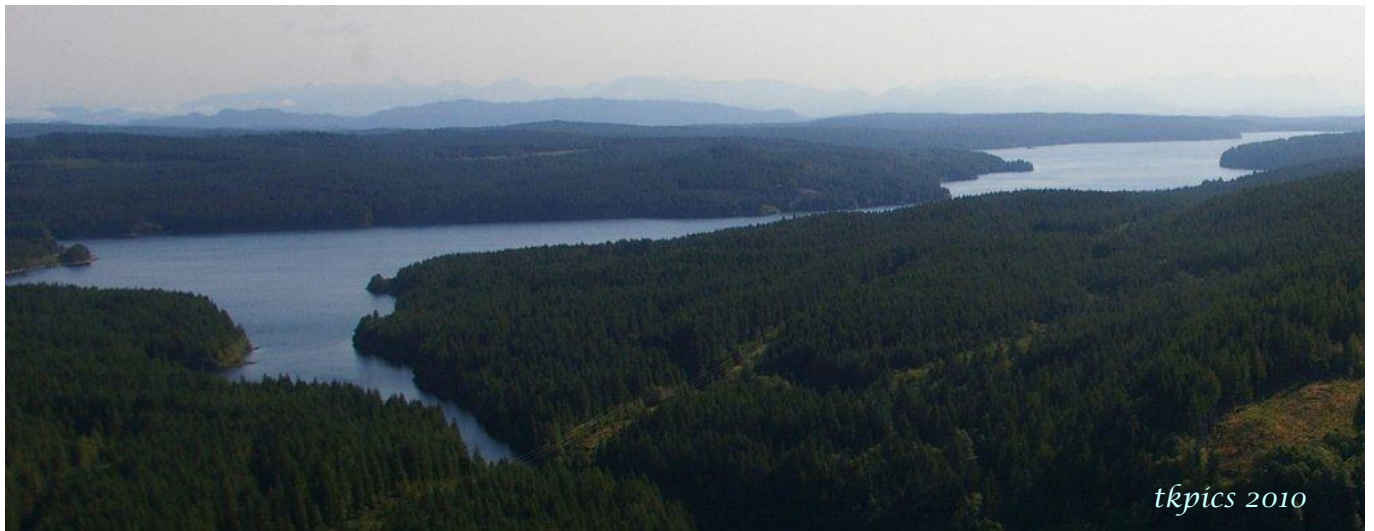


Vancouver Island Large Lakes Management Plan



By
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Cover Photo
Buttle and Upper Campbell Lakes, Vancouver Island, BC
Tim Burley, 2010

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Chapter 1. Vancouver Island Region Large Lakes Plan

1.0 Introduction

The purpose of the Vancouver Island Large Lakes Plan is to provide long-term direction for fisheries management at large lakes in the Vancouver Island region. Our plan includes a review of fish stock, fishery data, current regulatory schemes, operational objectives and management strategies including suggested regulations, and long-term monitoring programs. This document is not a blueprint for fisheries management; it is intended as a coarse level of data analysis and broad management perspective which can evolve as additional data is gathered. Sport fisheries in large lakes cannot be easily supplemented by stocking so these fisheries are entirely dependent on native, wild fish stocks. As a result, conservation of wild stocks is inherent in, and supersedes all other management objectives and we've considered this objective before determining if additional angling opportunities exist at large lakes. We've provided direction on the best management approach based on current data and, where that was not possible, the data gaps which must be filled to provide management direction in the future.

The objectives of our plan are to:

1. Review the status of fish stocks and fisheries trends at large lakes in the Vancouver Island region.
2. Identify optimum and maximum angler effort, catch and maximum harvest levels for large lake habitats.
3. Review stock status data and identify trends in target populations at individual large lakes.
4. Identify data gaps required for wild stock conservation, fisheries management and monitoring.
5. Identify fisheries objectives and management strategies for the region and individual large lakes.
6. Develop operational management plans including monitoring approaches for Vancouver Island large lakes.

Our plan is divided as follows:

1. Chapter 1: Overview of the Vancouver Island Region large lake habitats, target fish species and fisheries. This chapter includes a summary of fisheries based on data gathered through the Vancouver Island Lakes Questionnaire (VILQ) (Appendix 1), fisheries stocks, recommended fisheries management objectives, and an overall operational plan and management strategy for regional large lakes management.
2. Chapters 2 – 17: Summary information for individual large lakes, fish stocks and fisheries as well as recommended fisheries management objectives and action plans including assessment and monitoring schedules.
3. Appendices: Data, background and reference information used to develop fisheries objectives and management strategies presented in the body of the plan.

2.0 Overview of the Vancouver Island Region Large Lake Habitats and Fisheries

Physical Attributes of the Region

The Vancouver Island Region consists of two geographically distinct areas – Vancouver Island, which accounts for >70% of the total area of the region, and the adjacent Mainland Coast from Knight Inlet up to and including Kingcome Inlet (Figure 1). The region is dominated by heavy forest cover, with three major climatic zones including the relatively dry southeast coast, the wetter north, west and Mainland Coasts, and the cool, wet mountain area. Precipitation is greatest during the winter-spring period and generally low in the summer.

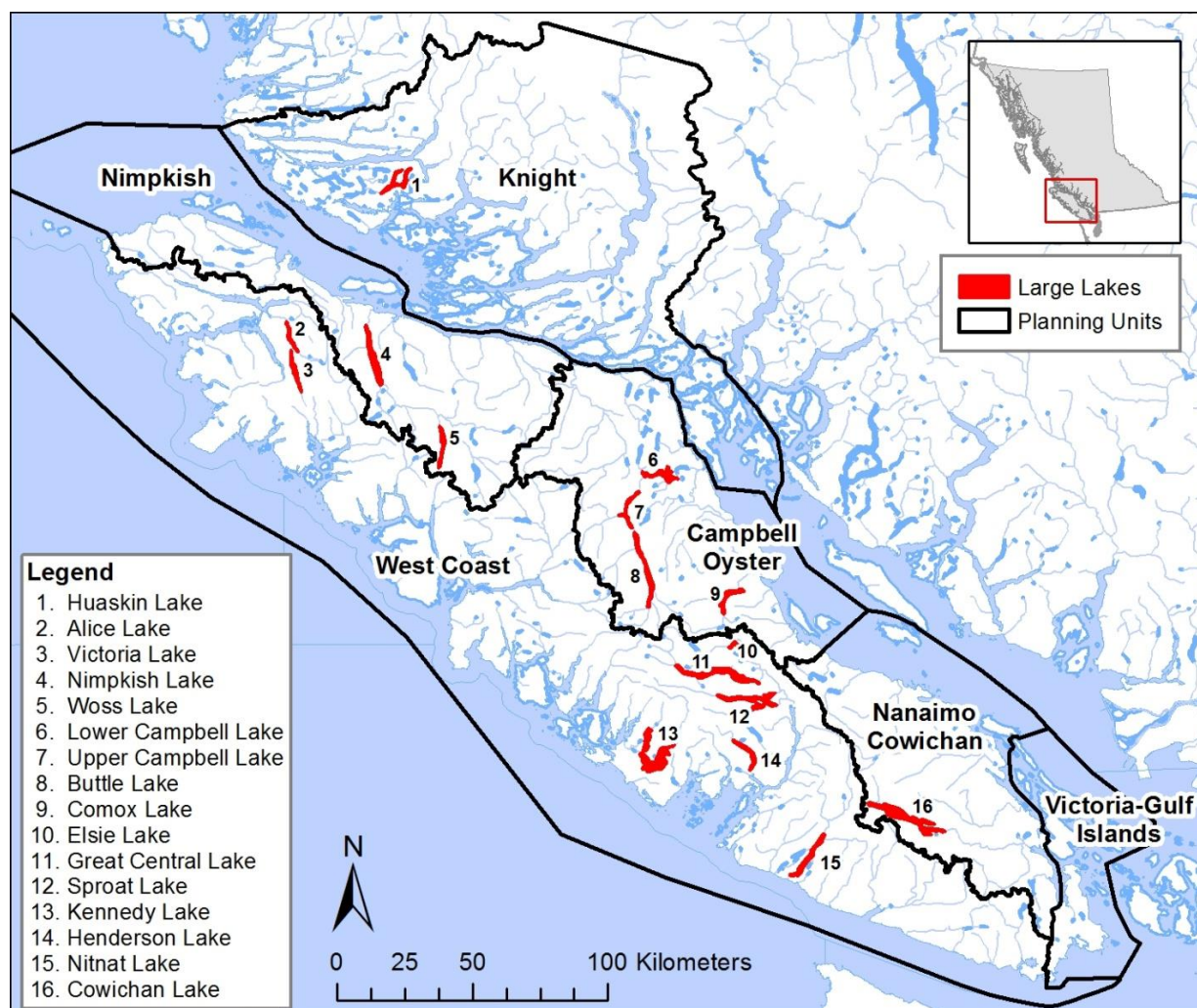


FIGURE 1. Overview of the Vancouver Island Region and distribution of Region 1 large (>1,000 ha) lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes) and Planning Units (Knight, Nimpkish, Campbell Oyster, Nanaimo Cowichan, Victoria Gulf Islands, West Coast) (Source: Integrated Land Management Bureau).

The Region is divided into six Planning Units (PU) based on major water precincts: Victoria/Gulf Islands; Nanaimo/Cowichan; West Coast; Campbell/Oyster; Nimpkish and Knight (Figure 1). Large lakes in the region occur in two main areas: the central mountains of Vancouver Island

from the Campbell River watershed south to the Cowichan watershed, and the north part of the Nimpkish and West Coast PU's.

3. 0 Vancouver Island Region Lakes

All lakes in the Vancouver Island region are what Northcote (1956) termed insular, coastal mountain lakes. Lakes in this category range from steep-sided, fjord-like lakes several square km in area and >300 m deep, to small, shallow basins formed on the hard granitic rocks by glacial scour. These lakes have high flushing rates with little summer depletion of oxygen in bottom waters. Lakes at low elevation also lack cover and circulate freely throughout the winter. Most lakes are clear and characterized by low (< 75 parts per million {ppm}) Total Dissolved Solid (TDS) content resulting in low standing crops of plankton, bottom fauna and fish (Northcote, 1956).

Large Lakes – General Information

Of the roughly 1,400 lakes in the region, 16 are >1,000 ha and are classified as large lakes (Table 1). Most large lakes in our region are dominated by a pelagic food web, which includes a prey target species (i.e. kokanee, sockeye, and/or stickleback) and a trout and/or char piscivore. Because each lake is unique, their management requires lake-specific data collection, analysis and regulations.

TABLE 1. Location, size, depth and water quality parameters at Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes (Source: Ministry of Forests, Lands and Natural Resource Operations (FLNRO) files, Nanaimo; Fish Information Summary System (FISS)).

Lake Name	Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)
Alice	West Coast	00107BRKS	1,218	40.6	71.3	30.9	7.1	46	8.5	1969
Buttle	Campbell Oyster	00362CAMB	3,095	74.4	120.7	61.3		40	13.0	1951, 1966, 1967, 1969, 1979, 1980, 1997
Comox	Campbell Oyster	01005COMX	2,100	40.7	109	61	7.1	22	10.0	1948, 1951, 1975, 1980, 1990
Cowichan	Nanaimo Cowichan	00408COWN	6,204	109.7	152	50.1	7.4			1950, 1953, 1960
Elsie	West Coast	00133ALBN	1,107	28.3	20.7	7.8	6.9	32	9.0	1969, 1980
Great Central	West Coast	00587ALBN	5,085	82.3	250	124	7.1	20	15.5	1969, 1975, 1986
Henderson	West Coast	01446ALBN	1,545	37.4	250	97	6.9	63		1972, 1975, 1986
Huaskin	Knight Inlet	00964SEYM	2,120	84.6	175	64.9				1991
Kennedy	West Coast	01168CLAY	6,475	111.9	145	38	7.2	21	7.5	1962, 1975, 1986
Lower Campbell	Campbell Oyster	00058CAMB	2,694	89.2	75.6	17.1	7.4	40	7.6-8.0	1951, 1980
Nimpkish	Nimpkish	00188NIMP	3,653	54.3	320	122	7.1	17	9.5	1975, 1986
Nitinat	West Coast	00056SANJ	2,748	56.0	~200			<10	7.5	1962

Lake Name	Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)
Sproat	West Coast	01128ALBN	3,775	90.8	195	74	7.1	32	14.7	1951, 1955, 1975, 1986
Upper Campbell	Campbell	00104CAMB	2,978	21.7	39.6	12.2		56		1951, 1980
Victoria	Oyster West Coast	00195BRKS	1,576	37.6	109.7	43.3	6.9	35	7.3	1969
Woss	Nimkish	00594NIMP	1,366	38.1	155	81			8.2	1970, 1986

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

4.0 Vancouver Island Large Lakes Fish Stocks

The fish species reported in Vancouver Island large lakes are provided in Table 2. Stocks of resident cutthroat (*Oncorhynchus clarki clarkii*) and rainbow (*O. gairdneri*) trout and Dolly Varden char (*Salvelinus malma*) are found in most lakes. Eleven lakes provide access to salmon species and many also provide habitat for anadromous stocks of cutthroat trout and steelhead (*O. gairdneri*). Kokanee salmon (*O. nerka*) are present in eight lakes. Other fish species include Pacific lamprey (*Lampetra tridentate*), river lamprey (*L. ayresii*) and the Cowichan Lamprey (*L. macrostoma*; also known as the Vancouver or Lake Lamprey). Smallmouth bass (*Micropterus dolomieu*) have been reported in some lakes but not verified.

TABLE 2. Trout, char, salmon, and other native and non-native fish species present in Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes (Source: FLNRO files, Nanaimo, FISS).

