Sayward Lakes
Fertilization Project Data Analysis and Criteria for Choosing Small Lakes Fertilization Projects on Vancouver Island

By
Tracy Michalski, Peter Law and Georgina Fosker
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1.0 Introduction

Lakes on Vancouver Island are characterized by low nutrients, Total Dissolved Solids (TDS) <100 mg/L, low to moderate numbers of plankton and bottom fauna, and poor fish values (Northcote and Larkin, 1956). This unproductive state arises due to natural conditions including geology, high rainfall and flushing rates, and outside factors such as logging and urbanization. As a result, in general, the fish produced on Vancouver Island are small, and most of the handful of lakes that historically produced big fish were in large lakes (>1,000 ha) (G. Reid, pers. com, 2007).

The Federal Lake Enrichment Program commenced on Vancouver Island in 1977 with the fertilization and study of six lakes (Nidle and Shortreed, 1985). The primary purpose of these projects was to enhance the growth and survival of rearing juvenile sockeye salmon (*Oncorhynchus nerka*) (Shortreed et al, 2001). The Province also began conducting lake fertilization studies beginning in the mid-1980's for a variety of reasons including increasing the yield of salmonids for recreational angling, and restoring declining salmonid populations in reservoirs influenced by hydroelectric development (Ashley, 1998).

Sayward Lakes Fertilization Experiment – Project Objectives

In 1989, the Vancouver Island Fisheries Section received funding from the Habitat Conservation Fund (HCF) and scientific and technical support from the UBC Fisheries Research Section to conduct a small lakes fertilization experiment in Region 1. Regional biologists were interested in determining whether the addition of nutrients could offset the naturally unproductive nature of Island lakes and thereby improve fishing in small lakes in the region. Regional staff met with staff from the University of BC Fisheries Research Section and determined the following project objectives:

1. Increase fish yield in fertilized lakes.
2. Determine whether the application of fertilizer results in a measurable increase in the length and weight of salmonids.
3. Identify small lakes (<100 ha in surface area) with populations of Coastal cutthroat trout (*O. clarkii*) that would benefit from fertilization.
4. Develop a low technology and cost effective method for applying fertilizer to small lakes.

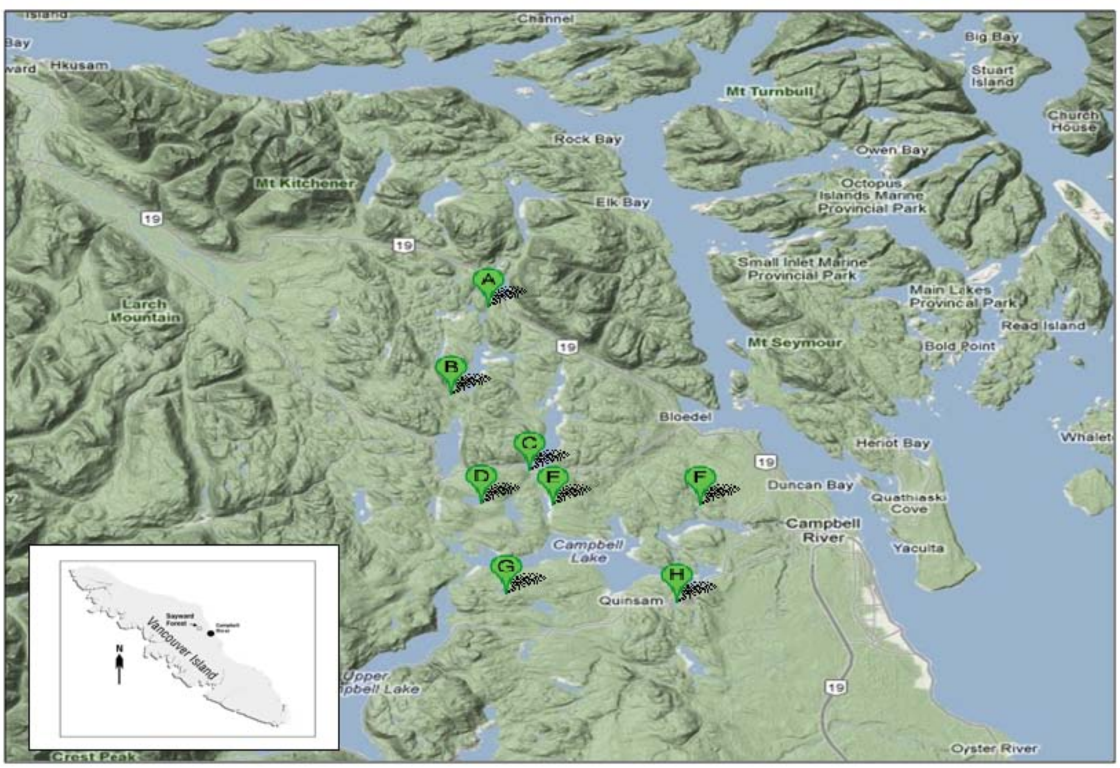
2.0 Methods

Project staff identified the following biophysical criteria which were used for identifying candidate lakes to be included in the experiment:

1. Low flushing rate[1]
2. Lake surface area <100 hectares.
3. Lake maximum depth <10 metres.
4. Lake elevation <1,000 metres.
5. Unrestricted lake access.
6. No conflict with other water users.
7. No major outlets from the lakes between June and September.
8. Utilization of at least 100 angler days annually.
9. Similar geographical location.

Biophysical, water chemistry and fish population sampling began at 13 Island lakes in the spring of 1980. Based on the results of that sampling, staff identified 4 control and 4 test lakes in the Sayward Forest near Campbell River to be included in the fertilization experiment (Figure 1) (Table 1) (Appendix 1).

FIGURE 1. Approximate geographic locations of Vancouver Island study lakes: Cedar Lake (A), Surprise Lake (B), Lawier Lake (C), Merrill Lake (D), Gosling Lake (E), Lost Lake (F), Reginald Lake (G), and Mirror Lake (H) (Source: Google Maps).



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[1] no quantitative value for flushing rate was found in the project files.

TABLE 1. Summary of physical and chemical parameters of control lakes (Cedar, Lost, Mirror and Surprise) and test lakes (Gosling, Lawier, Merrill and Reginald) Note: detailed descriptions of each lake and bathymetric maps can be found in Appendix 1.

Parameter	Control Lakes				Test Lakes			
	Cedar	Lost	Mirror	Surprise	Gosling	Lawier	Merrill	Reginald
Area (ha)	31	3.4	14.9	48	62.5	9.2	65	32.3
Elevation (m)	200	259	260	210	225	213	260	335
Shoal area (ha)	26.4	1.2	6.8	33.1	28.1	2.6	25	
Shoal area (%)	85	35	46	69	45	28	38	~ 40 %
Max Depth (m)	21	11	16	17	40	10.5	29	27.9
Mean Depth (m)	3	4.2	6.7	8.6	8	4.2	11.1	6
Fish Community	cutthroat, cottids, stickleback	cutthroat, kokanee	cutthroat Dolly Varden, cottids	cutthroat, kokanee, cottids	cutthroat	cutthroat, cottids	cutthroat, rainbow	stocked with steelhead
TDS (mg/L)	25	26	28			30		
LPcrit (mg/P/m^2/yr)	97	118	157	182	174	118	211	147
pH	6.7	6.8	7.8			7.2	8.5	
Secchi depth (m)	7	5.8	7		9.5	8.1	7.8	11.5

The experimental design used a before-after, control-impact pair (BACIP) design as outlined in Stewart-Oaten et al, 1986. A complete discussion of the study design can be found in Johnston et al, 1999.

Data Collection

Monthly monitoring was conducted at each of the Sayward Lakes by agency staff and contractors before and during the experimental period (Appendix 2). Data was tabulated for some parameters and provided to the Regional office by UBC staff some contractors.

Water Quality

Dissolved oxygen concentrations and temperature profiles were measured with a model 57 YSI meter, secchi depths were measured with a standard Secchi disc, and depth-integrated water samples were collected for the analysis of ammonia, nitrate, total kjeldahl nitrogen, soluble reactive phosphorus (SRP), total dissolved phosphorous (TDP), and total phosphorous (TP). Water samples were also analyzed for silica concentrations, pH, specific conductance, total alkalinity, and TDS.

Water was filtered in the field for the collection of phytoplankton for the analysis of chlorophyll a concentrations and zooplankton were collected using two vertical hauls of a Wisconsin net (150 µm mesh).

Fish Sampling

Fish sampling was done with overnight gillnet sets of 1 floating and 1 sinking standard experimental gang net (Resource Inventory Standards Committee, 1997). Nets were set with the smallest mesh size panel near shore and extended perpendicular into deeper water. Both nets were set late in the afternoon, left overnight (12-15 hours), and retrieved the following morning. The gillnet set was repeated for a 2nd night. Gillnets were placed in the same pre-selected locations on the lake each time and sampling occurred in the 2nd or 3rd week of September each year. Fish were sampled for length, weight, sex, and stomach contents and scales were taken for fish ageing (Appendix 3).

Lake Fertilization

Gosling, Lawier, Merrill and Reginald Lakes were fertilized in 1993, 1994, and 1995. Fertilizer was applied monthly from May – August using a 225 US gallon tank and spray hose placed on a ¾ ton pickup truck (Figure 2) (Appendix 3). In all years, the fertilizer consisted of a liquid solution of 10-34-0 and 32-0-0 applied at variable rates and volumes determined by a limnologist from UBC. Monthly sampling of water chemistry, phytoplankton, zooplankton and fish continued during the fertilization period.

FIGURE 2. Application of liquid fertilizer at a test lake.

Stocking at Control and Test Lakes

Two control (Lost and Mirror) and 3 test lakes (Gosling, Merrill and Reginald) were stocked throughout the experimental period (Table 2). Mirror and Lost Lakes were stocked with cutthroat trout; Mirror was stocked only in 1991 and Lost in 1991, 1993 and 1995. Gosling Lake was stocked with cutthroat trout in 2 pre-fertilization years and 1 year during fertilization, Reginald Lake was stocked with steelhead 2 years before it was fertilized, then stocked again in 1993 and 1995 during the fertilization period, and Merrill Lake was stocked every year of the experimental period.

