtnarkL_85	48	1986
	Kimsquit		Kimsqui_86	62	1986
7	Tankeeah		Tankeea_86	78	1986
6	Canoona		Canoona_86	79	1986
5	Kitlope		Kitlope_86	41	1986

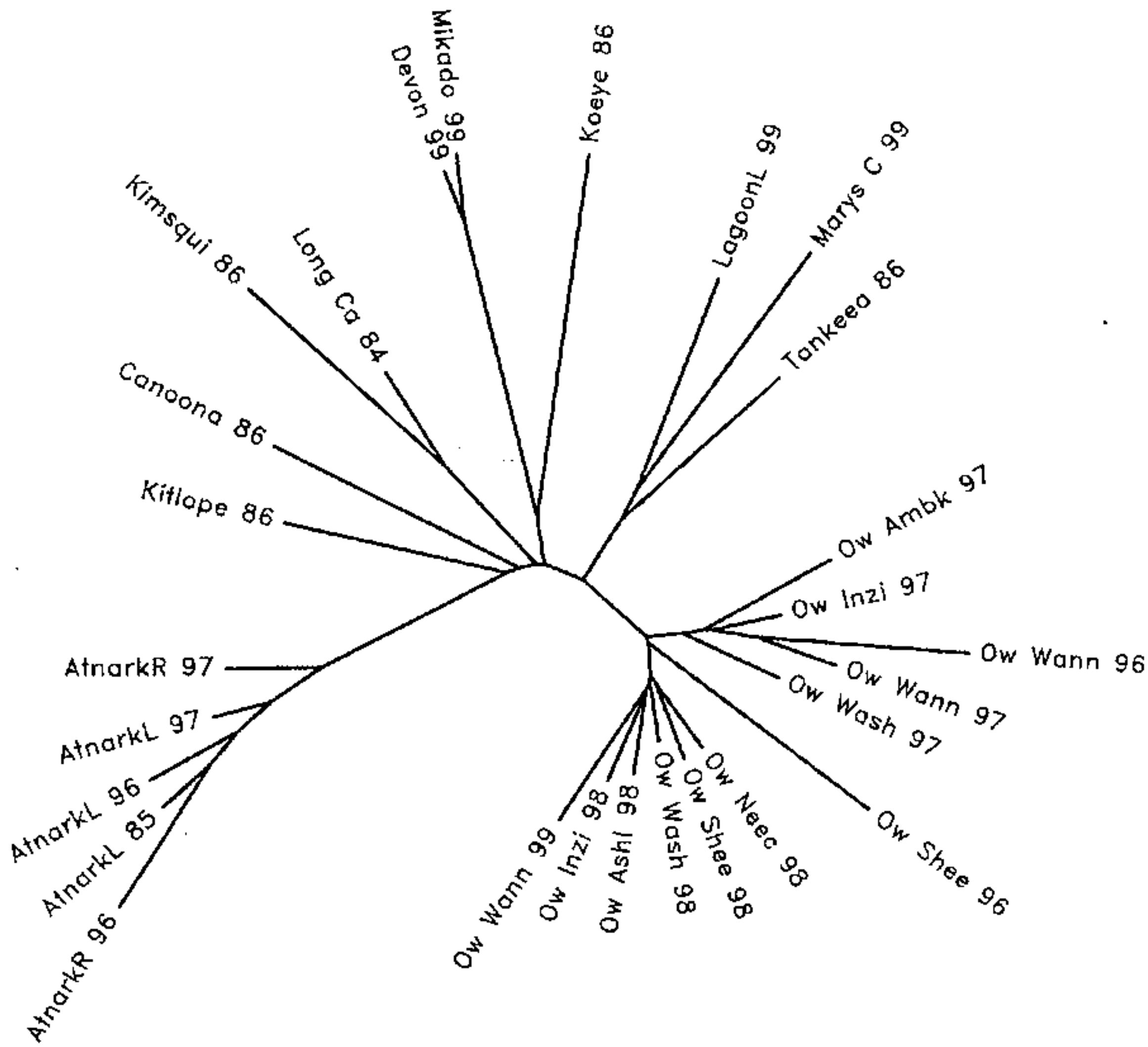

Figure 1. Neighbor joining tree constructed from pairwise genetic chord distances among samples averaged across 10 loci. Length of branches is proportional to genetic distance; labels as in Table 1.