Lake Name	Fish Species Present in Lake																										
	Trout			Char	Salmon							Other											Non-Native				
	Cutthroat	Rainbow	Steelhead	Dolly Varden	Chinook	Chum*	Coho	Pink	Sockeye	Kokanee	Salmon General	Coast range Sculpin	Prickly Sculpin	Slimy Sculpin	Sculpin General	Lake lamprey	Pacific Lamprey	River Lamprey	W. Brook. Lamprey	Lamprey Gen.	Peamouth Chub	Threespine Stickleback	Atlantic Salmon**	Brook Trout*	Brown Trout	Brown Catfish	Pumpkinseed
Alice	x		x	x	x		x		x		x																
Buttle	x	x		x	x		x		x		x			x													
Campbell (Lower)	x	x	x	x								x			x												
Campbell (Upper)	x	x		x																							
Comox	x	x	x	x	x	x	x			x																	
Cowichan	x	x	x	x	x	x	x			x																	
Elsie	x	x	x	x	x					x					x												
Great Central	x	x	x	x	x	x	x	x		x					x					x							
Henderson	x	x	x	x	x	x	x	x		x					x												
Huaskin	x		x	x	x		x																				
Kennedy	x		x	x	x		x		x	x											x						
Nimpkish	x		x	x	x	x	x	x		x			x														
Nitinat	x		x		x	x	x		x																		
Sproat																											
Victoria	x	x	x	x			x		x				x														
Woss	x	x		x	x		x		x	x	x				x												

*in the watershed

**reported but not confirmed

5.0 Angling Statistics

Angler Effort

Vancouver Island provides year-round sport fishing opportunities for anglers but lakes are by far the most important component of the fishery accounting for ~80% of the total angler days in the region (Reid, 1982). In the 1980's, angler effort at large lakes comprised 28% of the angling on lakes in the region (Table 3). Over the years, angling effort in these lakes has declined and in 2011 angler effort was ~42,300 angler days, down from 51,000 angler days in 2006, and 55,600 angler days in 2002.

TABLE 3. Total angler effort (angler days) at Region 1 large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) 1986-2006 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013, in prep.).

Habitat Type	Angler Effort (angler days)					
	1986	1989	1992	2002	2006	2011
Vancouver Island	155,235	224,746	241,397	238,792	236,318	in prep.
Large Lakes	42,766	44,640	58,006	55,628	51,249	42,283
Percent of Total	28	20	24	23	22	in prep.

Angler effort at large lakes built through the late 1980's and into the early 1990's when it reached a maximum of ~60,000 angler days (Figure 2). Angler effort then began declining after 1992 and since 2002, angling effort at large lakes has declined from ~56,000 angler days in 2002, to ~51,000 angler days in 2006, and ~42,000 angler days in 2011. In 2011, angler effort was below the long-term average of ~51,000 angler days and we've projected that angler effort will continue to decline at large lakes further over the next decade.

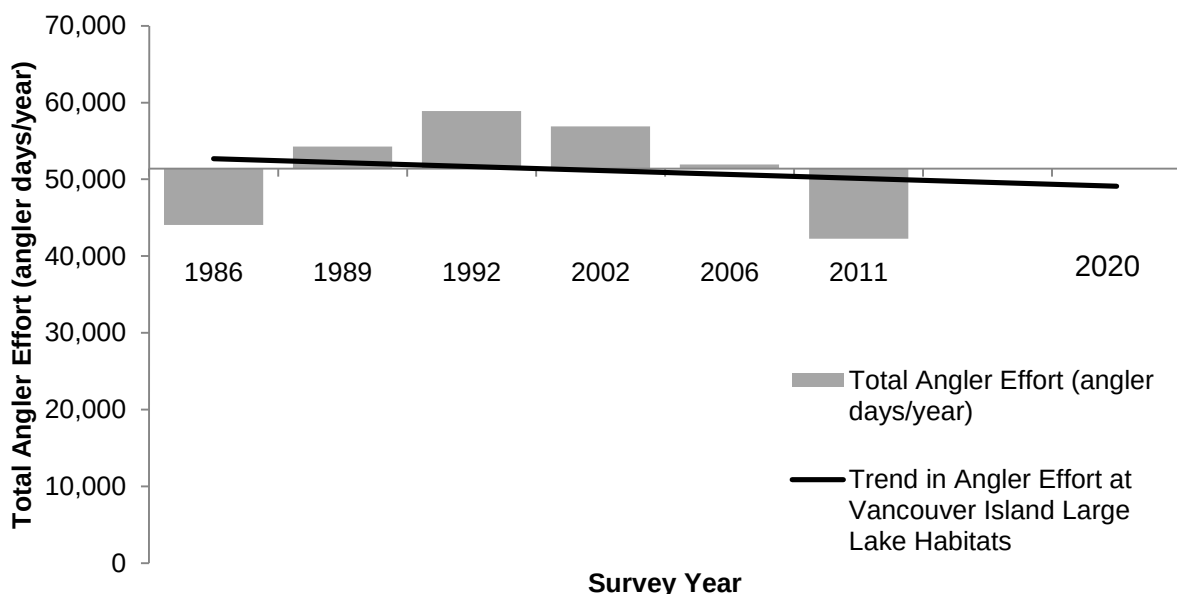


FIGURE 2. Total angling effort (angler days/year) compared to the mean angling effort (51,398 angler days/year) over the 25 year survey period of the Vancouver Island Lakes Questionnaire (1986 – 2011), trend in angling effort and projected trend at large lakes over the next ~10 years at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper

Campbell, Victoria and Woss Lakes) 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013, in prep.).

Angler Catch

In 1986, fish caught at large lakes comprised 23% of the total of fish caught in lakes on Vancouver Island (Table 4). As angler catch in small lakes has increased over the past three decades, however, the percentage of total catch from large lakes has decreased and since 1992, catch from large lakes has averaged ~18% of the total catch from regional lakes.

TABLE 4. Total catch at Region 1 large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) 1986-2006 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013, in prep.).

Habitat Type	Total Catch					
	1986	1989	1992	2002	2006	2011
Vancouver Island	293,100	427,078	474,868	445,281	477,011	in prep.
Large Lakes	66,221	93,608	76,028	88,909	83,969	68,261
Percent of Total	23	22	16	20	18	in prep

Total catch at large lakes in the Vancouver Island region has been decreasing slightly since the VILQ began in 1986 (Figure 3). In 1986, total catch was ~66,000 fish. As angler effort increased catch also increased to ~93,000 fish in 1989. In 1992, angler effort hit its peak but total catch dropped to 76,000 fish then rose again in 2002 to ~89,000. Total catch was ~84,000 fish in 2006 and ~68,000 in 2011. That year, angler catch was at an historic low having decreased by 14% from the mean catch over the survey period, and by 18% since 2006. We've projected that total catch will remain ~constant over the next ten years.

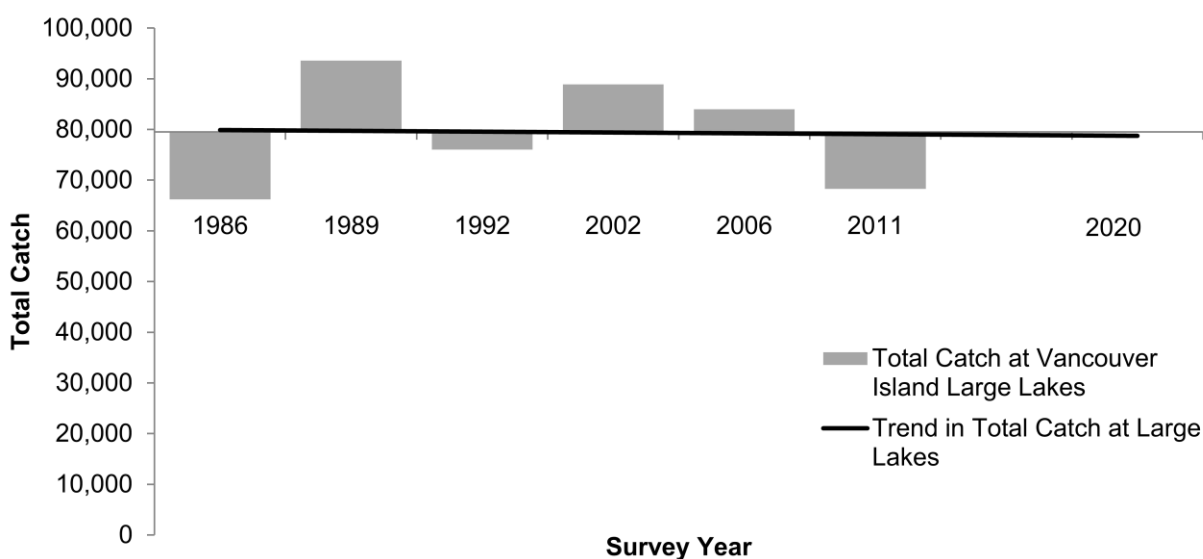


FIGURE 3. Total catch of cutthroat and rainbow trout and Dolly Varden compared to the mean catch (79,499 fish) over the 25 year survey period of the Vancouver Island Lakes Questionnaire (1986 – 2011), trend and projected trend in total catch over the next ~10 years at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes) (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013, in prep.).

Rainbow and wild cutthroat trout provide the backbone of the catch on Vancouver Island with these species accounting for >90% of the catch at large lakes (Table 5). In 2006, cutthroat trout made up 60% of the catch while rainbow trout comprised 35% and Dolly Varden made up 5% of the angler catch at large lakes (Andrews, 2007). In 2011, cutthroat trout comprised 53% of the total catch, while rainbow trout and Dolly Varden accounted for ~43% and ~3% respectively (Silvestri, 2013 in prep.).

TABLE 5. Estimated catch of rainbow trout, cutthroat trout, Dolly Varden and other species* at Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes compared to estimated catch in all Vancouver Island habitats in 2011 (Source: Andrews, 2007; Silvestri, 2013 in prep.).

Year	Total Catch by Species								
	Rainbow Trout		Cutthroat Trout		Dolly Varden		Other*		Total
	Total	Percent	Total	Percent	Total	Percent	Total	Percent	
2006	29,387	35.0	50,379	60.0	4,198	5.0	136	<1	83,965
2011	29,432	43.1	36,170	53.0	2,603	3.8	56	<1	68,261

*unconfirmed reports of smallmouth bass

Angler Success

Angler catch/day at large lakes has been as high as 1.7 fish/angler day (fish/day) in 1989 and as low as 1.3 fish/day in 1992 when angler effort was at its highest level (Table 6; Figure 2). Although angler effort declined between 2002 and 2011, angler success stayed constant at 1.6 fish/ day which is roughly the long-term average for regional large lakes. We project that angler success at large lakes will increase as angler effort continues to trend downward (Figure 4).

TABLE 6. Angler success (catch/angler day) by year at small (<1,000 ha) and large lake (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) in the Vancouver Island Region 1986 - 2006 (Source: Aitzhanova, et al. 2003, Andrews, 2007, Silvestri, 2013, in prep.).

Habitat Type	Angler Success (catch/angler day)						
	1986	1989	1992	2002	2006	2011	Mean
Small Lakes*	2.1	2.0	2.2	2.0	1.7	in prep.	2.0
Large Lakes	1.5	1.7	1.3	1.5	1.6	1.6	1.56

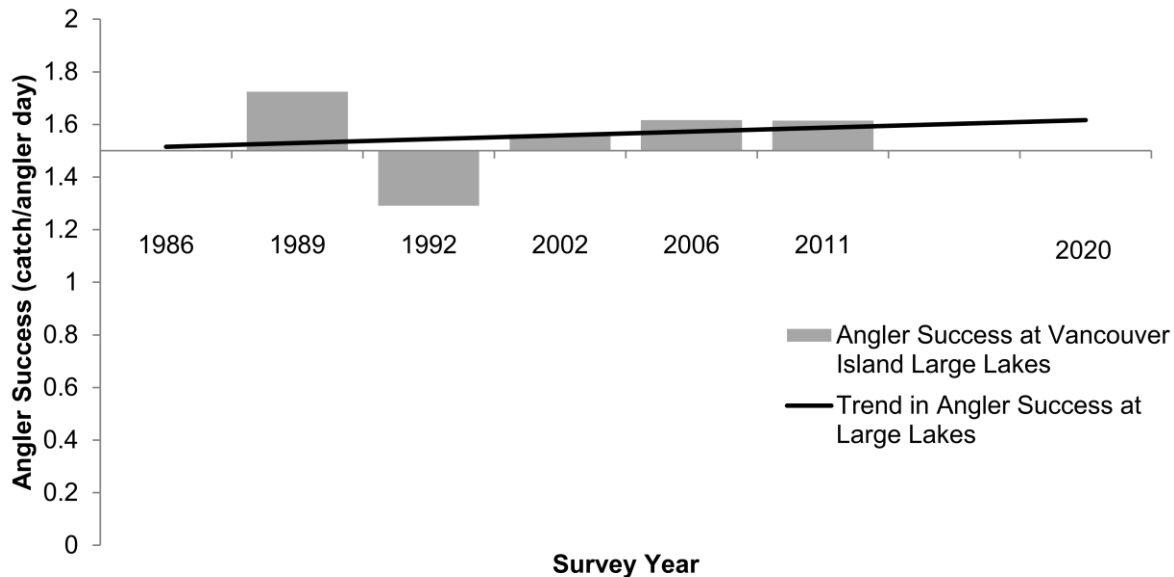


FIGURE 4. Angler success (catch/angler day) compared to the mean angler success (1.56 fish/angler day) over the 25 year survey period of the Vancouver Island Lakes Questionnaire (1986 – 2011), trend and projected trend in angler success over the next ~10 years at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes) (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013, in prep.).

6.0 Large Lakes Management on Vancouver Island

In his Regional Management Statement, Reid (1984) highlighted a number of challenges associated with managing large lakes in this region including: limited catch statistics; a lack of life history information on trout stocks and their status in large lakes; the naturally oligotrophic nature of all regional lakes; and the combined effects of poor land-use practices and rapidly expanding foreshore development. Reid also noted that as of 1984, there was no active management program targeting large lake stocks, and the database on angler harvest and distribution was limited and subject to error. He identified the following priorities for managing fisheries in large lake habitats:

1. Develop a method of defining the total fish production associated with large lake fisheries.
2. Determine the optimum harvest rates for large lake stocks.
3. Develop a plan for conducting angler surveys in the future.
4. Implement angler opinion surveys to assist in defining management objectives.
5. Develop a monitoring program for key large lakes.