TABLE 2. Species, range in number of fish stocked and average weight of fish stocked from 1988 – 1995 at Lost and Mirror (control) and Gosling, Merrill and Reginald (test) lakes. (ct=cutthroat; rb=rainbow; st=steelhead).

Lost (control)				
Year	Date Stocked	Species	Number	Mean Weight (g)
1991	05-Apr.	ct	1,000	42.7
1993	31-Mar	ct	500	41.4
1995	03-Apr	ct	500	44
1995	11-Apr.	ct	500	48

Mirror (control)				
Year	Date Stocked	Species	Number	Mean Weight (g)
1991	----	ct	1,000	9.71

Gosling (test)				
Year	Date Stocked	Species	Number	Mean Weight (g)
1992	06-May	ct	1,000	38.7
1994	21-Mar.	ct	1,000	32.5

Merrill (test)				
Year	Date Stocked	Species	Number	Mean Weight (g)
1990	04-Jun.	rb	5,000	15.4
1991	06-Jun.	rb	5,000	16.9
1992	13-May	rb	2,000	17.7
1993	17-May	rb	2,000	20.4
1994	09-May	rb	2,000	19.3
1995	03-May	rb	2,000	18

Reginald (test)				
Year	Date Stocked	Species	Number	Mean Weight (g)
1988	----	st	21,500	9.92
1991	----	st	7,886	6
1993	----	st	4,804	13.8
1995	----	st	4,735	4.22

Data Analysis and Project Summary

We analyzed existing data and data summaries to determine if the project objectives were met. In addition, we reviewed the lake selection criteria from this experiment, as well as the results of a similar study conducted at Twin Lakes in the Fraser Valley (Johnston et al, 1999) to identify criteria for selecting candidate small lakes for fertilization. We then used those criteria to identify suitable lakes on Vancouver Island for future fertilization experiments.

3.0 Results

Water Chemistry

It appears that epilimnetic total phosophorus (TP) increased in test lakes during the fertilization period (1993 – 1995) (Figure 3a). The mean value of TP for test lakes was also higher in test lakes compared with control lakes in 1993 and 1995. Both test and control lakes returned to pre-fertilization levels in the year following the experiment. Note: TP measurements were reported in different units over the course of the experiment and some outliers were also reported. We converted measurements and removed outliers, however, this data should be interpreted with caution.

Secchi depths in control lakes remained between 6 and 7 meters throughout the experimental period while secchi depths decreased in test lakes during the fertilization period (Figure 3b). In 1994, the average secchi depth in test lakes was 6 – 7 m, whereas during the pre-fertilization period secchi depths in these lakes ranged from 7 – 8 m.

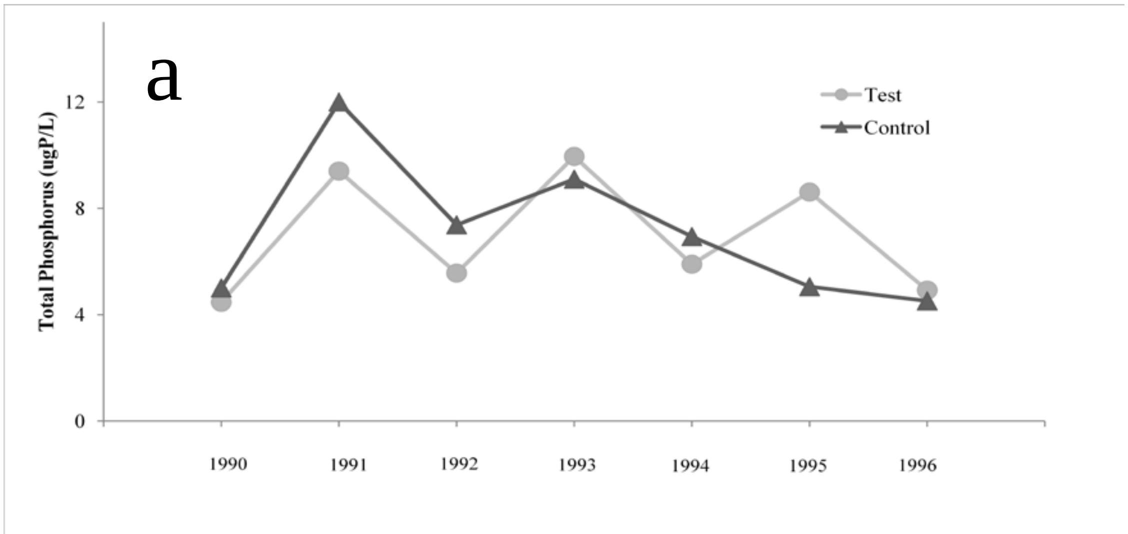
Phytoplankton Volume

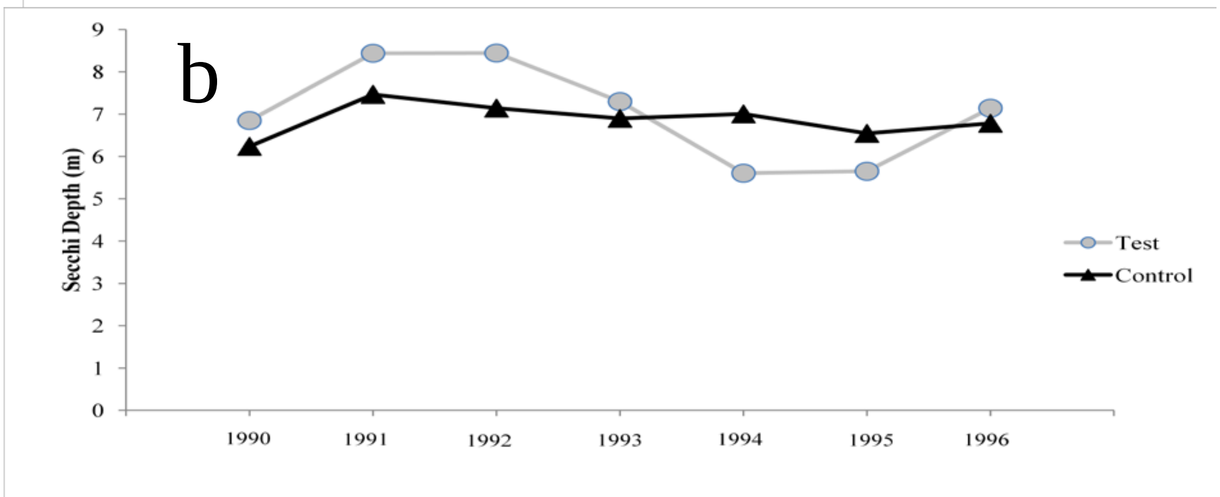
The volume of phytoplankton between July – September increased in test lakes in fertilized years compared to the years before fertilization (Figure 3c). Although the volume of phytoplankton was higher in test lakes compared to control lakes, this variable did also increase in control lakes in the last year of the study (1995).

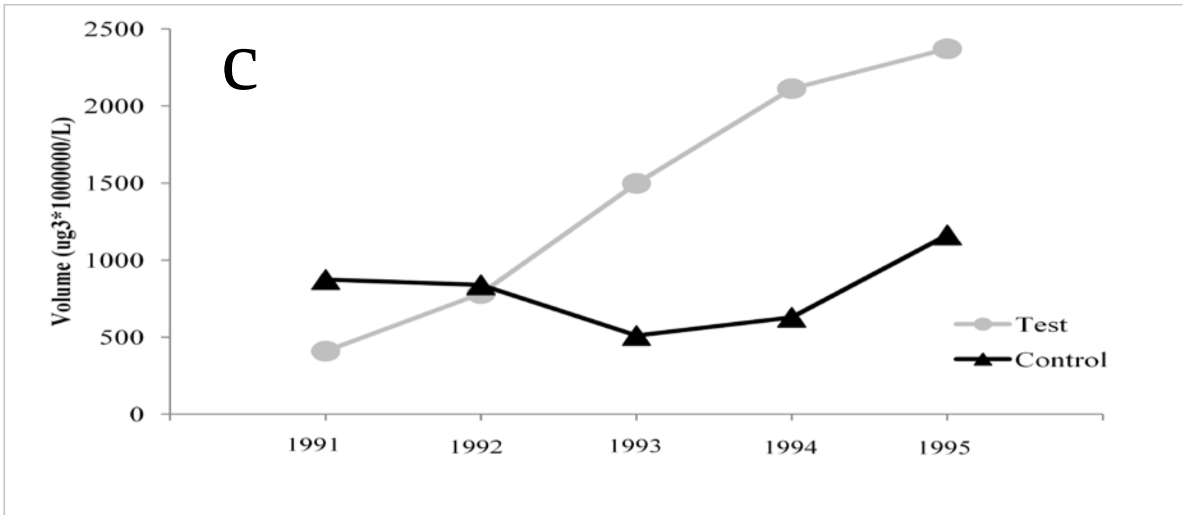
Chlorophyll a

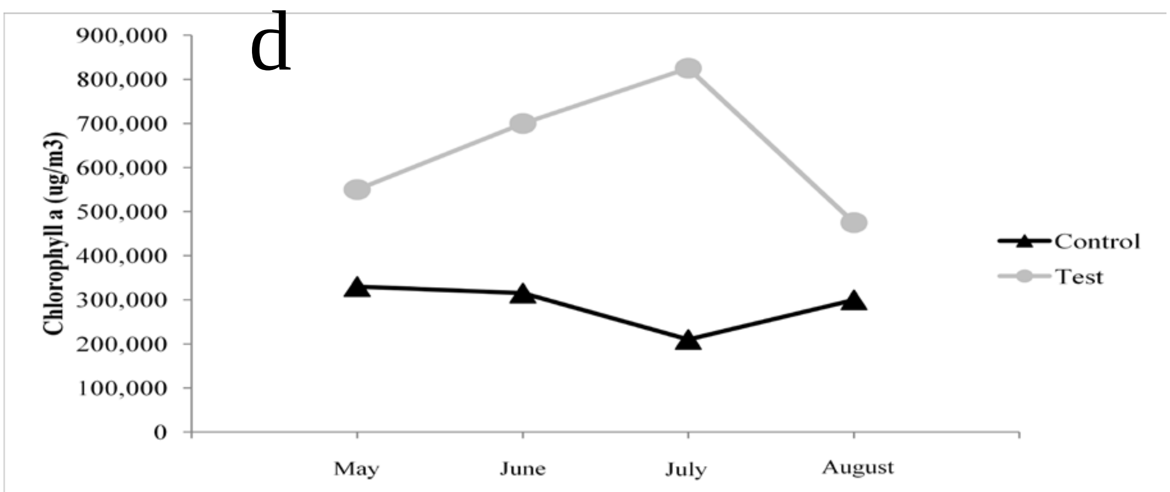
Unfortunately, information for chlorophyll a is only available for 1995 and we could find no raw data in the files so created Figure 3d from a figure previously provided by a contractor. The contractor provided data for 2 stations in control and test lakes which we averaged to compare the response of this parameter for test and control lakes. Our analysis shows that chlorophyll a was higher throughout the summer of 1995 at test lakes than it was at control lakes (Figure 3d).

FIGURE 3. Mean values response variables in control (Cedar, Lost, Mirror, Surprise) and test (Gosling, Lawier, Merrill and Reginald) Lakes before and during fertilization. Summer average epilimnetic concentrations of Total Phosphorus (a), mean secchi depths (m) (b), mean volume of phytoplankton (ug^3*1000000/L) (c), Chlorophyll a levels (ug/m3) (d).





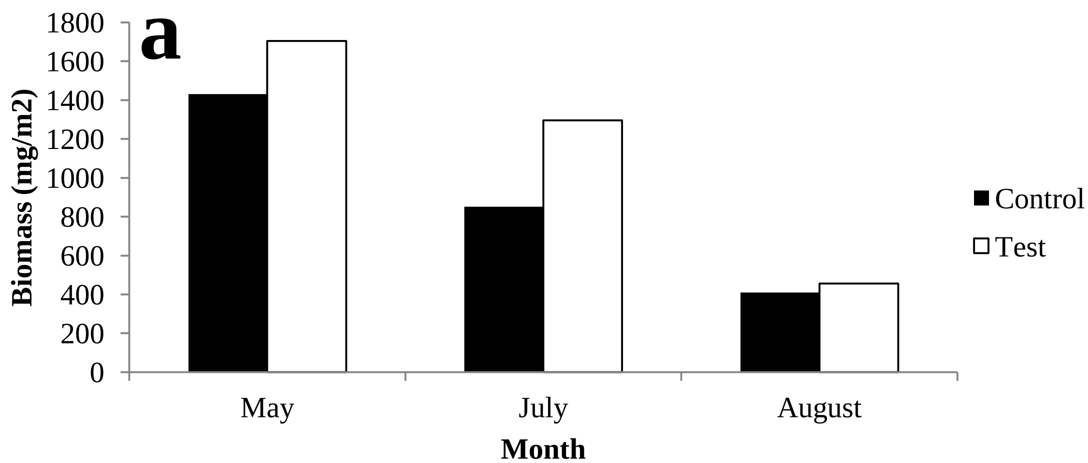

c
Volume (ug3*1000000/L)
2500
2000
1500
1000
500
0
1991
1992
1993
1994
1995
Test
Control

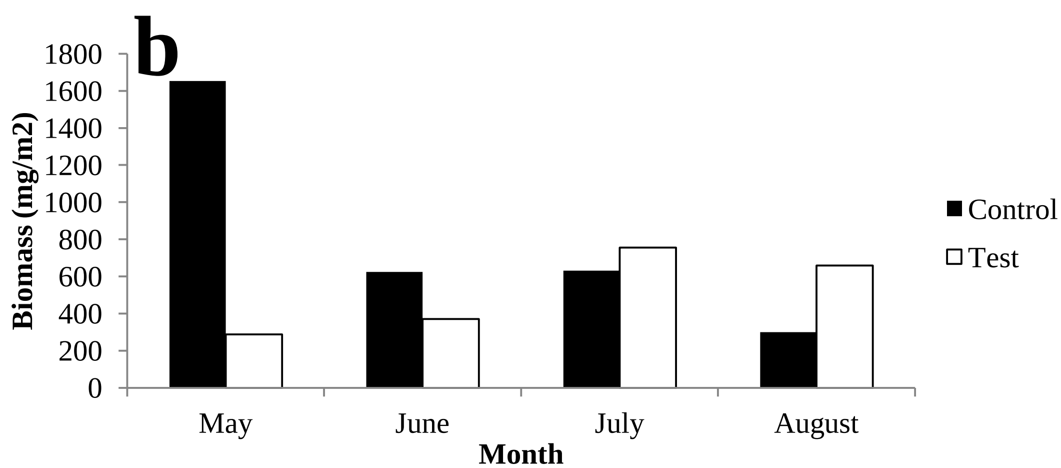

d
Chlorophyll a (ug/m3)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
May
June
July
August
Control
Test

Zooplankton

Although zooplankton biomass was measured each year of the experiment, data was entered into Lotus between 1991 and 1993 and we could not retrieve these files for analysis. However, we were able to summarize data from 1994 and 1995 and our analysis suggests that total zooplankton biomass was higher at test lakes during fertilization period during July and August of 1994 (Figure 4a) and 1995 (Figure 4b).

FIGURE 4. Total zooplankton biomass (mg/m2) at control (Cedar, Lost, Mirror, Surprise) (dark bars) and test (Gosling, Lawier, Merrill and Reginald) (open bars) Lakes in May, July and August 1994 (a) and May, June, July, August 1995 (b).





Fish - Total Catch, Biomass and Yield

Total catch varied during the beginning of the experiment, increasing by over 200% between 1990 and 1991, and decreasing by >50% the following 2 years, one of which was a test year. Overall, there was a decrease of 4% in total catch, but an 18% increase in total biomass and yield (kg/ha) during the fertilization period (Table 3).

TABLE 3. Total catch and biomass and percent change/year of total catch and biomass of all salmonids captured in fertilized (Gosling, Lawier, Merrill and Reginald) lakes before (1990-1992) and during (1993-1995) fertilization.

Year	Total Catch	Total Biomass (kg)	Yield (kg/ha)
1990	82	11.9	0.07
1991	281	35.6	0.211
1992	167	41.9	0.248
1993	148	40.7	0.241
1994	208	43.8	0.259
1995	155	20.9	0.124
Summary			
1990-1992	530	89.5	0.529
1993-1995	511	105.4	0.624
Overall Change	-19 fish (-4%)	+ ~16 kg (+ 18%)	+0.095 kg/ha (+18%)

We examined catch, biomass and yield of cutthroat and rainbow trout at test lakes to determine if there was a different response by each species. We found that catch of cutthroat increased by 102 fish (35%) during the fertilized period, however, biomass and yield only increased by 5% during that period (Table 4). It is possible that the increased catch of cutthroat may have been due to stocking at Gosling Lake in 1992 and 1994. By contrast, the catch of rainbow decreased by 131 fish (56%) but the biomass and yield of this species increased by ~60%

TABLE 4. Total catch, biomass and yield (kg/ha) of cutthroat and rainbow trout at test lakes (Gosling, Lawier, Merrill and Reginald) before (1990-1992) and during (1993-1995) fertilization. Note: yield is calculated for total area of all test lakes (169 ha).

	Cutthroat			Rainbow		
Year	Catch	Biomass (kg)	Yield (kg/ha)	Catch	Biomass (kg)	Yield (kg/ha)
1990	49	4.78	0.028	33	7.09	0.042
1991	128	25.87	0.153	151	7.8	0.046
1992	111	29.17	0.173	52	9.63	0.057
1993	132	24.42	0.144	16	16.24	0.096
1994	148	23.06	0.136	45	18.39	0.109
1995	110	15.44	0.091	44	4.41	0.026
Summary						
1990-1992	288	59.82	0.354	236	24.53	0.145
1993-1995	390	62.92	0.372	105	39.03	0.231
Overall Change	102 (+35%)	3.1 (+5%)	0.018 (+5%)	-131 (-56%)	14.5 (+59%)	0.086 (+59%)

Rainbow Trout - Total Catch, Biomass and Yield

Merrill and Reginald Lakes were the only test lakes in the Sayward Lakes experiment with rainbow trout. We compared the response at each lake and found that at Merrill Lake, catch of rainbow trout decreased by 75% while biomass and yield decreased by 62% (Table 5). The total catch of rainbow trout also decreased at Reginald Lake, however, only by 6%, while the biomass and yield increased by 100% during fertilization.