Budget and staffing shortfalls throughout the 1990's prohibited the region from implementing the priorities Reid identified. In addition, lakes management in the region focused on small lakes which, along with anadromous (steelhead) fisheries dominated the regional priorities (Reid, 1986). Large lakes fisheries were estimated to account for only 5% of the total regional angling activity and the information available suggested there was an adequate supply of fish to meet angler demand at those habitats to the year 1990 and beyond. Consequently, apart from studies on high-use lakes such as Cowichan and Sproat Lakes, only limited investigation has so far been conducted on fisheries and stocks at large lake habitats.

Our goal was to address Reid's priorities so we could provide long-term direction for fisheries management for regional large lakes. We felt the most appropriate place to start was to identify

a method of determining fish production which we could then use to determine maximum allowable harvest. The following section outlines how we addressed the issue of determining maximum harvest at large lakes, and how we subsequently integrated stock status data into our analyses to develop operational objectives and associated management actions.

7.0 Defining Optimum Fish Production and Determining Optimum Harvest Rates at Vancouver Island Large Lakes

Rawson (1952) points out that it's necessary to have an understanding of biological productivity and to attempt to discover their rates of production to provide a baseline from which to determine management objectives. We wanted to determine optimum production so we could define the maximum harvest rate at large lakes in the Vancouver Island region. The BC-developed Large Lakes Kokanee Model was created for the purpose of defining optimum production at large lakes. Unfortunately, we were unable to run this model on Island lakes without sockeye or kokanee. Of the lakes where we used the model, we found no correlation ($R^2 = 0.034$) between the yield of predators predicted by the model, and the actual yield based on angler catch determined by the VILQ and estimated harvest (see Appendix 2 for details).

In the absence of the Large Lakes model, we used the morphoedaphic index (MEI) to predict yield for large lakes on the Island. The MEI is the ratio of TDS to mean depth (Z), and provides a predictor of standing crop, yield or biomass of lentic systems (Jenkins, 1967; Ryder et al, 1975). We used Ryder's simplified regression and found that predicted yield varies from 0.41 to 2.36 and averages ~1 lb/ac. at Island large lakes (Table 7; Appendix 3). One consideration in using MEI is that Island lakes are oligotrophic. In fact, large lakes on Vancouver Island are among the most nutrient poor and consequently unproductive lakes on the continent. Consequently, Ryder's regression may overestimate production at our lakes and so we viewed our estimation of productivity using MEI as a generous threshold.

TABLE 7. Minimum, maximum and mean predicted yield based on MEI (TDS/mean depth in pounds/acre/year) calculated using Ryder's (1965) simplified regression $Y = 2\sqrt{X}$ where Y = fish yield and X = MEI at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) (Source: FLNRO files, Nanaimo).

Factor	TDS (ppm)	Mean Depth (ft)	MEI	Surface Area (acres)	Predicted Yield based on MEI (pounds/acre/yr)
Minimum	10	25.74	0.042	2,733	0.41
Maximum	63	409.2	1.391	15,988	2.36
Mean	33.6	189.442	0.360	7,406	1.04

Determining Maximum Allowable Harvest

In 1984, Provincial fisheries managers recommended an allowable harvest rate of 40% for island large lakes (Andrusak and Brown *in* Reid, 1984). Andrusak and Brown did not provide details on how the maximum harvest rate was determined though their recommendation was consistent with the harvest rate of 44% for Vancouver Island determined by the 1985 National Sport Fish Survey (Levey and Williams, 2003).

We compared predicted yield based on MEI with actual yield using catch data from the VILQ and harvest rates determined from the National Sport Fish Survey (Levey and Williams, 2003) and the VILQ. We felt this was a suitable comparison given that sport fishing yields are closely correlated with angling effort (Jenkins and Morais, 1971; McCombie, 1983; Schlesinger and

McCombie, 1983). We found that actual yield was well below what we predicted using MEI (Table 8) and, as a result, we feel a maximum allowable harvest rate of 40% should be a reasonable limit for Vancouver Island large lakes.

TABLE 8. Yield (pounds/acre) based on total catch determined by the VILQ from 1986 – 2011 at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss). Harvest rate was calculated thusly: using a harvest rate of 44% in 1986 and 1989; 39% in 1992; 33% in 2002 (Levey and Williams, 2003); 27% in 2006 and 18% in 2011 (Andrews, 2007; Silvestri, 2013, in prep). No harvest rate was available for 2002 so the 1992 and 2006 harvest rate means were used. We estimated that the mean size of cutthroat in island large lakes is 0.5 pounds based on all available data from Ministry files and used that to calculate total pounds of fish harvested. Yield is calculated as pounds of fish/total surface area of all large lakes (113,835 acres) (Source: FLNRO files, Nanaimo).

Factor	1986	1989	1992	2002	2006	2011
Total Catch (# of fish)	66,221	93,608	76,028	88,909	83,966	68,261
Harvest (# of fish)	29,137	41,188	29,651	29,340	22,671	12,287
Pounds	14,569	20,594	14,825	14,670	11,335	6,143
Yield (pounds/acre)	0.13	0.18	0.13	0.13	0.10	0.05

We plotted angler effort and total catch to estimate the maximum and optimum angler effort and catch for Island large lakes and found that angler effort and catch were at optimum levels during the 1980's (Figure 5). When angling pressure began to build late that decade, angler catch also expanded, and increases in angler effort in the early part of the 1990's may have resulted in a catch and harvest of fish approaching the maximum.

If catch and harvest approached the maximum or crossed the equilibrium line, angler catch rates would have declined and angler effort would have decreased as anglers left the fishery. In fact, anglers did leave the fishery and in 2011, angler effort at regional large lakes was the lowest in the 25 year survey (Figure 2).

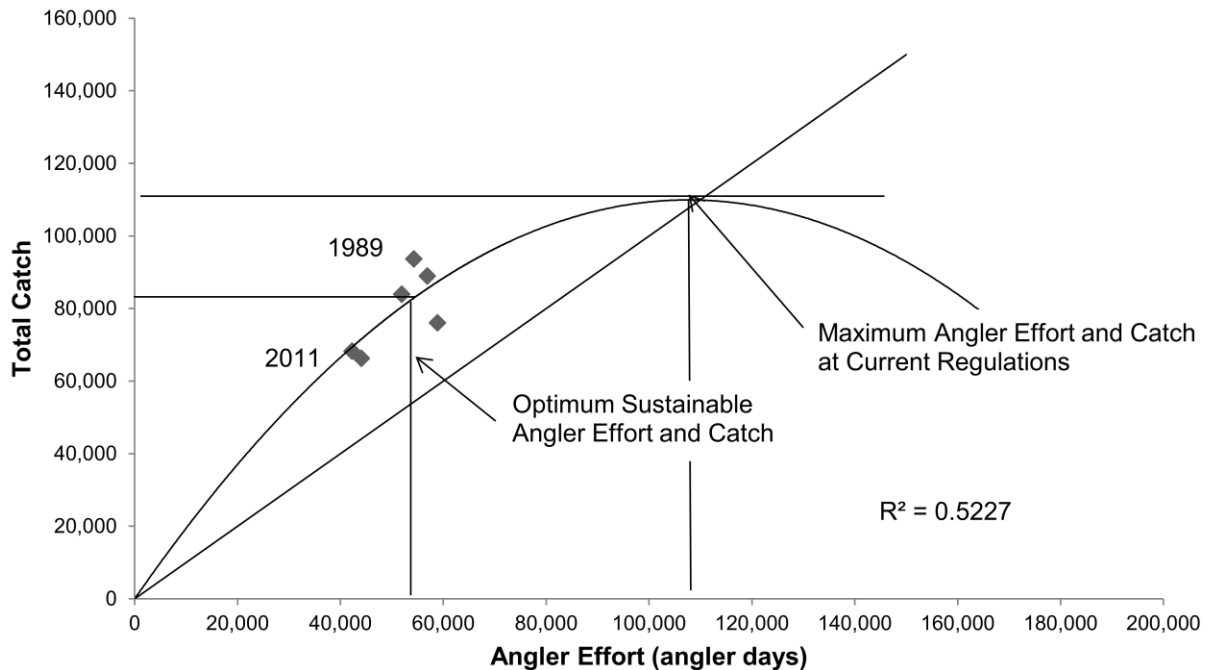


FIGURE 5. Angler effort (angler days) vs. total catch and maximum angler effort and catch at the current regulations, and maximum sustainable angler effort and catch at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes) 1986 – 2011 Note: the point at which the second degree polynomial curve diverges furthest from the 45 degree equilibrium line is where the optimum angler effort produces the highest sustained catch. In this case, 61,000 angler days would result in an optimal catch of ~90,000 fish (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Angler Success

The fact that angler effort and total catch increased then decreased suggests that overfishing may have occurred at the higher effort levels during the 1980's and 1990's despite the fact that allowable harvest rates may have been appropriate. Because angler success is proportional to the size of the fish population (Ricker, 1975), this response would be revealed as a decline in angler success.

Angler success rates reached a high of almost 1.7 fish/day in 1989 but by 1992 when angler effort was at its highest angler success was ~1.3 fish/day (Figure 6). Angler effort declined in the 1990's as anglers left the fishery and their departure resulted in an increase in success for remaining anglers. In 2011, angler success was 1.6 fish/day which is roughly the long-term average and the maximum angler success at the optimum angler effort for Vancouver Island large lakes (~50,000-55,000 angler days/year).

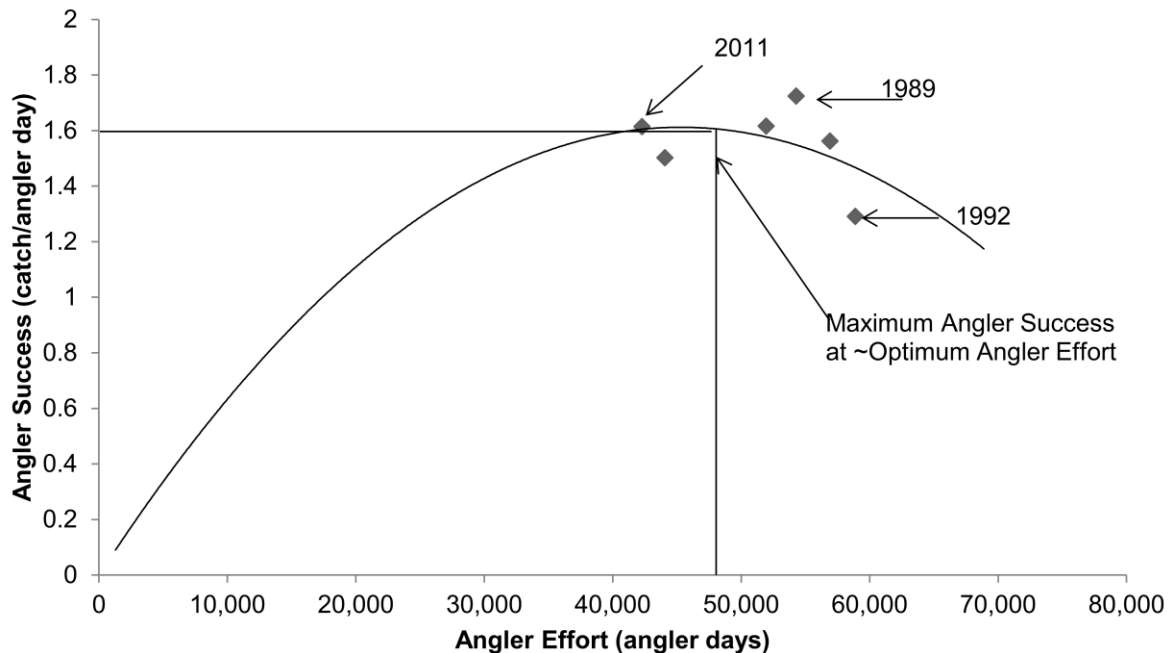


FIGURE 6. Angler effort (angler days/year) compared to angler success and maximum angler success at ~optimum angler effort at current regulations at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss Lakes) 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

8.0 Stock Status at Vancouver Island Large Lakes

Parkinson (undated) notes that the build-up of a new fishery generally follows a number of phases. In the early phases, total yield is low but angler success is high as larger, older fish are harvested with a modest amount of fishing effort. As angler effort builds, the yield rises but success drops due to declining standing crops. As angler effort increases, a population of fish becomes significantly reduced and harder to catch (Schlesinger and McCombie, 1983). Both yield and angler success drops as stocks almost inevitably become overfished.

Fisheries affect not only a change in stock levels, but also stock composition. Ricker's (1946) work demonstrated that a fishery will substantially increase the mortality of fish for many years and how, when enough years have elapsed to spread those effects through the stock, there is a marked decrease in the relative number of the oldest and largest fish.

The peak period for angling licence sales in British Columbia occurred in 1995. That year, there were a total of 279,259 annual licences purchased vs. 220,273 in 2009 (Clarke, 2012). There has been a region-wide decline in angler effort on Vancouver Island since the late 1990's for a variety of reasons including the economic downturn and the fact that people do not have as much time to participate in the sport as they once did (Levey and Williams, 2003).

Cutthroat Trout

We wanted to determine if there was a change in stock composition and/or stock status at Island large lakes which might have contributed to anglers leaving the large lakes fishery. We compiled fish data from each large lake and analyzed age and growth and catch indicator data for each

species to determine if there were changes in parameters such as mean and maximum fish length over the past three decades. Changes in these parameters would not only have affected angler satisfaction and likely caused them to leave the fishery, but would also indicate a change in stock status.

We found the maximum, mean and modal fork length of cutthroat caught by anglers has declined appreciably since the 1950's. In the 1950's the maximum size of cutthroat trout recorded was >700 mm, the mean was 420 mm and the modal length was ~500 mm. In the 2000's, the maximum size is 660 mm, and the mean and modal lengths are <300 mm (Table 9; Figure 7). It's important to note that although we did not find a statistical difference in the mean lengths of cutthroat trout caught by anglers in the 1950's vs. those caught in the 2000's,¹ statistical significance may not reflect the biological significance of larger, older fish being removed from the population. In addition, regardless of statistical significance, angler satisfaction would no doubt have decreased as anglers caught more, smaller fish and this would have contributed to anglers leaving the large lake fishery.

TABLE 9. Minimum, maximum and mean fork length (mm) of cutthroat trout captured by anglers by decade 1950 – 2000 (N=608) in Vancouver Island large (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950-2000 (Source: FLNRO files, Nanaimo).

Decade	N	Fork Length (mm)			
		Minimum	Maximum	Mean	Mode
1950	54	180	724	420.3	508
1970	99	125	673	404.3	432
1980	51	140	600	332.9	350
1990	53	190	660	373.3	360
2000	351	150	660	291.7	250

¹ We used an independent-samples t-test to test the differences in means of cutthroat trout caught by anglers in the 1950's vs. means of cutthroat trout caught by anglers in the 2000's ($t_{404}=0.25$ $P=0.05$ 1950 M 420; 2000 M = 291).

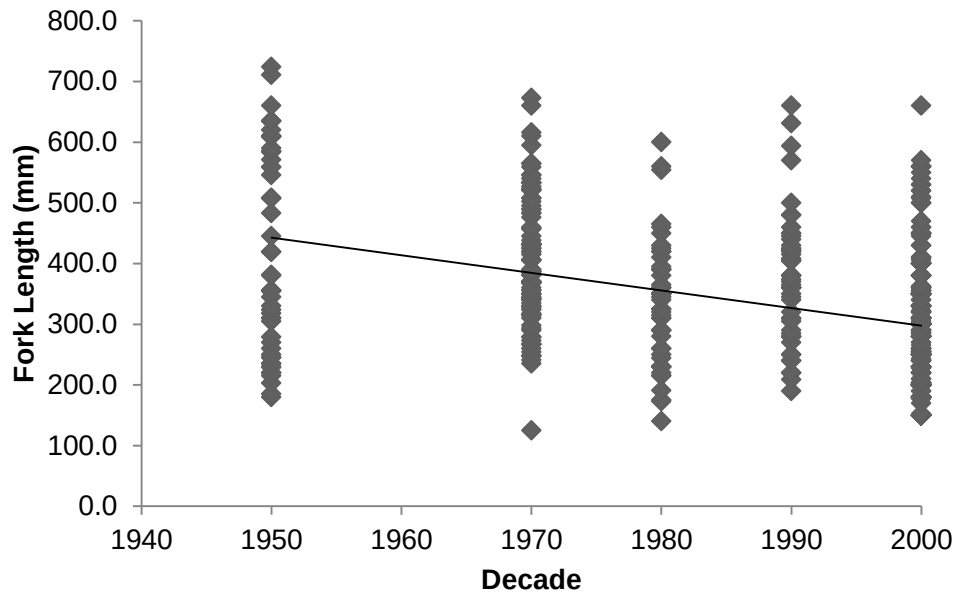


FIGURE 7. Fork lengths (mm) of cutthroat trout (N=608) captured by anglers at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950 – 2000 and difference between the means for each decade (Source: FLNRO files, Nanaimo).

We also compared length frequency distributions and found that anglers had higher catches of larger cutthroat trout in the 1950's compared to anglers in the 2000's who are catching more, smaller cutthroat more frequently. In particular, cutthroat >500 mm comprised ~40% of the angler catch in the 1950's (Figure 8A; Table 10), but <5% of the angler catch in the 2000's (Figure 8B; Table 10).

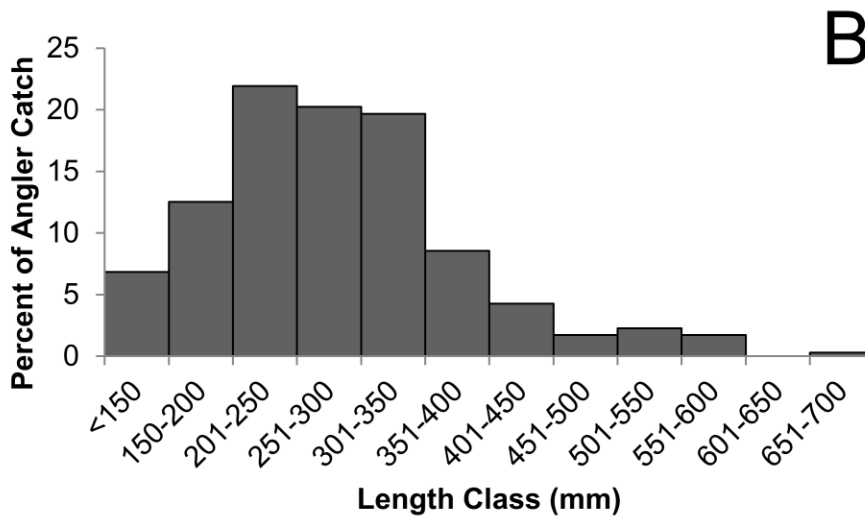
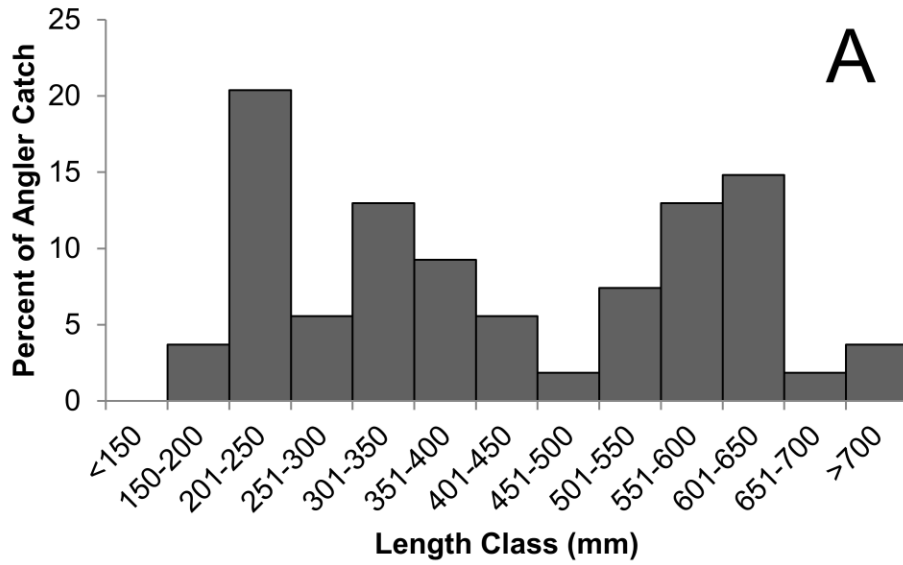


FIGURE 8. Length frequency distributions of cutthroat trout captured by anglers in (A) the 1950's (=N=54) and (B) the 2000's (N=351) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss); see Appendix 4 for complete length-frequency diagrams for each decade 1950-2000 (Source: FLNRO files, Nanaimo).

TABLE 10. Percent of angler catch of cutthroat trout in each size category in 1950 (N=54) and 2000 (N=351) in Vancouver Island large (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950-2000 (Source: FLNRO files, Nanaimo).

Length Category (mm)	Percent of Angler Catch	
	1950	2000
<300	29.6	61.5
<350	42.6	81.2
<400	51.9	89.7
<450	57.4	94.0
<500	59.3	95.7
>500	40.7	4.3

Also of note is the proportion of cutthroat trout <350 mm caught by anglers in the 1950's vs. in the 2000's. This is an important consideration because on average, cutthroat trout in large lake habitats on the island mature at ~320 mm (Figure 9). In the 1950's, 43% of the angler catch was <350 mm, while in the 2000's ~80% of the angler catch was <350 and, therefore, likely immature.

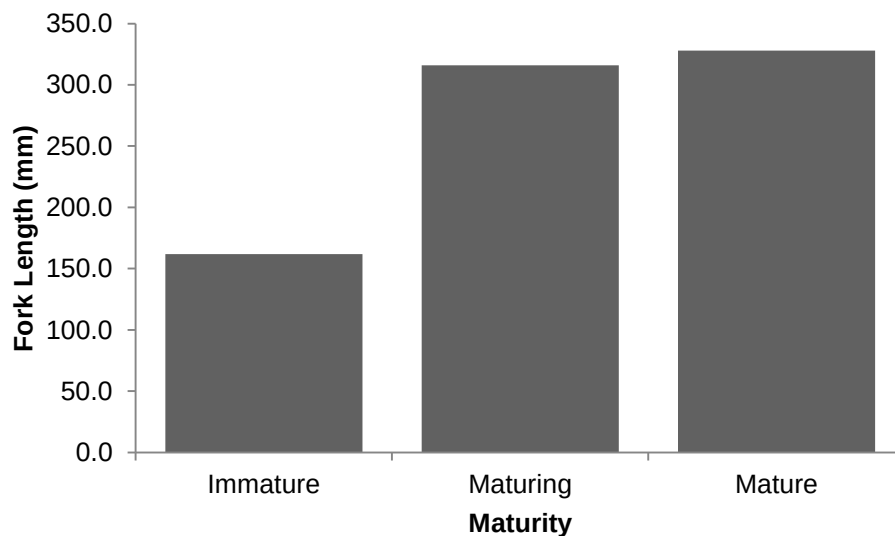


FIGURE 9. Mean length (mm) of immature, maturing and mature cutthroat trout captured in gillnets, seines, trap nets and by anglers 1948 – 2011 (N=705) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss). Note: we removed all rainbow trout >500 mm as these fish are likely steelhead (Source: FLNRO files, Nanaimo).

We compiled age data for cutthroat trout sampled in nets and by anglers and found that the mean age-at-length for fish sampled in the 1950's (Figure 10A) was larger than those sampled in the 2000's (Figure 10B). For example, the mean size of age 1+ fish in the 1950's was 205 mm vs. ~123 mm in the 2000's, the mean age of 2+ fish in the 1950's was ~290 mm vs. ~232 mm recently and of 3+ fish was ~335 mm in the 1950's and 320 mm in the 2000's. Age 4+ years cutthroat were, on average ~470 mm in the 1950's and ~354 mm in the 2000's, age 5+ fish averaged 484 mm in the 1950's vs. ~410 mm in the 2000's and age 6+ fish averaged 607

mm in the 1950's vs. 400 mm in the 2000's. Although cutthroat up to age 9+ were sampled in the 1950's, no fish older than 6+ were sampled recently².

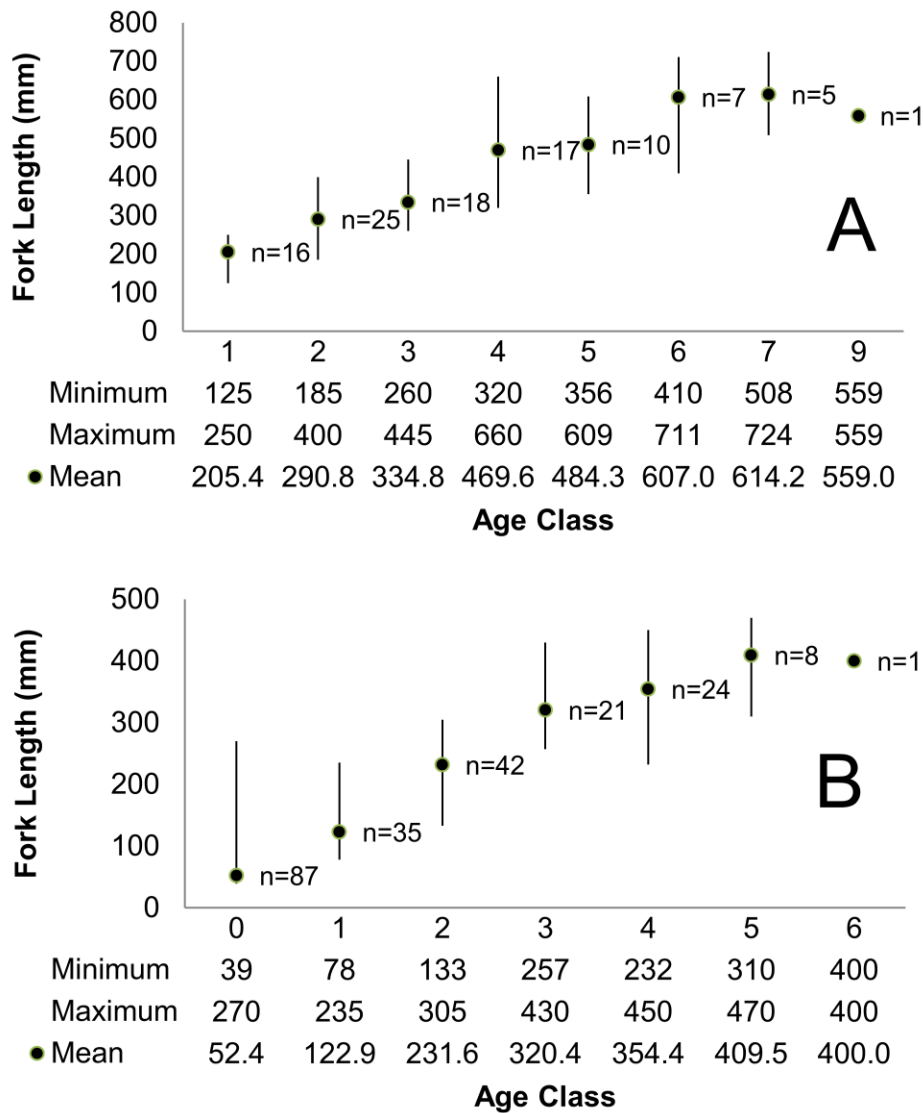


FIGURE 10. Minimum, maximum and mean length-at-age of cutthroat trout sampled in gillnets, seine nets, trap nets and by angling in (A) the 1950's (N=99) and (B) the 2000's (N=218) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) (Source: FLNRO files, Nanaimo).