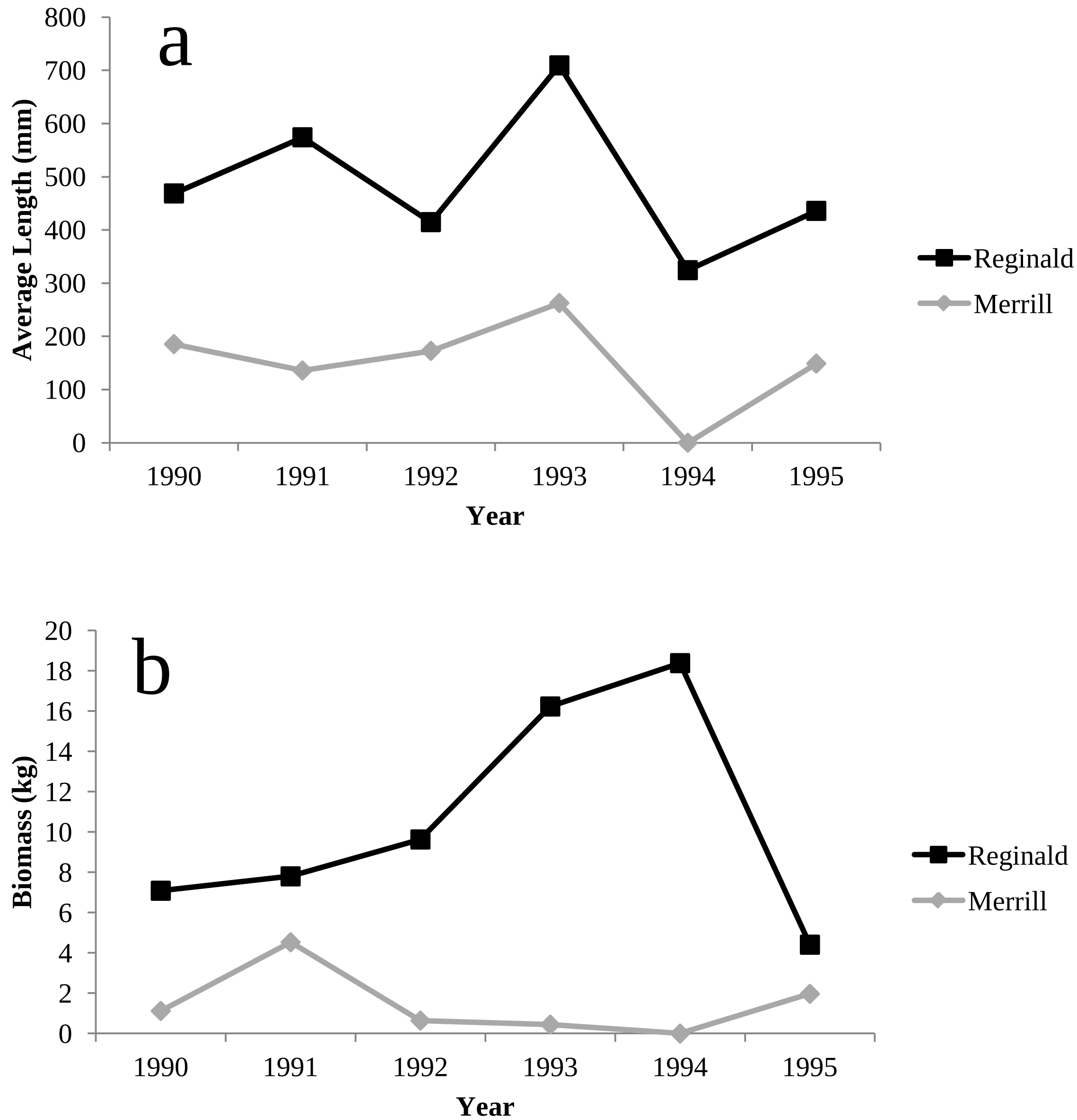
TABLE 5. Total and percent change in catch, biomass (kg) and yield (kg/ha) of rainbow trout at Merrill and Reginald Lakes before treatment (1990-1992) and during treatment (1993-1995).

	Merrill			Reginald		
Year	Total Catch	Biomass (kg)	Yield (kg/ha)	Total Catch	Biomass (kg)	Yield (kg/ha)
1990	12	1.12	0.017	21	5.97	0.185
1991	145	4.53	0.07	3	3.27	0.102
1992	9	0.64	0.01	43	8.99	0.279
1993	2	0.45	0.007	14	15.79	0.49
1994	0	----	----	45	18.39	0.571
1995	40	1.97	0.03	4	2.44	0.076
Summary						
1990-1992	166	6.3	0.097	67	18.23	0.566
1993-1995	42	2.42	0.037	63	36.62	1.137
Overall Change	-124 fish (-75%)	-3.9 kg (-62%)	-0.06 kg/ha (-62%)	- 4 fish (-6%)	+18.4 kg (+100%)	+0.57 kg/ha (+100%)

Size of Rainbow Trout at Reginald Lake

The data suggest that average length of rainbow trout increased in 1993 at both Reginald and Merrill Lakes (Figure 5a). However, there was a decline in average length the following year. The data also suggest an increase in biomass of rainbow trout at Reginald Lake in two of the 3 years of fertilization (Figure 5b).

FIGURE 5. Mean length (mm) (a) and biomass (kg) (b) of rainbow trout at Reginald (dark lines) and Merrill (grey lines) Lakes before and during fertilization.

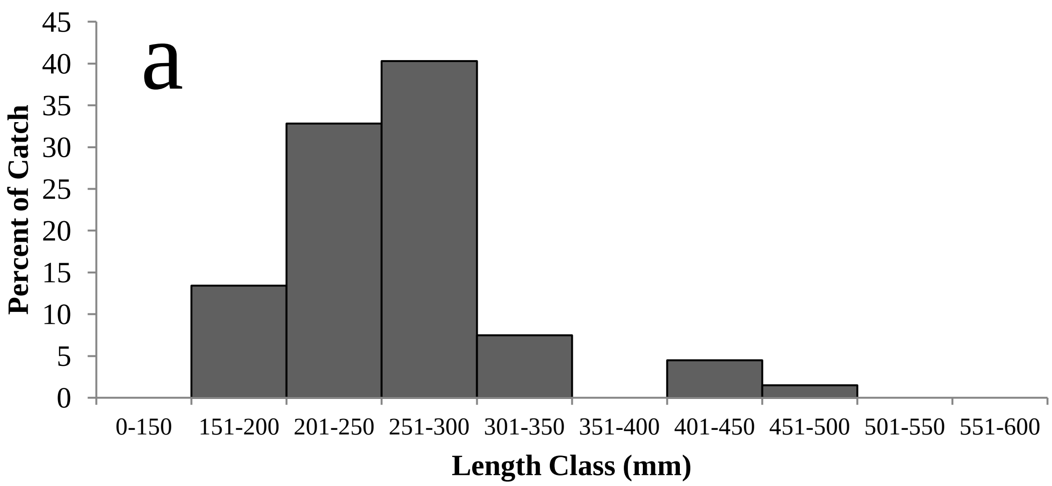


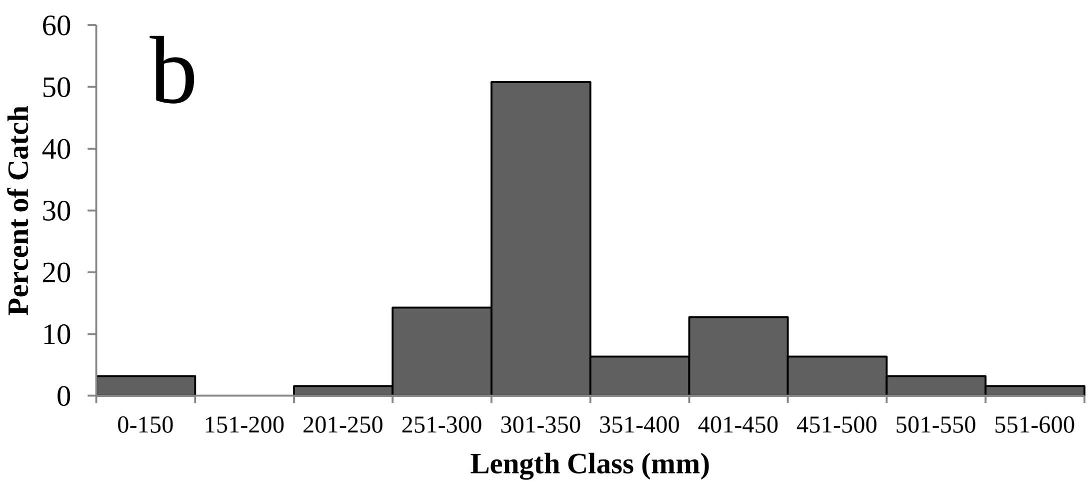
We found that maximum size of rainbow trout increased from 460 mm to 557 mm (21%), while the mode increased from 225 mm to 336 mm (~50%) during fertilization at Reginald Lake (Table 6). We also found a difference in the percent of trout in each length class before and during fertilization. Before fertilization, ~95% of the fish were <300 mm. Of these, 40% were 251-300 mm, 35% were 201-250 mm, and 15% were 151-200 mm (Figure 5a). During fertilization, ~80% of the fish were >301 mm. Of these fish, 50 % were 301-350 mm, 6% were 350-400 mm and ~13% were 401-450 mm. A further 10% were >451 mm (Figure 5b).

TABLE 6. Number and minimum, maximum and mean length (mm) of rainbow trout captured in Reginald Lake during pre-fertilization (1990-1992) and fertilized (1993-1995) periods.

		Length (mm)	
Year	N	Maximum	Mode
1990	21	334	279
1991	3	445	-----
1992	43	460	225
1993	14	557	450
1994	45	510	336
1995	4	465	-----
Summary			
1990-1992	67	460	225
1993-1995	63	557	336

FIGURE 5. Length frequency diagrams of rainbow trout captured at Reginald Lake before treatment (1990-1992; N=66) (a) and during treatment period (1993-1995; N=63) (b).





We constructed a box plot to show the means and confidence intervals of the mean lengths of rainbow trout captured before and during treatment at Reginald Lake (Figure 6). We then conducted a Welch Two Sample t-test and found evidence of a difference in the mean lengths of rainbow trout captured before vs. those captured during the fertilized periods (Figure 7).

FIGURE 6. Box plot of lengths mm), mean lengths and confidence intervals of mean lengths of rainbow trout captured at Reginald Lake before treatment (1990-1992; N=67) and during treatment period (1993-1995; N=63).

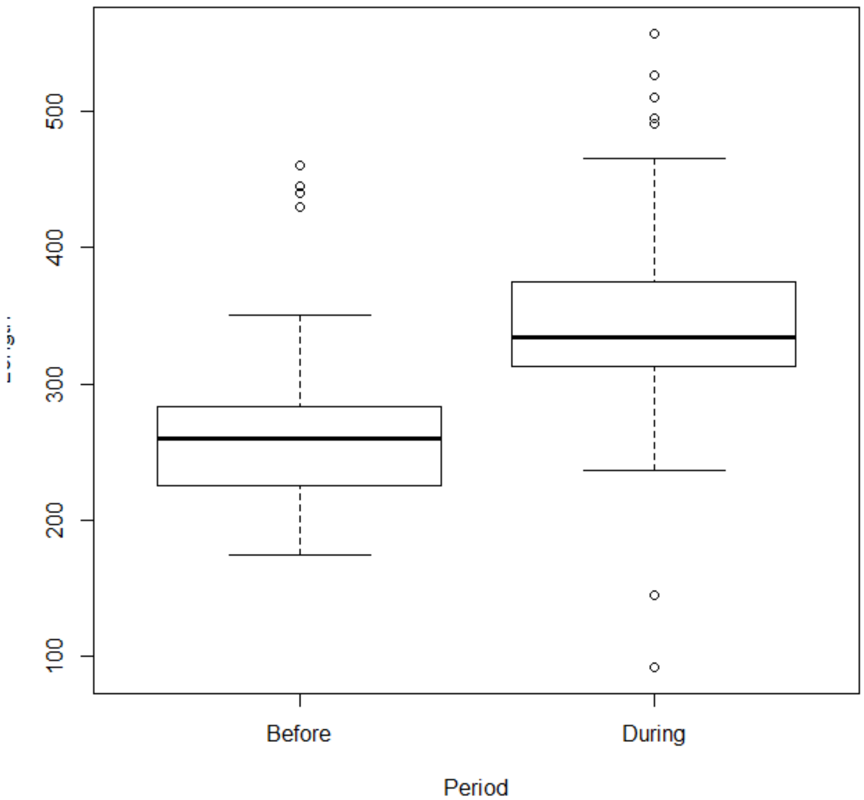


FIGURE 7. Summary of results of a Welch Two Sample t-test comparing average lengths (mm) of rainbow trout at Reginald Lake before treatment (1990-1992; N=67) ("before") and during treatment period (1993-1995; N=63) ("during").