Overall, the mean age of cutthroat trout caught by anglers has decreased from 3+ in the 1950's – 1970's, to 1+ in the 1990's and 2000's (Table 11).

² Cutthroat >500 mm and 7+ years were caught by anglers at Cowichan Lake in the 2000's but the data was not processed in time for this chapter. See Chapter 5 (Cowichan Lake) for the most up to date data for cutthroat trout captured.

TABLE 11. Total catch and mean age of cutthroat trout caught by anglers by decade 1950 -2000 (N=652) Vancouver Island large (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950-2000 (Source: FLNRO files, Nanaimo).

Decade	n	Mean Age
1950	99	3+
1970	49	3+
1980	119	3+
1990	167	1+
2000	218	1+

Rainbow Trout

As with cutthroat trout, despite the fact that we found no statistical significant difference between the sizes of rainbow caught by anglers in the 1950's vs. rainbow trout caught now³, there is considerable difference in fish size between the decades. For example, 50 years ago anglers were catching rainbow trout that were, on average ~320 mm and up to 490 mm in length. In the present decade anglers are catching rainbow up to 450 mm and averaging ~265 mm. The modal length of rainbow trout has also shifted from ~380 mm in the 1950's, to 250 mm in the 2000's (Table 12; Figure 11).

TABLE 12. Minimum, maximum and mean fork length (mm) of rainbow trout captured by anglers by decade 1950 – 2000 (N=308) in Vancouver Island large (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950-2000; Note: we removed all rainbow trout >500 mm as these fish are likely steelhead (Source: FLNRO files, Nanaimo).

Decade	n	Fork Length (mm)			
		Minimum	Maximum	Mean	Mode
1950	32	175	490	319.7	381
1970	37	320	495	434.9	457
1980	106	215	495	290.0	260
1990	47	172	450	292.3	300
2000	86	120	450	265.5	250

³ We used an independent-samples t-test to test the differences in means of rainbow trout caught by anglers in the 1950's vs. means of cutthroat trout caught by anglers in the 2000's (t117)=0.175 P=0.05 1950 M 320; 2000 M = 265).

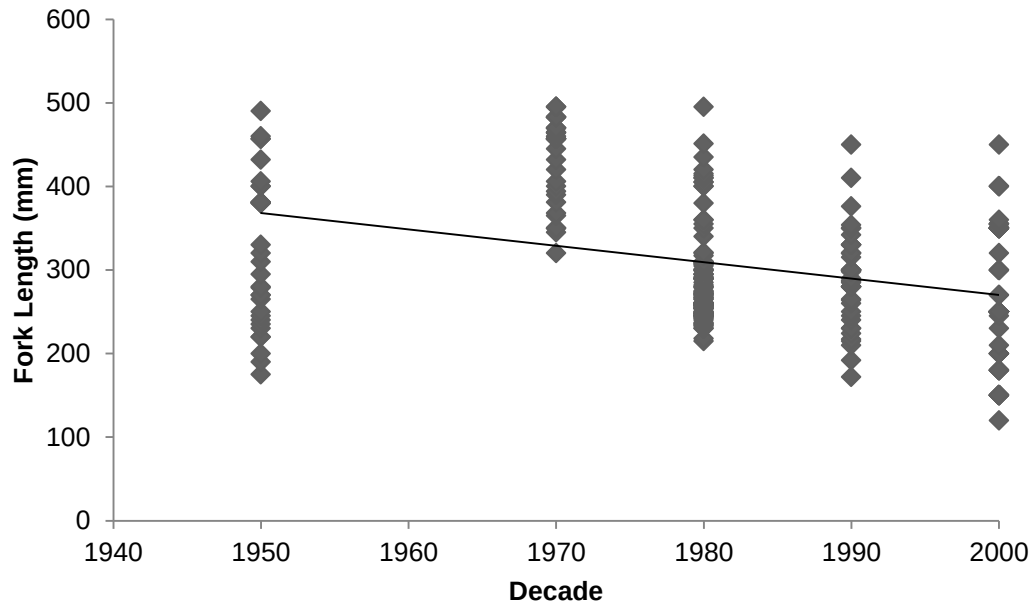


FIGURE 11. Fork lengths (mm) of rainbow trout (N=308) captured by anglers at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950 – 2000 and difference between the means for each decade. Note: we removed all rainbow trout >500 mm as these fish are likely steelhead (Source: FLNRO files, Nanaimo).

We compared length frequency distributions of rainbow trout caught by anglers and found that in the 1950's, 20% of the rainbow trout catch was 350 mm - 400 mm and 15% was >400 mm (Figure 12A). In the 2000's, >40% of the catch was 201 mm – 250 mm with only ~10% of rainbow >350 mm (Figure 12B).

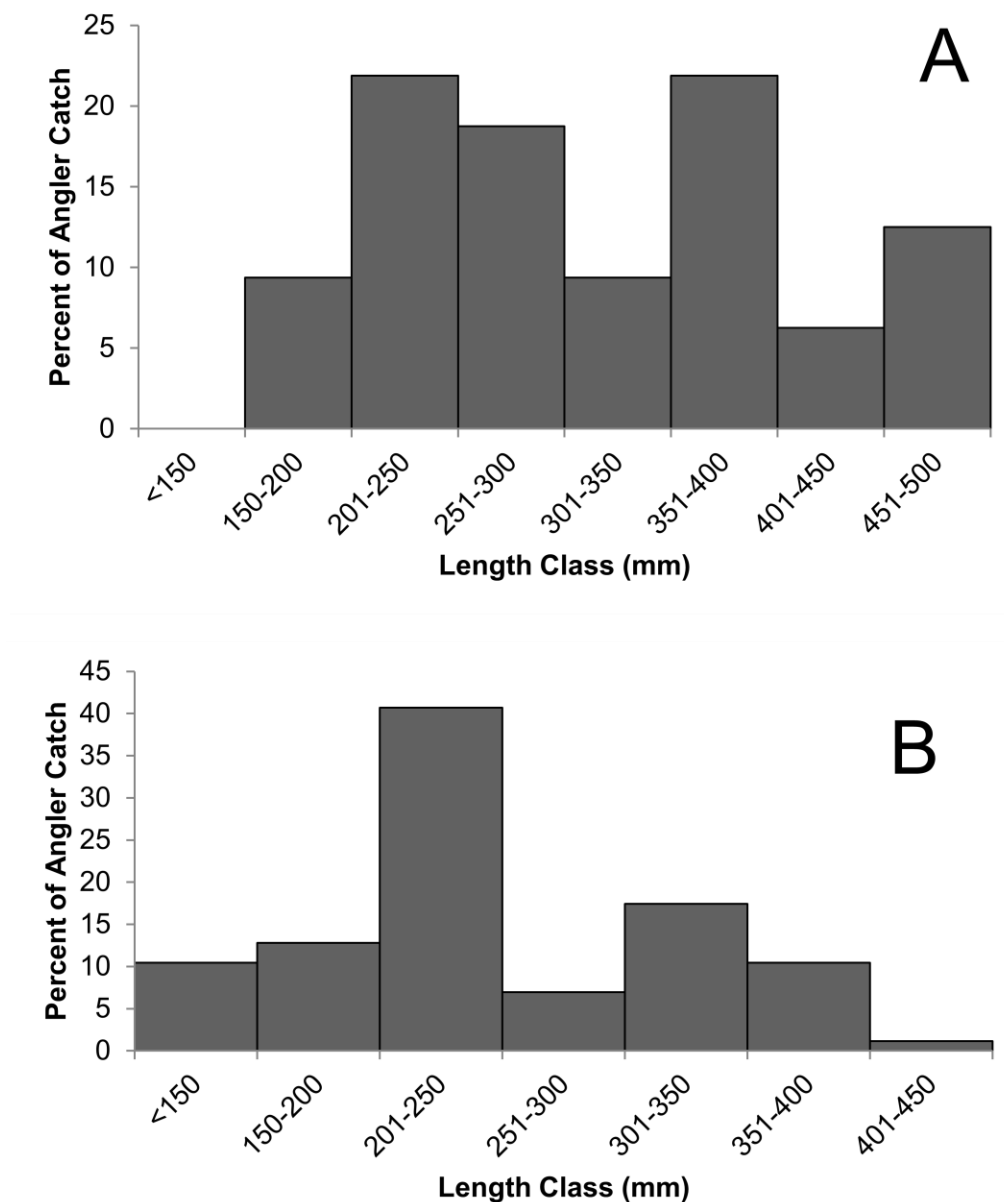


FIGURE 12. Length frequency distributions of rainbow trout captured by anglers in (A) the 1950's (=N=32) and (B) the 2000's (N=86) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss). Note: we removed all rainbow trout >500 mm as these fish are likely steelhead. Note: see Appendix 4 for complete length-frequency diagrams for each decade 1950-2000 (Source: FLNRO files, Nanaimo).

Also of note is that in the 1950's, ~60% of the angler catch of rainbow trout was <350 mm and ~40% was >350 mm (Table 13). In the 2000's, however, 88% of the angler catch of rainbow was <350 mm while only ~12% of the catch was >350 mm. Rainbow trout in Island large lakes mature at ~200 mm – 250 mm (Figure 13), therefore, anglers in the 2000's are catching more immature rainbow trout than anglers caught in the 1950's.

TABLE 13. Percent of angler catch of rainbow trout in each size category in 1950 (N=32) and 2000 (N=86) in Vancouver Island large (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950-2000. (Note: all rainbow trout >500 mm were removed as these fish are likely steelhead (Source: FLNRO files, Nanaimo).

Length Category (mm)	Percent of Angler Catch	
	1950	2000
<200	9.4	23.3
<250	31.3	64.0
<300	50.0	70.9
<350	59.4	88.4
>350	40.6	11.6

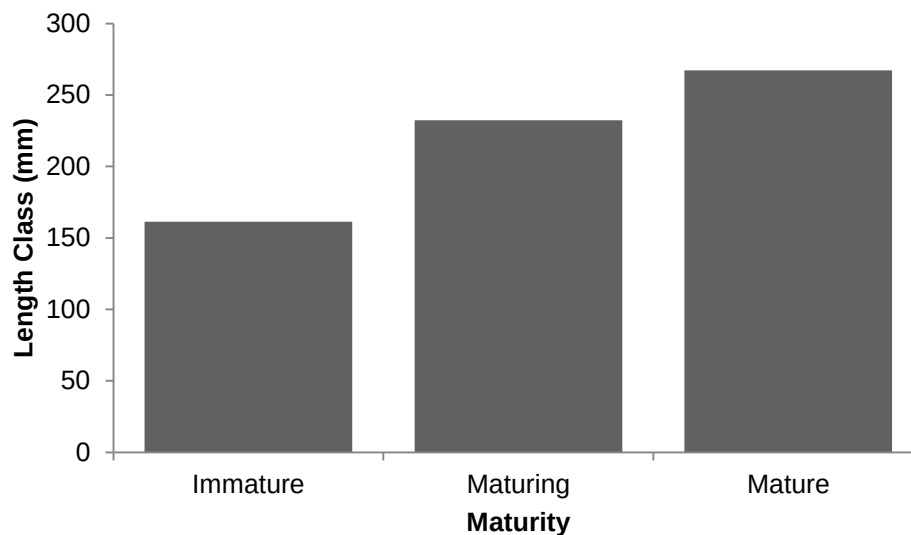


FIGURE 13. Mean length (mm) of immature, maturing and mature rainbow trout captured in gillnets, seines, trap nets and by anglers 1948 – 2011 (N=511) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss); Note: we removed all rainbow trout >500 mm as these fish are likely steelhead (Source: FLNRO files, Nanaimo).

We reviewed age data for rainbow trout and found that the mean length-at-age in the 1950's was larger for each age class captured. For example, the mean length of 2+ rainbow in the 1950's was 245 mm and in the 2000's is ~121 mm, while the mean length of 3+ rainbow in the 1950's was 267 mm vs. ~156 mm in the 2000's (Figure 14A; Figure 14B). Rainbow aged 4+ were, on average, 287 mm in the 1950's compared to 215 mm in the 2000s, rainbow aged 5+ averaged 351 mm in the 1950's and ~242 mm in the 2000s' and rainbow aged 6+ averaged ~383 mm in the 1950's vs. ~300 mm in the 2000's. Aged 7+ and 8+ rainbow trout were captured in the 1950's, however, no rainbow older than 6+ were captured and aged in the 2000's.