Welch Two Sample t-test

Data: Length by Period
t = -6.8498, df = 114.238, p-value = 3.94e-10
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-110.04732 -60.67479
sample estimates: mean in group "before" mean in group "during"
263.6866 349.0476

Fisheries at Control and Test Lakes

Angler effort and total catch stayed relatively constant at control lakes between 1992 and 2002 as did angler success which varied from 2.5 fish/day before the fertilization period (1992), to 2.8 fish/day after fertilization (2002). At test lakes, however, angler effort increased almost 65% from 544 days to 896 days between the two periods (Table 7). Total catch also increased by 57% from 1,530 fish caught at test lakes in 1992, to 2,407 fish in 2002.

TABLE 7. Angler effort (angler days), total catch and angler success at control (Cedar, Lost, Mirror and Surprise) and test (Gosling, Merrill and Reginald) lakes before fertilization (1992) and after fertilization (2002) (Source: Vancouver Island Lakes Questionnaire, 1992; 2002).

	Control Lakes		Test Lakes		Change
Fisheries Statistics	1992	2002	1992	2002	
Angler Effort	370	364	544	896	Increase of 352 days (+64.7%)
Total Catch	933	1,042	1,530	2,407	Increase of 877 fish (+57%)
Angler Success	2.52	2.86	2.81	2.69	Decrease of ~5%

The increase in catch was not enough to offset the increase in angler effort at test lakes, however, and angler success decreased by ~5% from the pre-fertilization, to the post-fertilization period (Table 7). There was an order of magnitude difference in the angler effort, and a 500% increase in total catch at Reginald Lake between pre-fertilization and post-fertilization periods and angler success dropped by almost one half from 6.3 fish/day to ~4 fish/day (Table 8).

TABLE 8. Angler effort (angler days), total catch and angler success at control (Cedar, Lost, Mirror and Surprise) and test (Gosling, Merrill and Reginald) lakes before fertilization (1992) and after fertilization (2002) (Source: Vancouver Island Lakes Questionnaire, 1992; 2002).

	Control								Test					
Fisheries	Cedar		Lost		Mirror		Surprise		Gosling		Merrill		Reginald	
Statistics	1992	2002	1992	2002	1992	2002	1992	2002	1992	2002	1992	2002	1992	2002
Angler Effort	126	104	26	177	152	-----	66	83	411	271	93	198	40	427
Total Catch	99	250	132	323	219	----	483	469	1066	219	212	667	252	1521
Angler Success	0.79	2.4	5.08	1.82	1.44	----	7.32	5.65	2.59	0.81	2.28	3.37	6.3	3.56

4.0 Project Summary

The results of the Sayward Lakes experiment are incomplete and, with respect to most response variables, unclear. The fact that epilimnetic concentrations of TP were higher in 2 of 3 test years may indicate a response; however, there is no explanation as to why there would be a decrease in this parameter in a test year. It appears as though there was a response from phytoplankton and chlorophyll a at test lakes, but additional experiments are needed to confirm this. Finally, it appears that stocking confounded the results especially since various stocking rates and different species were used at test lakes. Additional complications that contributed to poor experimental results include:

- Project staff did not limit the selection criteria for experimental lakes to lakes where wild recruitment was limited or non-existent.
- The sport fishery was not monitored closely enough during the fertilization phase of experiment. It would have been better if Catch-and-Release regulations were implemented so results would have been clearer.
- Stocking was an issue: regional staff suggested that all lakes selected in 1991 be wild only, but research advisors suggested the experiment should include a cross section of lakes that were diverse in how they were managed; i.e. if lakes were stocked before the experiment, they should continue to be managed that way during the experiment. This was to create a "dramatic effect" and the advice was that stocking would not reduce the size and growth comparisons between lakes.
- Merrill Lake contained both rainbow and cutthroat trout; there may have been predation by cutthroat on stocked rainbow which may have impacted the gillnet catch of this species and further confounded results.
- Reginald Lake was barren before 1988 when it was stocked for the first time. It was stocked again in 1991 at the start of the experiment. The stocking of steelhead into an originally barren lake may be responsible for why fish grew to a larger size at this location. Although our results show an increase in length of rainbow trout, this must be interpreted with caution since it is not clear if the response was due to fertilization, or a barren-lake effect.
- It was not clear where recruitment of fish came from in the test lakes as these lakes had fish moving between them.
- The volume of fertilizer may not have been enough to invoke a response from salmonids over the experimental period.

Notwithstanding the above, we believe there may have been a positive response in the growth of rainbow trout at Reginald Lake during test years. Although there were fewer fish in test years, the average, modal and maximum length of fish present in years during fertilization were larger than in pre-fertilization years. In addition, there was a higher percentage of rainbow trout in larger length classes during fertilization. Despite the larger fish, we did not see an increase in fish yield and suggest that the reason this response may not be evident could be because of increased angler effort at Reginald Lakes during the experiment.

One of the original project objectives was to identify small lakes with populations of Coastal cutthroat trout that would benefit from fertilization. This objective does not appear to have been met. This objective may have been met for rainbow trout at Reginald Lake, however. We used this result, as well as the positive results reported for rainbow trout at East Twin Lake to identify biophysical parameters that could indicate suitable candidate lakes for future fertilization experiments (Table 9, Table 10). We further used these criteria to select candidate lakes on Vancouver Island to be included in future fertilization experiments (Table 11).

TABLE 9. Biophysical parameters and species mix at Reginald and Twin Lake East (Source: Ashley, 1998).

	Lake	
Parameter	Twin Lake East	Reginald
Elevation (m)	460	335
Area (ha)	4.5	32.3
Maximum Depth (m)	11	27.9
Mean Depth (m)	2.9	6
% Littoral Area (defined as <6 m depth)	90	~40%
Species	rainbow (stocked)	steelhead stocked

TABLE 10. Recommended biophysical parameters and species mix for selecting small lakes for fertilization on Vancouver Island.

Biophysical Parameters and Species Mix	Criteria
Nutrients	phosphorus limited
Elevation (m)	<500
Surface Area (ha)	<50
Shoal Area (ha) (<6 m depth)	>40%
Maximum Depth (m)	<30
Average Depth (m)	<6
Outlet	No major outlets from the lakes from June-September
TDS/MEI	average or higher of Planning Unit average
Species	Stocked rainbow[1] Single species only (rainbow only, no cutthroat)

[1] Notes about Stocking and Fishing Regulations

Stocking should be done during high growth/high daylight periods when water temperatures and sunlight are increasing. We suggest the following periods for stocking experimental lakes:

Preferred: April 1st – 30th
Alternate: May 1st – 15th

Stock rainbow at 15-20 grams (i.e. East Twin Lake); stock the lake according to the Provincial stocking formula to maintain consistency between lakes and years; stock a minimum of 1,000 fish.

We suggest that lakes be Catch-and-Release fishing only during fertilization experiment as increased effort from anglers once they realize a lake is fertilized will confound results (e.g. Reginald Lake). Lakes can be opened to retention once the results of the experiment are complete.

TABLE 11. Size, % shoal area, mean and maximum depth, fish species present, stocking and stocked species in small lakes that meet the suggested criteria for fertilization.

Lake	Size	Shoal Area (%)	Mean Depth	Max Depth	Fish Species Present	Stocked?	Species
Spectacle	4	100	1.9	7	rainbow	y	rainbow
Mitchell	3	~65	5.9	8	rainbow	y	rainbow
Collwood	27	100		5.5	rainbow	y	rainbow
Matheson	25	100	15	5	rainbow	y	rainbow
Cathers	4.5	100		3.8	rainbow	y	rainbow
Blind	3	40	4.8	8.5		y	
Spider	44	70		13	Steelhead, rainbow	y	steelhead rainbow
Martha	9.9	100	2.5	10	rainbow	y	rainbow
Whymper	<30	>80					
Reginald	32.3	40	6	27.9	rainbow	y	rainbow
Wowo	35	100	3.9	19	rainbow	y	rainbow
Antler	20	50	5.3	10	rainbow	y	rainbow
Larry	7.5	80	13.5	10	rainbow	y	rainbow
Frost	17.3	53	19.5	42	rainbow	y	rainbow

The Sayward Lakes project had a final objective to develop a low technology and cost effective method for applying fertilizer to small lakes. This objective has been addressed by Ashley (2011) who provides guidelines for small lake fertilization on Vancouver Island including the fertilizer blend and application techniques.