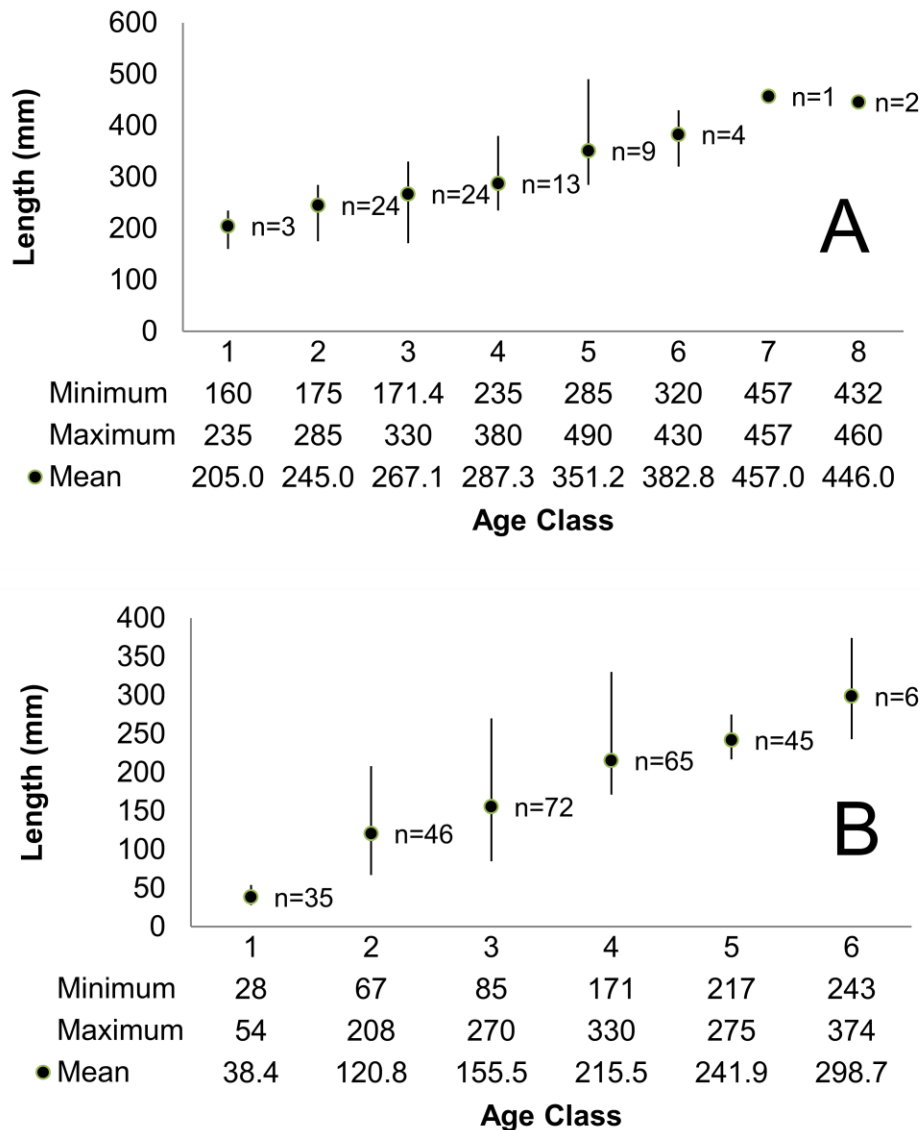


FIGURE 14. Minimum, maximum and mean length-at-age of rainbow trout sampled in gillnets, seine nets, trap nets and by angling in (A) the 1950's (N=80) and (B) the 2000's (N=269) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss). Note: all rainbow trout >500 mm were removed as these fish are likely steelhead (Source: FLNRO files, Nanaimo).

The mean age of rainbow trout caught by anglers in Island large lakes was 3+ in the 1950's, 5+ in the 1970's and 4+ in the 1980's (Table 14). In the past two decades, the mean age of angler-caught rainbow trout has been 2+ years.

TABLE 14. Total catch and mean age of rainbow trout caught by anglers by decade 1950 -2000 (N=622) Vancouver Island large (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950-2000 (Source: FLNRO files, Nanaimo).

Decade	N	Mean Age
1950	80	3+
1970	52	5+
1980	165	4+
1990	56	2+
2000	269	2+

Dolly Varden

We've presented the minimum, maximum, mean and modal lengths for Dolly Varden captured by anglers over the past 50 years in Table 15. The decreasing trend in length we found for cutthroat and rainbow trout captured by anglers has not been repeated for Dolly Varden. In fact, the maximum size of Dolly Varden caught by anglers now is larger than it was in the 1950's. Note, however, the Dolly Varden statistics were evaluated based on small sample sizes which make statements regarding changes in stock status for this species unreliable.

TABLE 15. Minimum, maximum and mean fork length (mm) of Dolly Varden captured by anglers by decade 1950 – 2000 (N=18)) in Vancouver Island large (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) by decade 1950-2000. Note: all rainbow trout >500 mm were removed as these fish are likely steelhead (Source: FLNRO files, Nanaimo).

Decade	N	Fork Length (mm)			
		Minimum	Maximum	Mean	Mode
1950	10	225	340	252.5	240
1970	2	457	483	470.0	-----
1980	1	410	410	410.0	-----
1990	9	290	480	402.8	480
2000	6	150	430	246.7	250

9.0 Summary of the Large Lakes Fishery and Target Fish Stocks

We've suggested that fish yield based on harvest rates of ~40% is within the theoretical production of Island large lakes as estimated by the MEI (Table 7). We do, however, suspect that anglers harvested too many larger, older cutthroat and rainbow trout in the expanding phases of the large lakes fishery. Angler effort increased in the 1980's and during that decade and the preceding years, anglers caught higher percentages of larger, older cutthroat and rainbow trout. Recently, anglers have been catching more smaller cutthroat and rainbow trout, and higher percentages of immature fish of both species.

One of the goals of the Ministry of Forests, Lands and Natural Resource Operations (FLNRO) is to increase angler participation. However, it's critical to determine whether fish stocks at large lake habitats can accommodate additional angler effort before facilitating additional participation at these habitats. At present, we are within optimal angler effort and catch and we've projected angler effort will decrease over the next decade. Even so, we have concerns regarding conservation of wild stocks. The downward trend in fish size and the increasing frequency of the catch of immature fish by anglers must be addressed before we can develop targets and

strategies for facilitating additional angler effort at large lake habitats on Vancouver Island. The following section provides fisheries objectives and management strategies to provide angling opportunities while also protecting wild fish at regional large lakes.

10.0 Current Regional Regulations at Large Lakes

Regional daily catch quotas

Trout, 4 but not more than 1 >50 cm.
2 hatchery steelhead >50 cm are allowed.
2 from streams (must be hatchery).

Anglers must release all char (Dolly Varden).

Notwithstanding the above, Sproat and Great Central Lakes have a maximum size limit of 60 cm for rainbow trout. Comox Lake has a maximum size limit of 50 cm and a minimum size limit of 30 cm for cutthroat trout, Sproat Lake has a mandatory release of cutthroat trout and Cowichan Lake has a cutthroat daily quota of 2 and a maximum size limit of 50 cm for cutthroat trout

With the exception of the 30 cm minimum size limit for cutthroat at Comox Lake, there is no general minimum size limit for trout in lakes.

11. 0 Fisheries Objectives and Management Strategies

The following regional fisheries objectives were designed to conserve wild stocks while maintaining angling opportunities. We recognize our recommended regulations could result in decreased angler effort initially at large lakes. Over time these management actions will result in increased angler satisfaction and angler success because mean fish size and the number of fish available to the angler as a result of these actions will increase. Therefore, in the long-term angler participation at large lakes may increase resulting in a requirement for additional conservation regulations. We recommend that the type and level of management response developed at that time be based on the results of ongoing fishery and stock status monitoring according to the process and schedule outlined in Figure 15 and Table 16.

In addition to conserving wild stocks, our goals are to maintain angler effort at ~optimum levels, maintain the long-term angler success rate of 1.6 fish/angler day, and to stay below a regional yield of 1.0 lb/ac at all island large lakes combined. To that end, we recommend the following:

1. Monitor the regional angler statistics at large lakes using the VILQ.
2. Maintain a region-wide angler success of 1.6 fish/day according to the VILQ. If angler success drops by 10%, review angler statistics at individual lakes to determine at which lake(s) success has dropped then gillnet those lakes to determine stock status (Figure 15).
3. If angler effort drops to 40,000 (a 10% drop from 2011 levels) according to the VILQ, identify lake(s) of concern, implement gillnetting and additional angler surveys (i.e. angler creel surveys and angler satisfaction questionnaires) to determine if additional management actions such as regulations are required (Figure 15).
4. Do not exceed the region-wide harvest threshold of 1 lb/ac. This is the average yield of island large lakes predicted by the MEI (Table 7).

5. Develop management strategies to protect large fish, provide an opportunity for fish to return to historic sizes, and establish consistency in the regional regulations.
 - At lakes where cutthroat is a target species implement a maximum size limit appropriate to the lake. At some lakes (e.g. Cowichan) 50 cm will be suitable for protecting large cutthroat.
 - At lakes where rainbow is a target species implement a maximum size limit appropriate to the lake. In most cases, 40 cm will be suitable for protecting large rainbow.
6. Develop management strategies to permit sufficient survival of immature fish and allow fish to spawn at least once before they recruit to the fishery.
 - At lakes where cutthroat is a target species implement a minimum size limit of 30 cm.
 - At lakes where rainbow is a target species implement a maximum size limit of 25 cm.
7. Conduct gillnetting or angling survey assessments to establish stock status and monitor stocks at large lakes according to their priority: immediate need, high, medium and low priority (Table 16).
8. Monitor using the VILQ to identify if angler effort increases by >10% from 2011 levels (>50,000 angler days) and catch increases by 10% to ~88,000 fish; or if angler effort and catch exceed optimum levels. Design regulations to maintain catch but decrease harvest so angler success meets the target of 1.6 fish/angler day.

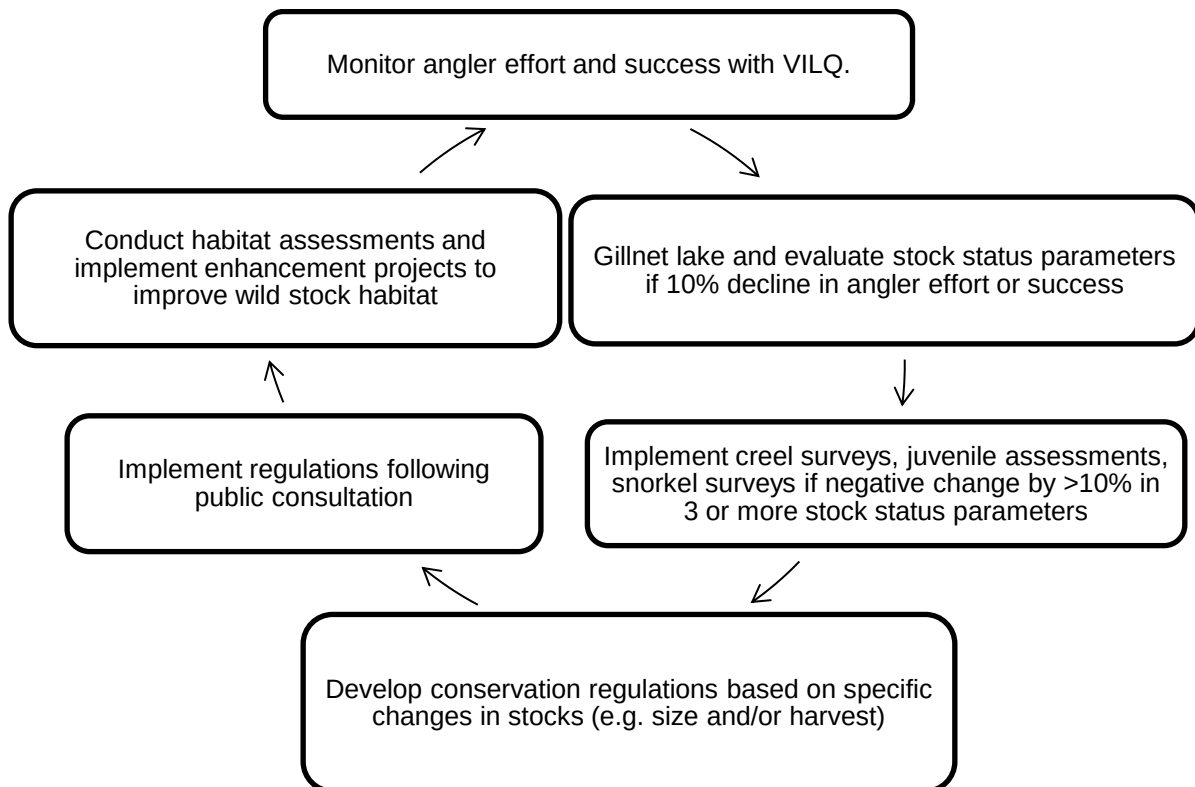


FIGURE 15. Flow chart outlining recommended process for establishing reasons for change in angler effort and/or angler success as determined by changes in the results of the VILQ. Note: gillnetting is initiated if there is a negative change by >10% in angler success or angler effort. Additional surveys focused on angler catch and satisfaction is implemented if a change in stock status is revealed through gillnetting.

TABLE 16. Gillnetting schedule for lakes that must be netted immediately (Alice, Victoria and Woss), and for high priority (Cowichan, Comox, Sproat, Upper and Lower Campbell), middle priority (Great Central, Buttle, Alice, Woss, Victoria), and low priority (Elsie, Nimpkish, Henderson, Huaskin and Nitinat) lakes. We prioritized lakes based on points assigned for angler effort, total catch and angler success data collected through the VILQ from 1986 – 2011 (see Appendix 5 for details) (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Net Immediately	High Priority	Middle Priority	Low Priority	Low Priority
	Net every three years starting in 2014	Net every four years starting in 2015	Net every five years starting in 2018	Net in 2023
Alice Victoria Woss	Cowichan Comox Sproat Upper Campbell Lower Campbell	Great Central Buttle Lake <u>starting in 2017</u> Alice Victoria Woss	Elsie Nimpkish Henderson	Huaskin Kennedy Nitinat

Large Lakes Monitoring

Gillnetting

We've outlined a monitoring schedule in Table 16. Although they are not high priority lakes, we recommend that Alice, Victoria and Woss Lakes be netted immediately as there is no recent gillnetting data to establish stock status at these lakes. The remainder of the lakes are netted on a rotating schedule depending on their priority. We prioritized lakes based on angler effort, total catch and catch rates; the higher the angler effort and catch, and the lower the angler success rates, the higher the lake priority (see Appendix 5 for details). We've recommended that high priority lakes (Cowichan, Comox, Sproat Lake and Upper and Lower Campbell Lakes) be netted every three years beginning in 2014, medium priority lakes (Great Central, Buttle, Alice, Victoria, Woss) be netted every four years, and low priority lakes (Elsie, Nimpkish, Henderson, Huaskin, Nitinat) be netted every five years or in 2023 in the case of Huaskin and Nitinat Lakes. Netting schedules may conflict in some years and the decision regarding which lake to net should be made based on the priority of the lake, and the status of the fishery as determined by the VILQ (Figure 15).

In the past, some gillnetting surveys have occurred at different times of the year which biased comparisons between data sets. We recommend gillnetting in August to allow the collection of mature fish of all species prior to spawning. We also recommend using the procedures outlined in Fish Collection Methods and Standards (Resource Inventory Committee (RIC), 1997). While we recognize this procedure was developed for small lakes sampling, the objective of gillnetting is to compare stock status indicators over time. These comparisons can be made if nets are set in the same location, and at the same time each year that gillnetting is completed.

Given the size of some lakes it may be wise to set more than two sets of nets in a lake⁴. Overly-extensive sampling of the lake is not required because as a rule, the length, weight, and age

⁴ The standard procedure in BC requires that two gangs of gill nets be set overnight. Usually one net is floating and the other is sinking. The floating net is set directly off shore and perpendicular to the beach. The sinking net is set

data from 30 fish of each species is required to develop statistically useful relationships (RIC, 1997). We suggest that six nets be set initially, and additional nets set if there are insufficient sample sizes of target species. In addition, we recommend the initial net locations be randomized over the entire area of the lake, and these locations be re-netted in subsequent years.

Additional Surveys and Actions

We've recommended conducting fisheries surveys including angler creel surveys and angler satisfaction questionnaires if gillnetting results show a 10% decrease in three or more stock status parameters (Figure 15). Additional conservation regulations may follow as should habitat assessments and enhancement projects focused on the improvement of wild-stock habitat. Thereafter, the fishery is monitored using the VILQ and the process repeated if VILQ data indicates further declines. We also recommend, where practical, continued annual or biannual snorkel surveys on priority tributaries of high-priority lakes as part of the overall lake monitoring program.

12.0 Individual Large Lakes Management Plans

The remainder of this document provides detailed data and information regarding fisheries and stocks at each large lake in the Vancouver Island region. We reviewed data files and reports (Appendix 6) and conducted the same or similar analyses for angler success, harvest, and effort and stocks status as we did for the region to determine the state of the fishery and stock status (Appendix 7) and lake-specific fisheries objectives and management actions. Finally, we've identified data and information gaps which, in addition to regular monitoring using gillnets, must be completed to have a thorough understanding of the lake fishery and stocks. In some cases, we've recommended additional surveys to supplement data from the VILQ because even if the VILQ is conducted every three years as was originally intended (Law, P, 2012, pers. com.) there could be a delay between when fishery declines begin, and when these declines are discovered. This is particularly true at very low effort lakes where the VILQ may not be sensitive enough to pick up changes in harvest and success. We'll have a better chance of detecting changes in lower-effort fisheries with angler-targeted studies such as angler creel surveys.

further off shore by connecting the near-shore end of the net to 15 to 30 m of rope that is tied off on shore and then setting the net from the end of the rope.

Chapter 2. Alice Lake

Lake	Alice
Planning Unit	West Coast
Watershed	Marble River
Surface Area (ha)	1,2185
Mean Depth (m)	31
Key Tributaries	Marble, Benson, Link Rivers
Freshwater Fish Species	Cutthroat, Rainbow
Limits to Production	Logging, Mining,
Regional Priority*	8
<u>Angling Statistics 2011</u>	
Angling Effort	223 angler days
Total Catch	56 fish
Angler Success (catch/day)	0.25 fish/angler day
Current Harvest Rate	25%
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	Unknown; angler success is decreasing but netting data incomplete.
Data Gaps	Gillnetting; fish assessment (streams); snorkel surveys
Management Actions	Declines in angler success and angler effort and small size of cutthroat; develop new regulations if necessary following gillnetting assessment.
Operational Plan Priorities	Gillnetting assessment and development of conservation regulations; snorkel surveys and stream inventories; angler creel survey, review of stocking data, and Level 2 WRP assessments
Potential Partners	Port Alice Fish and Wildlife Association

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Alice Lake Watershed

General Information

Alice Lake is located 40 kilometres south of Port Hardy on Port Alice Road in the West Coast (WC) Planning Unit (PU). The majority of the watershed is low in elevation, and is in the sub-montaine, very wet maritime coastal western hemlock biogeoclimatic zone (Fielden, 1998). The area surrounding the lake consists of low rolling mountains and mostly logged coniferous forest (Ministry of Environment (MOE), 1969). Alice Lake is situated 38 m above sea level, has a surface area of 1,218 ha and a perimeter length of 40.6 km. This lake has a maximum depth of 72 m, a mean depth of 31 m, a TDS of 46 ppm and a pH of 7.1 (Figure 1, Table 1).

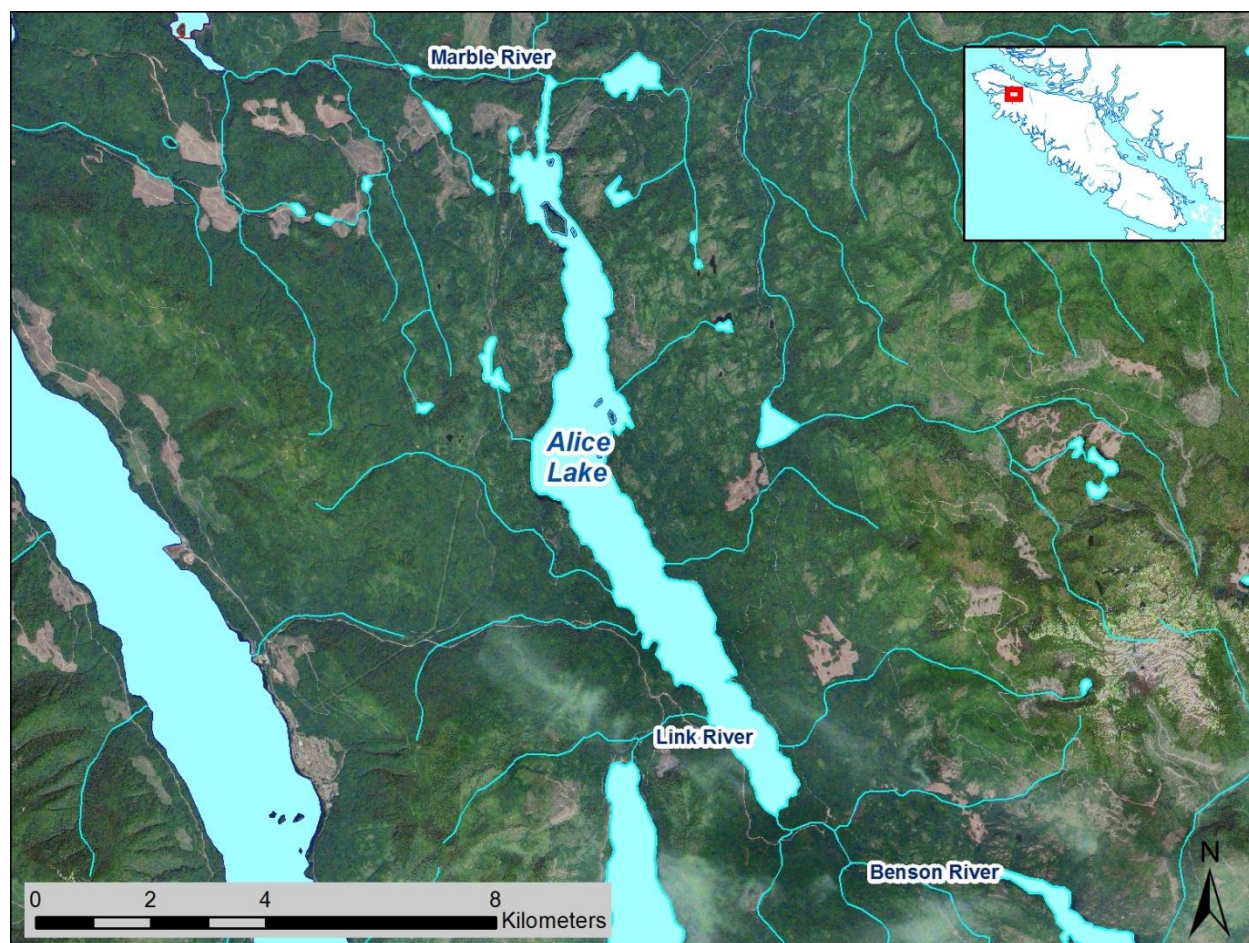


FIGURE 1. Map of Alice Lake and tributaries; bathymetric profile of this lake is provided in Appendix 9. (Source: iMap BC)

TABLE 1. Location, size, depth and water quality parameters at Alice Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
West Coast	00107BRKS	1,218	40.6	72	31	7.1	46	8.5	1969

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Although Alice Lake has a steep shoreline, it is accessible. In 1964, three sites including the mouth of the Marble River where it enters Victoria Lake, the northern end of Alice Lake, and the lower ~2.5 km of the lower portion of the Benson River were proposed as Provincial parks. The resulting 1,419 hectare Marble River Provincial Park is a popular destination for recreational angling, including fly-fishing on the river, and tidal water fishing for Chinook and coho salmon, steelhead, cutthroat and rainbow trout and Dolly Varden.

Tributaries

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Alice Lake (Source: Fielden, 1998, Fisheries and Oceans Canada, 1968)

Tributary	Length (km) and/or Drainage Area (km ²)	General Information
Lower Marble River	8.0 km	Alice Lake outlet; up to ~15 m wide and 6 m deep; considerable silting and erosion in tributaries; water levels low in summer and winter, high during spring and fall freshets; falls at ~1.5 km, 6 km and 11 km are passable unless water levels low; fishway at Bear Falls allows coho and Chinook access; lake outlet falls located at top of Reach 6; 3.6 m falls is passable because of natural channel around area; top of Reach 6 crossed by Port Alice highway and Alice Lake.
Lower Marble Unnamed Tributary	Flows into Reach 5 of Marble and drains Sara Lake; Sara lake used by coho.	
Lower Marble Tributary 2	6.4 km	Has anadromous access; drains Larry Lake 6.4 km upstream.
Lower Marble Tributary 3	5.0 km	4 unnamed lakes and 2 unnamed marshes; may have a barrier to anadromous fish at lower end; upper reaches have cutthroat.
Lower Marble Tributary 4	2.5 km	Flows into Marble River from southeast above Bear Falls; drains a small lake; coho access.
Lower Marble Unnamed Tributary 5	Flows into Lower Marble and drains into an unnamed lake.	
Lippy Creek	6.4 km	Flows east into Alice Lake; 4 reaches; entire watershed logged to stream banks ~30 years ago; low flow in lower reaches 1.5 m falls in Reach 2 limits coho access; cutthroat access to Reach 4; number of roads provide access.
Sorenson Creek	6.0 km	Flows into Alice Lake from the west; 7 reaches; entire watershed logged – some reaches to the stream banks; limestone canyon up to 15 m high in Reach 2; 4 barriers in Reach 2 prevent anadromous access; upper reaches are steep and lack flow.
Pinch Creek	4.6 km	Flows west down small mountain to southeast end of Alice Lake; 3 reaches; most of the stream has been logged to the stream banks; spring provides summer flow but high winter flows may reduce egg-to-fry survival; upper reaches dry and are high gradient.
Benson River	300 km ² drainage area; 26 km	2 lakes – Kathleen Lake and Benson Lake located 7 km and 10.5 km upstream from mouth; Raging River is tributary draining ~100 km ² and flows into Maynard Lake 600 m upstream; 12 m high dam built at Maynard Lake for hydro to Benson Lake Mines; dam and power plan now closed; limestone canyon through Reach 2 and Reach 4; sockeye spawning in Reach 4.
Malook Creek	3.1 km	Flows east into the lower reaches of the Benson River; coho, Dolly Varden in lower reaches; Reach 3 flows underground; uppermost

Tributary	Length (km) and/or Drainage Area (km ²)	General Information
Yootook Creek	8.9 km ² ; 7.4 km	reach logged and has steep gradient. Located east of Howlal Creek and flows north into the Benson River 2 km upstream of Benson mouth; steep, fast flowing creek; Yootook valley heavily logged ~25 years ago- all timber removed from valley; logjam in Reach 2 is upper limit for anadromous; Dolly Varden present until top-most reach (47% gradient).
Howlal Creek	10 km ² ; 7.1 km	Flows south for ~7 km before entering Benson River; watershed extensively logged ~40 years ago; 3 reaches; coho observed to Reach 3; Reach 3 gradient increases to 60%.
Jeune Creek	Flows east into the Link River between Alice and Victoria Lakes; roads into the upper part of the watershed are no longer accessible except on foot.	
Alice Lake Unnamed Tributaries	There were 14 tributaries to Alice Lake (some marked on TRIM maps did not exist during field survey) surveyed during the assessment by Fielden and detailed information is contained in Fielden 1989; some streams with impacts from logging; some with steep gradients and low flows; trout, Dolly Varden and anadromous fish including sockeye and coho were observed in some streams.	

Species Composition

Dolly Varden, resident cutthroat, resident rainbow trout and steelhead have been recorded in Alice Lake (FLNRO files, Nanaimo). There are Chinook and coho salmon stocks in the watershed and sockeye have been listed for various tributaries including Pinch Creek and Link River (Chambers, 1988a; Ministry of Environment, 1989). A DFO stream and spawning ground assessment in 1968 notes that sockeye occur above Alice Lake, and Fielden (1998) notes that sockeye salmon spawn in the lower reaches of some of the Alice Lake tributaries. Coho salmon are widespread and spawn in many Alice Lake tributaries, the Link and Benson Rivers. The main Chinook salmon spawning areas are in the lower Marble River below Alice Lake, and the Benson River below Kathleen Lake. Chinook have also been found spawning in the Link River, Sorenson, Lippy, Pinch and Yootook Creeks, and Alice Lake Unnamed Tributary 8.

Rainbow trout juveniles are found in the lower reaches of Pinch, Howlal and Yootook Creeks, and Benson and Link Rivers. Stream resident rainbow trout have been captured in Jeune Creek and cutthroat trout have been found in many smaller systems. Fielden (1998) suggested that all of the cutthroat trout he sampled were probably non-anadromous as falls in the lower river probably restrict anadromous cutthroat to the tributaries of the lower Marble River. He also noted there are fluvial and adfluvial cutthroat, and that adfluvial cutthroat are associated with the lakes. According to Fielden (1998), only age 0+ and 1+ juveniles are found in the streams with lake access including Lower Marble River tributaries, Lippy and Sorenson Creeks.