5.0 Literature Cited

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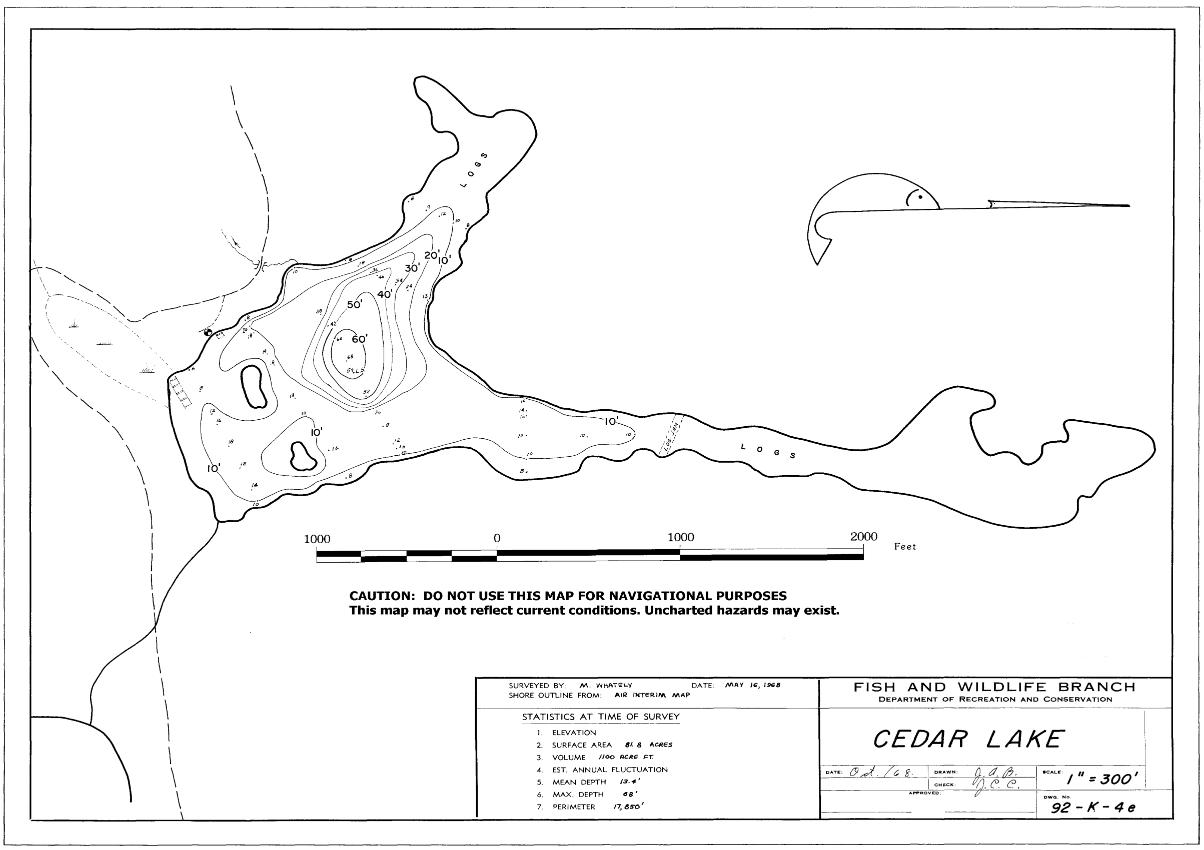
Appendix 1. Descriptions and Bathymetic Maps of Sayward Forest Experimental Lakes

Cedar Lake

Cedar Lake is located ~32 km northwest of Campbell River in the Campbell-Oyster Planning Unit. Situated at 200 m above sea level, Cedar Lake has a surface area of 31 hectares, a maximum depth of 21 meters, a mean depth of 3 meters, a TDS of 25 ppm and a pH of 6.7. Cedar Lake flows southwest initially into Muskeg Lake then Farewell Lake and Amor de Cosmos Creek where the drainage flows north, eventually entering the Pacific Ocean at Humpback Bay in Johnstone Strait.

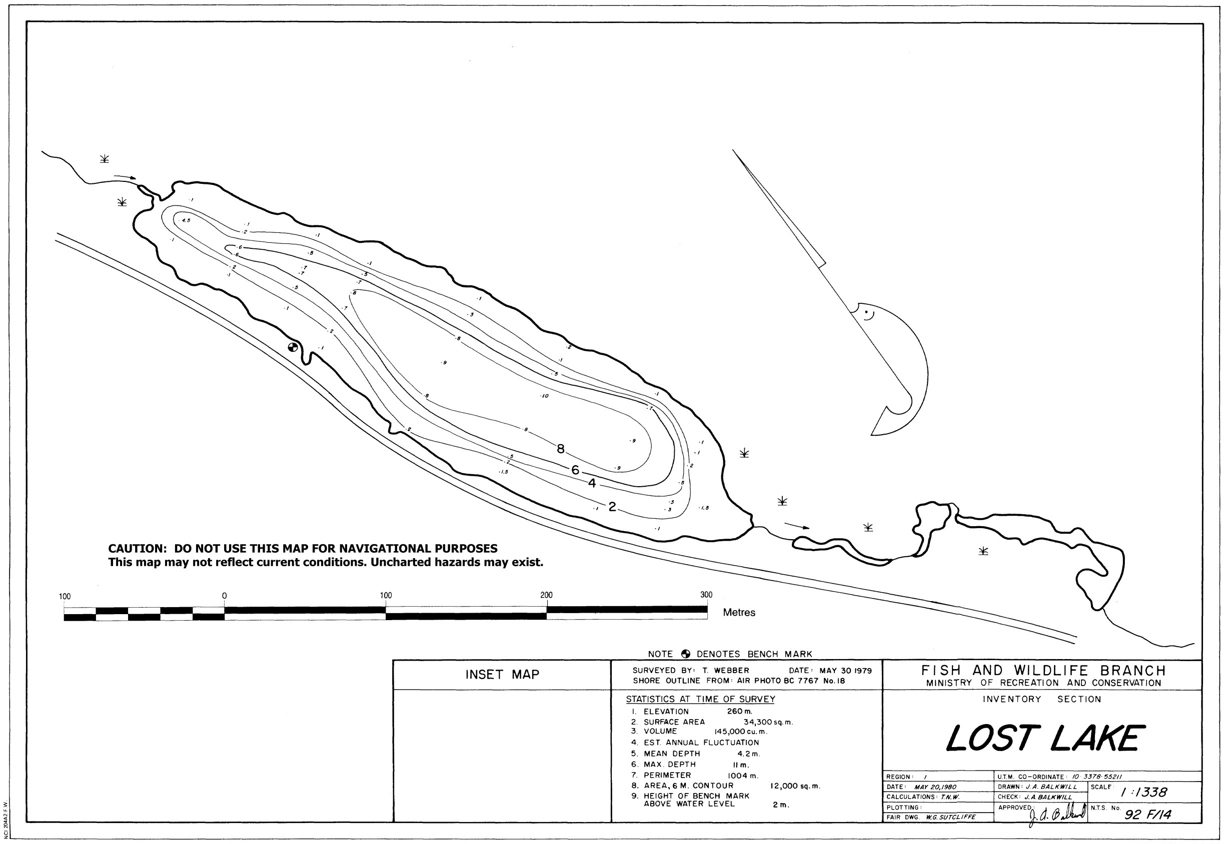
Bathymetric map of Cedar Lake (Source: Fisheries Information Summary System).



Lost Lake

Lost Lake is located ~ 25 km northwest of Courtenay in the Campbell-Oyster Planning Unit. Situated at 259 m above sea level, Lost Lake has a surface area of 3.4 hectares, a maximum depth of 11 m, a mean depth of 4.2 m, a TDS of 26 ppm and a pH of 6.8. Lost Lake flows into John Hart Lake and then into Campbell River, which enters the Pacific Ocean in Discovery Passage.

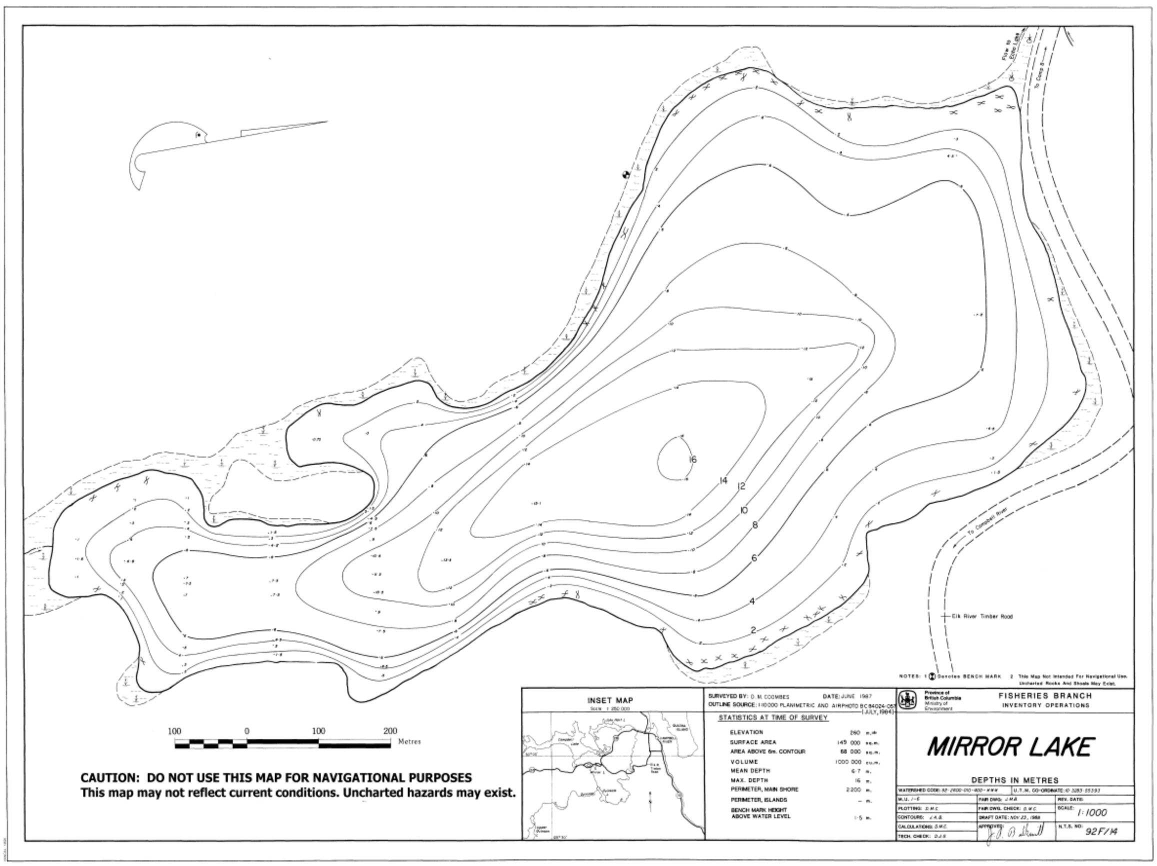
Bathymetric map of Lost Lake (Source: Fisheries Information Summary System).



Mirror Lake

Mirror Lake is located ~15 km east-southeast of Campbell River in the Campbell-Oyster Planning Unit. Situated at 260 m above sea level, Mirror Lake has a surface area of 14.9 hectares and is 750 m long and 400 m wide at its widest point. The lake has a maximum depth of 16 m, a mean depth of 6.7 m, a TDS of 28 ppm and a pH of 7.8. Mirror Lake is the expansion of an unnamed creek, which flows into another unnamed creek a few meters downstream of the lake. This second creek flows through Echo Lake and into Quinsam Lake approximately 4 km from Echo Lake. From Quinsam Lake, the Quinsam River flows into Campbell River, which enters the Pacific Ocean in Discovery Passage.

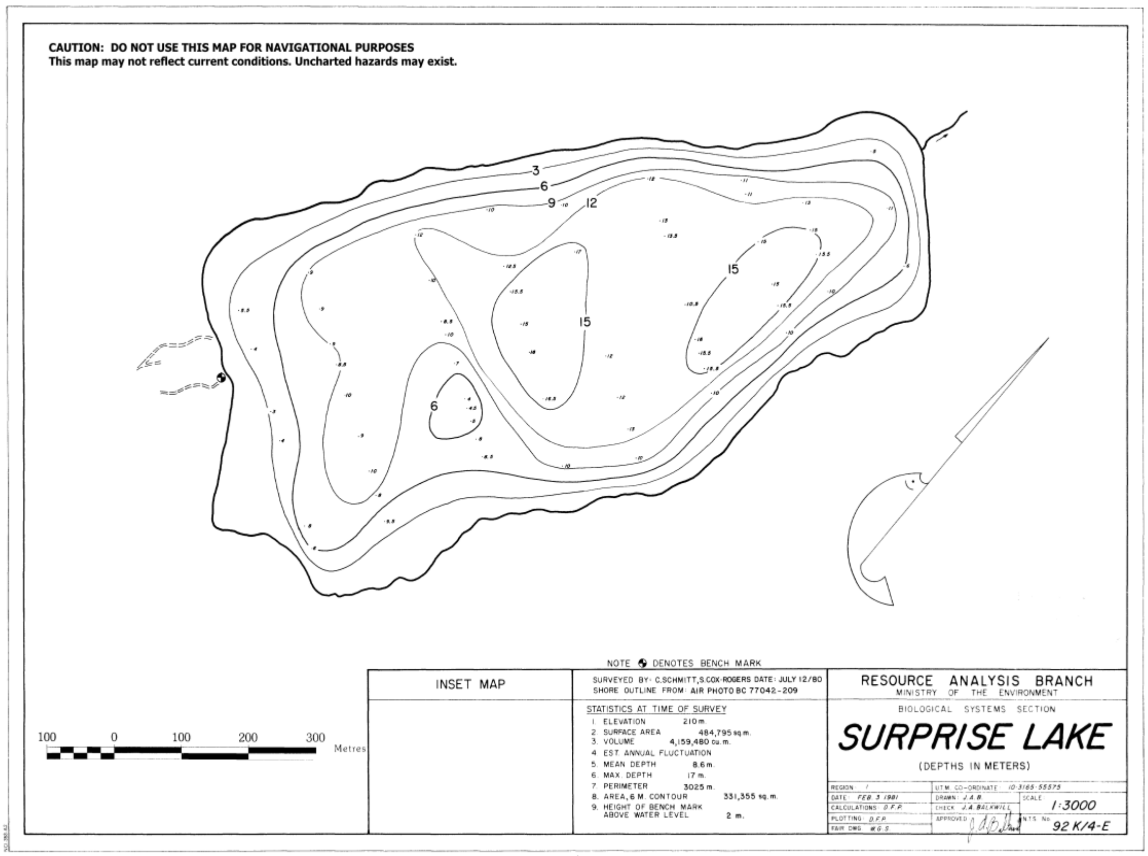
Bathymetric map of Mirror Lake (Source: Fisheries Information Summary System).



Surprise Lake

Surprise Lake is ~35 km northwest of Campbell River in the Campbell-Oyster Planning Unit. Situated at 210 m above sea level, Surprise Lake has a surface area of 48 hectares, a maximum depth of 17 meters and a mean depth of 8.6 meters. Surprise Lake flows into Amor Lake, which flows into Blackwater Lake, which flows into Farewell Lake and then into Amor de Cosmos Creek where the drainage flows north, and eventually enters the Pacific Ocean at Humpback Bay in Johnstone Strait.

Bathymetric map of Surprise Lake (Source: Fisheries Information Summary System).



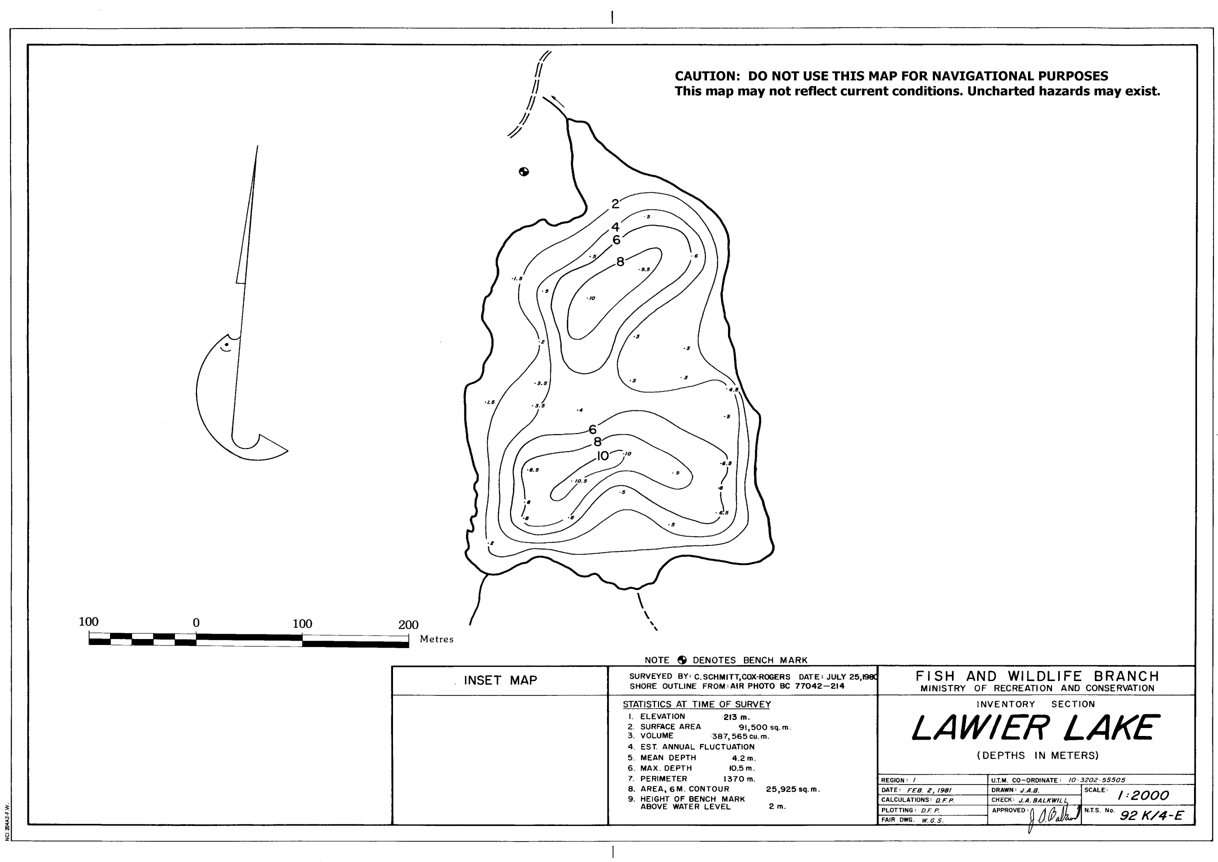
Gosling Lake

Gosling Lake is ~15 km northwest of Campbell River in the Campbell-Oyster Planning Unit. Situated at 225 m above sea level, Gosling Lake has a surface area of 62.5 hectares, a maximum depth of 40 m, and a mean depth of 8 m. Gosling Lake flows south into Campbell Lake, which empties into Campbell River and eventually discharges into Discovery Passage of the Pacific Ocean. There is no bathymetric map available for Gosling Lake.

Lawier Lake

Lawier Lake is located ~ 27 km northwest of Campbell River in the Campbell-Oyster Planning Unit. Situated at 213 m above sea level, Lawier Lake has a surface area of 9.2 hectares, a maximum depth of 10.5 m, a mean depth of 4.2 m, a TDS of 30 ppm and a pH of 7.2. Lawier Lake flows north into Mohun Lake which empties into Mohun Creek (also known as Trout Creek), which flows southeast and discharges into the Pacific Ocean at the south end of Menzies Bay in Discovery Passage.

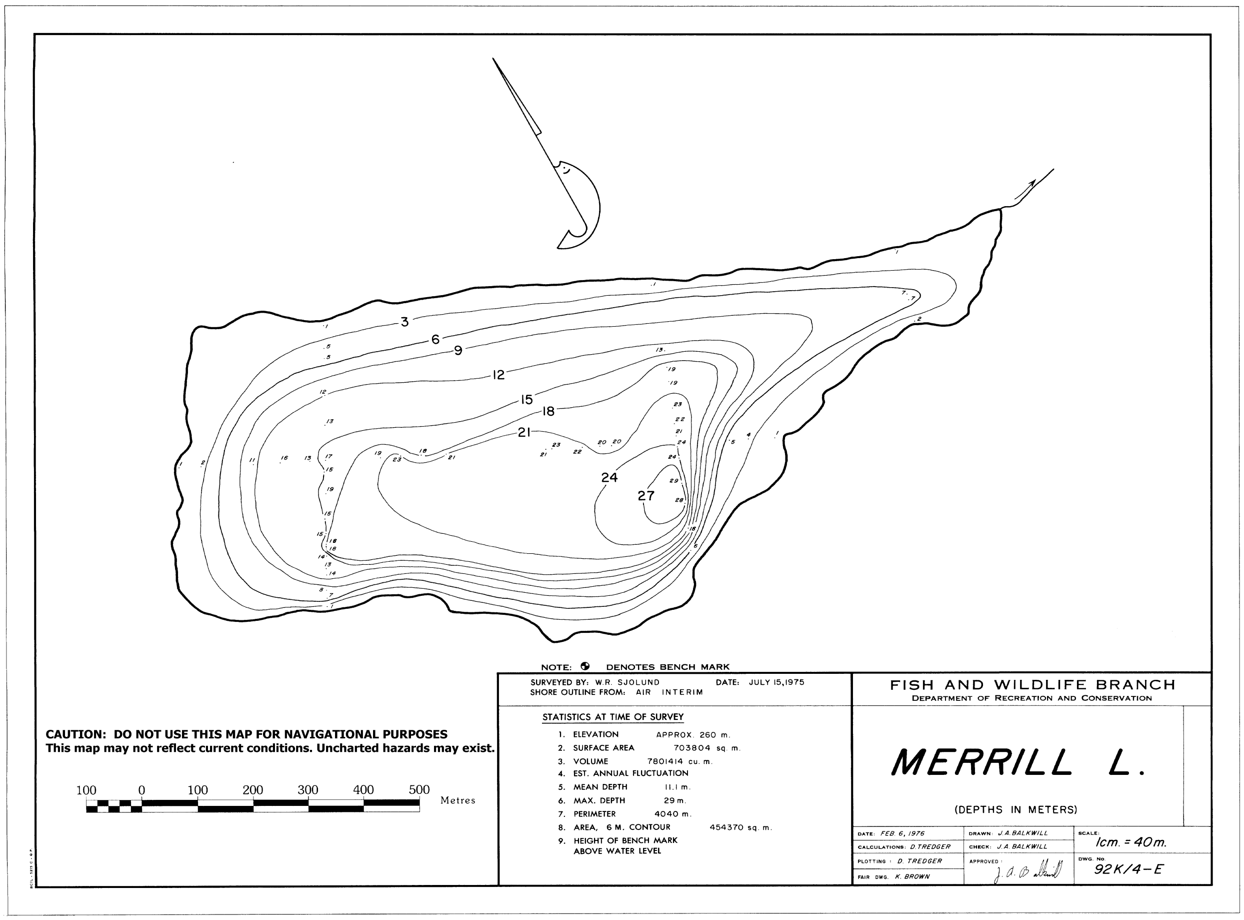
Bathymetric map of Lawier Lake (Source: Fisheries Information Summary System).



Merrill Lake

Merrill Lake is ~ 27 km northwest of Campbell River in the Campbell-Oyster Planning Unit and is located between Lower Quinsam River and Upper Campbell Lakes. Situated at 260 m above sea level, Merrill Lake has a surface area of 65 hectares, a maximum depth of 29 m, a mean depth of 11.1 m, and a pH of 8.5. Merrill Lake flows southwest into Lawson Lake, then Campbell Lake and the Campbell River, which flows east and discharges into the Pacific Ocean in Discovery Passage.

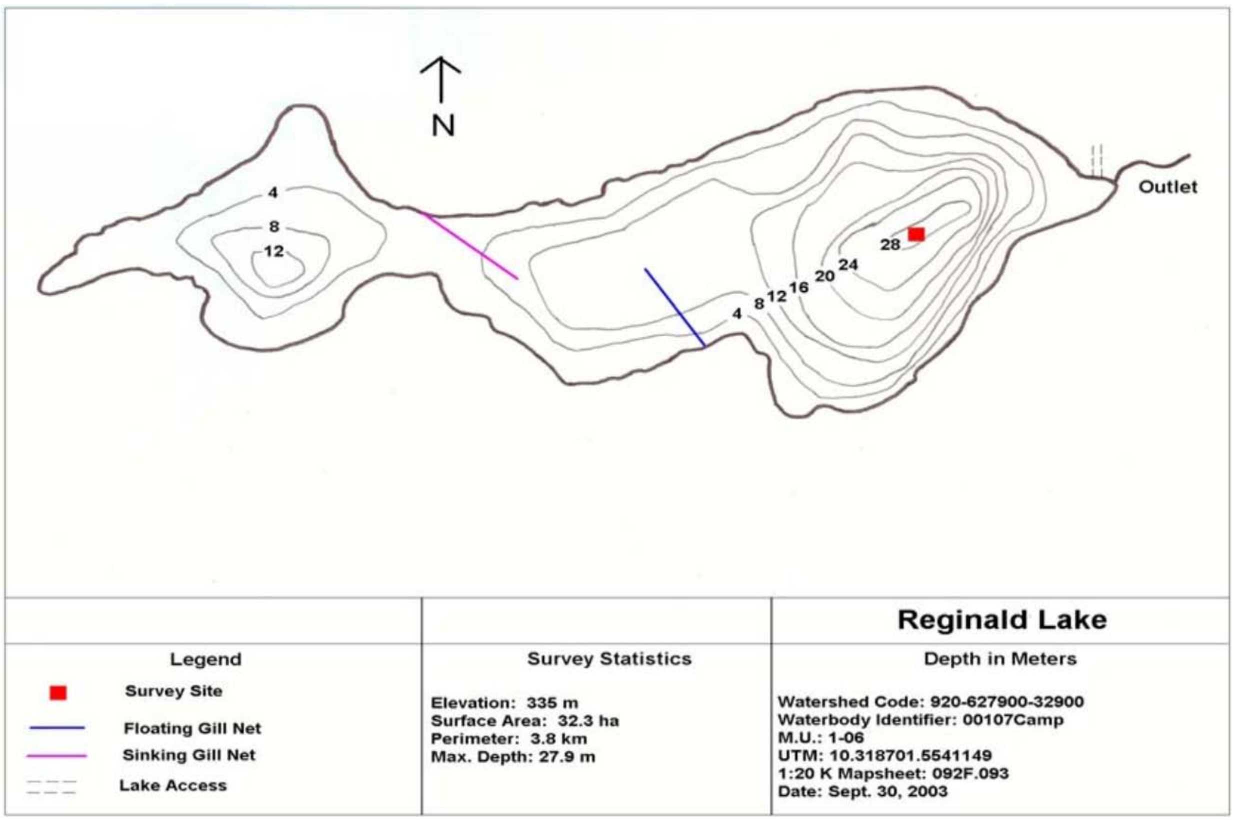
Bathymetric map of Merrill Lake (Source: Fisheries Information Summary System).



Reginald Lake

Reginald Lake is located ~ 27 km southwest of Campbell River in the Campbell-Oyster Planning Unit. This lake is situated 335 m above sea level and has a surface area of 32.3 hectares. The lake has a maximum depth of 27.9 m and a mean depth of 6 m Reginald Lake flows west into Campbell Lake, John Hart Lake and then the Campbell River, which flows east and into the Pacific Ocean in Discovery Passage.

Bathymetric map of Reginald Lake (Source: Silvestri and Fosker, 2003)



Appendix 2. Sayward Lakes Project Lake Monitoring Schedule and Summary of Agency/Contractors Responsible for Data Collection and Analysis

Data collected and agency/contractor responsible for collection and analysis during the Sayward Lakes Fertilization Project 1989-1996.

			Data Collection and Analyses					
			Phytoplankton/ Zooplankton		Water Chemistry		Fish	
Year	Activity	Responsibility	Collected	Analyzed	Collected	Analyzed	Collected	Analyzed
1989	Lake selection	Limnotech/ Regional Staff/UBC	N/A					
1990	Pre-monitoring	Limnotech	✓	Tabulated Only	✓	Tabulated Only	✓	Tabulated Only
1991	Pre-monitoring	Limnotech	✓	Tabulated Only	✓	Tabulated Only	✓	Tabulated Only
1992	Pre-monitoring	Regional Staff/UBC	✓	Tabulated Only	✓	Tabulated Only	✓	Tabulated Only
1993	Project Review; Fertilize	Regional Staff/UBC	✓	Tabulated Only	✓	Tabulated Only	✓	Tabulated Only
1994	Fertilize	Regional Staff/UBC	✓	Tabulated Only	✓	Tabulated Only	✓	Tabulated Only
1995	Fertilize	Regional Staff/UBC	✓	Preliminary Results	✓	Preliminary Results	✓	Tabulated Only
1996	Post-monitoring	Regional Staff/UBC			✓			

Appendix 3. Summary of Fertilizer Loading Rates and Costs, Materials Used to Deliver Fertilizer and Project Photographs

Fertilizer Loading Rates[1], Amounts and Cost of the Sayward Lakes Fertilization Project

Lake	Total load per year (litres)	Total load per year (kg)	Total load per month (litres)	Total load per month (gallons)	Estimated truck trips per month	Recommended number of application sites
Lawier	493	660	123	27	0.2	1
Gosling	4500	6029	1125	248	2.2	3
Reginald	2121	2842	530	117	1.0	2
Merrill	4451	5964	1113	245	2.2	3

[1]Fertilizer was a mixture of liquid 10-34-0 and 32-0-0 (UAN). The density of 10-34-0 was 1.42 kg/l; the density of 32-0-0 was 1.327 kg/L; the density of mixture was 1.34. The N: P ratio was 20:1 (wt/wt) (45:1 at wt/at wt). The target P load over 4 months was 14 μg/L P.

Materials used to deliver the fertilizer and cost.

Item	Amount	Total Cost
Blended fertilizer (N-P_2O_5-K2O) ratio is 30-3.2-0 at 1.34 kg/litre	11564 L (15.446 metric tons)	$4633
Steel storage tank	1	$501
Poly 225 US gallon pickup tank	1	$325
2” steel fertilizer pump and motor	1	$490
Flow metre	1	$745
Braided 1” delivery hose	200 ft.	$300
Braided 2” delivery hose	20 ft.	$59
Spray nozzle	1	$75
Valves and fittings	As required	$180
Total		$7308

Note: the blended fertilizer and storage tank was purchased and delivered by Cascade Fertilizer. Equipment was placed on a ¾ ton pickup truck for the fertilization process.

Liquid fertilizer in 225 US gallon tank on ¾ ton GMC long box truck.

Setting up the hoses for liquid fertilizer application.

Rainbow trout sampled at Reginald Lake in 1993

Cutthroat trout sampled at Lawier Lake in 1993

Rainbow trout sampled in 1995.

Dolly Varden sampled in 1995.