The only population of fluvial rainbow trout Fielden (1998) sampled were from Jeune Creek which contained some older, larger individuals not found in adfluvial populations. The Marble River was sampled in 1996 and fish found included: prickly sculpin; threespine stickleback; coho salmon; cutthroat trout; rainbow trout and Dolly Varden (Fielden, 1998). Coho juveniles were the most ubiquitous species of fish in the anadromous areas. Coho out-plants from the Marble River hatchery were also found in non-anadromous areas in Sorenson Creek (Fielden, 1998). Dolly Varden with lake access were found in Yootook, Lippy and Malook Creek and the Link River. The Dolly Varden captured in these areas were generally age 0+ and 1+. Adfluvial Dolly Varden were found in Alice Lake Tributary #7.

The estimated annual escapement in the Marble River for winter steelhead is 50 fish and for summer steelhead is 100 fish (Wightman, 1998). Steelhead spawn in the lower Marble River below Alice Lake, the Link River and throughout the Benson River to the upper reaches (Fielden, 1998). The Marble River has supported populations of 4,000 sockeye; 7,500 Chinook; 20,000 coho; 4,000 chum and 1,500 pink salmon (Chambers, 1988a). Chum and pink salmon are restricted to the lower 2 km of the Marble River (Fielden, 1998).

Summary of Work and Reports

In 1996, MOE contracted Aquatic Resources Ltd. to review information on the Marble River watershed, and conduct a reconnaissance survey of fish and fish habitat on the Marble River and some of its tributaries. The resulting report includes fish and habitat information for Lippy, Sorenson, Howlall, Malook, Yootook, and Jeune Creeks, the Benson and Teihsum Rivers, and unnamed tributaries to Alice Lake, Victoria Lake and the Lower Marble River (Fielden, 1998). Hamilton (1980) provides a detailed summary of the hydrology, fisheries, and watershed development of the Marble River.

2.0 Limits to Fish Production

Water Withdrawal

Fielden (1998) suggests that fish populations may have been impacted by the removal of water by the Western Forest Products pulp mill in Port Alice and the BHP Copper Mine on Rupert Inlet. He also notes this water extraction could reduce juvenile rearing habitat during the summer in the Link and Lower Marble Rivers when flows can reach a low of 1.9 m²/s (Fielden, 1998).

Logging

Of all the industrial activity in the watershed, logging has probably had the most impact on fish populations, particularly in the tributaries feeding the lakes (Fielden, 1998). The valley bottoms throughout most of the watershed have been logged to the stream banks over the past 50 years, and ~50% of the Alice Lake shoreline has been logged to the shore.

In addition to logging around Alice Lake, a large portion of the Marble watershed has also been logged. Sprout and Fraser (1981) state that fisheries problems from logging were most notable in the Marble River and that problems from logging along with mining activity have caused the dramatic decline in Chinook and coho stocks in this river. Fielden (1998) further points out that logging has likely contributed to channel instability, increased channel widths, reduced Large Woody Debris (LWD) in the channel, and a loss of habitat complexity. A report in 1975 by DFO noted that the falls on the Marble River had a partial collapse and this in combination with unstable water levels because of increased logging and increased water use in the Marble River could lead to difficult access for fish (Fisheries and Oceans Canada, 1975).

Mining

Most of the mining activity in the watershed has taken place around Benson Lake. Sprout and Fraser (1981) report that heavy metals from the discharge of mine tailings into Benson Lake by the Benson Lake Copper Mine may have had an impact on Chinook and coho in the system. There are two copper mines and three iron mines in this area and, as of 1998, four prospects in

the vicinity of Alice Lake, mainly around the Link River (Fielden, 1998). The main commodities from these sites are zinc, iron, gold, copper, magnetite and lead (Fielden, 1998). There is one operating mine, as well as six past-producing mines and developed and undeveloped showings in the Marble River watershed (Fielden, 1998). A limestone quarry operated by Imasco Minerals Ltd. is also currently operating in the watershed.

Fish Stocking

A Salmonid Enhancement Program (SEP) Community Development Program hatchery has operated at the north end of Alice Lake since 1981 (Fielden, 1998) and coho have been released into Sorenson and Howlall Creeks, Little and Marble Rivers, and Sara and Larry Lakes. Juveniles are released back into the systems that the broodstock were taken from (Anderson, 1998). In 1996, the hatchery took eggs from Chinook, coho and steelhead (Anderson, 1998). As of 1988, >1.2 million Chinook and 250,000 coho had been reared and released into the drainage area (Chambers, 1988b). No assessment of the success of these programs has been completed.

Fielden (1998) conducted extensive fish habitat and fish assessments of the Marble River watershed and found that Pinch and Lippy Creeks had the highest proportion of habitat available for trout due to a high proportion of shallow, slow-flowing riffle habitat, while Malook Creek had the smallest proportion of trout fry compared to actual fish densities. Fielden also found that habitat in eight tributaries was under-utilized by Dolly Varden and trout, but was near or above capacity for coho juveniles at most sites. He further noted that Dolly Varden and trout fry and parr densities were well below predicted maximum salmonid densities in all eight systems. Fielden suggests that one reason for the low densities of trout and Dolly Varden fry could be due to lack of appropriate substrate and suitable cover. He also suggested that the high densities of coho juveniles in the creeks may have helped depress the Dolly Varden and trout fry and parr populations.

Stream Habitat

An assessment of four unnamed streams flowing east into Alice Lake was conducted in 1995 for MacMillan Bloedel Ltd. (NVISEA, 1995). This assessment found that Unnamed Stream #1 and #2 suffered from low summer flows and that Stream #3 had a barrier 245 m upstream of the confluence with Alice Lake. Stream #4 contained coho and trout, and had excellent spawning areas for salmonids (NVISEA, 1995). This report also notes that LWD piles from shake-block waste and previous logging activities had accumulated at the mouths of these and other creeks flowing into Alice Lake, and that these materials were disrupting the natural migration pattern of salmonids.

3.0 Angling Statistics

Angler Effort

The average angler effort since 1986 at Alice Lake is ~1,200 angler days/year (Figure 2). However, there has been a decreasing trend in angler effort over the survey period. Angler effort dropped from ~2,000 in 1986 to ~1,500 in 1989 and to ~1,200 in 1992. In 2002, angler effort increased to ~1,900 angler days but angler effort fell again to 880 in 2006 angler days and to 220 angler days in 2011.

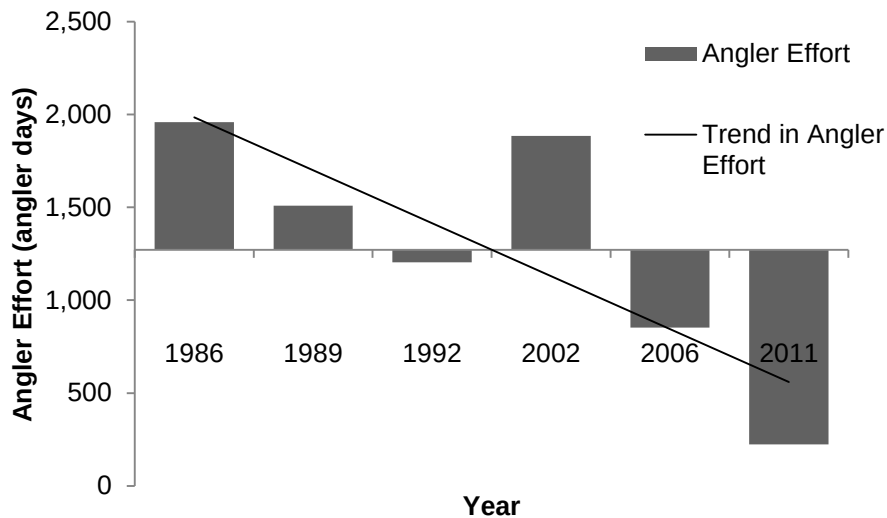


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Alice Lake 1986 – 2011. Note that the fisheries estimates from the VILQ on a low effort lake such as Alice Lake are subject to high variability as the VILQ is not sensitive enough to pick up subtle changes in parameters including catch and harvest on lightly-fished lakes such as Alice Lake. In the case of Alice Lake, only seven anglers responded to the mail-out VILQ; fewer anglers sampled means higher variability and catch and success estimates are subject to error (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Catch

Total catch has also been declining over the survey period and mirrors that of angler effort (Figure 3). In 1986, total catch was at its highest at 3,700 fish. Between 1989 and 2002 total catch ranged from ~2,500 fish to 2,700 fish. In 2006, total catch dropped to 900 fish and in 2011, total catch dropped to its lowest level at an estimated 56 fish.

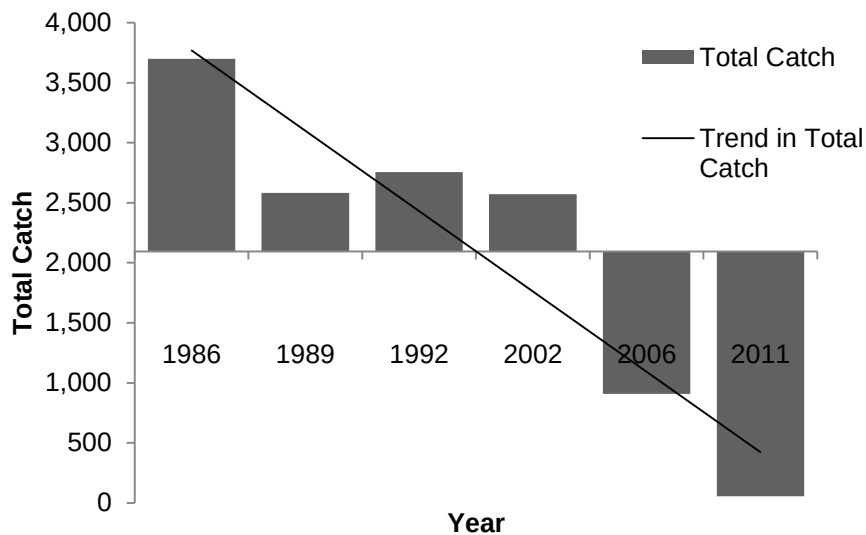


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Alice Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Fifty-one percent of the angler catch in 2006 was cutthroat trout (466 fish) while ~49% was rainbow trout (443 fish) (Table 3). In 2011, all 56 fish caught by anglers were cutthroat trout.

TABLE 3. Catch of rainbow and cutthroat trout at Alice Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	466	51.3	56	100.0
Rainbow	443	48.7	0	0
Total Catch	909		56	

Angler Success

Between 1986 and 1989 angler success reported by the VILQ averaged ~1.7 fish/day (Figure 4). This is similar to reporting by Wolter and Gwilt (1980) who reviewed angler creel census reports from early in the decade which suggested that Alice Lake received moderate angler use with anglers maintaining average catch success rates of 0.5 fish/hour (~2 fish/day for a 4-hour day).

In 1992, angler success increased to 2.2 fish/day likely in response to the decrease in angler effort that year (Figure 2). Thereafter, angler success began a steady decline to 1.3 fish/day in 2002, 1 fish/day in 2006, and 0.25 fish/day in 2011. The declines in the last two survey years reflect the decline in angler effort and total catch at this lake. Overall, the average angler success at Alice Lake is 1.4 fish/day.

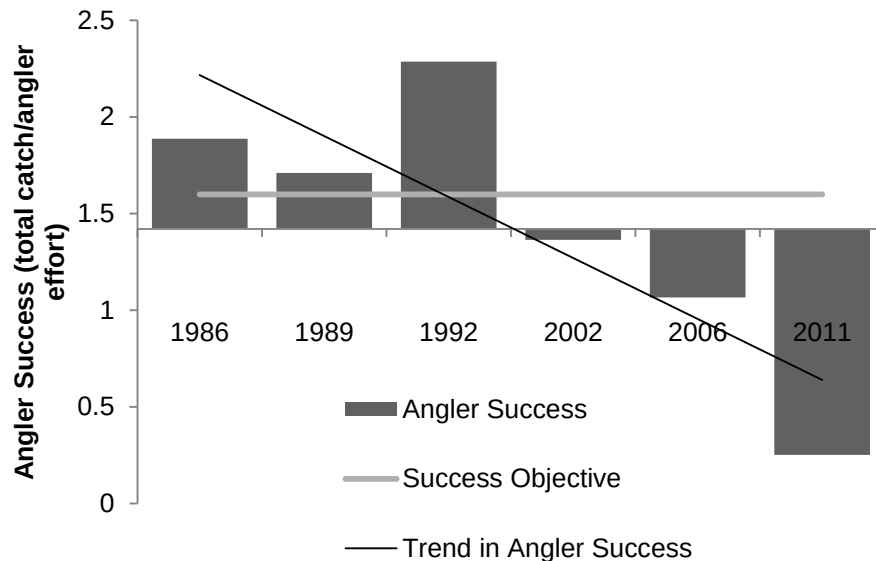


FIGURE 4. Angler success (total catch/total angler effort in angler days) and trend in angler success compared to average angler success and the objective for angler success (1.6 fish/angler day) at Alice Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Harvest

In 2006, anglers harvested ~30% of their cutthroat trout (136 fish) and ~28% of their rainbow trout (125 fish) (Table 4). The overall harvest rate at Alice Lake that year was ~30%. In 2011, anglers harvested 25% of their cutthroat (14 fish).

TABLE 4. Catch, harvest and percent harvest of rainbow and cutthroat trout at Alice Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	466	136	29.2	56	14	25.0
Rainbow	443	125	28.2	0	0	0.0
Total	909	261	28.7	56	14	25.0

4.0 Stock Status Indicators

Relative Abundance

Alice Lake has been sampled twice by gillnet; once in August 1969 when 25 fish were caught, 80% of which were cutthroat trout, and again in September 1980 when seven fish were caught (Figure 5). Rainbow trout were collected only in 1980 and comprised ~60% of that sample. Dolly Varden comprised ~20% of the sample collected in 1969 and none of the 1980 sample. Because Dolly Varden move into the tributaries to spawn in September these fish may not have been available for the 1969 netting which was conducted that month.

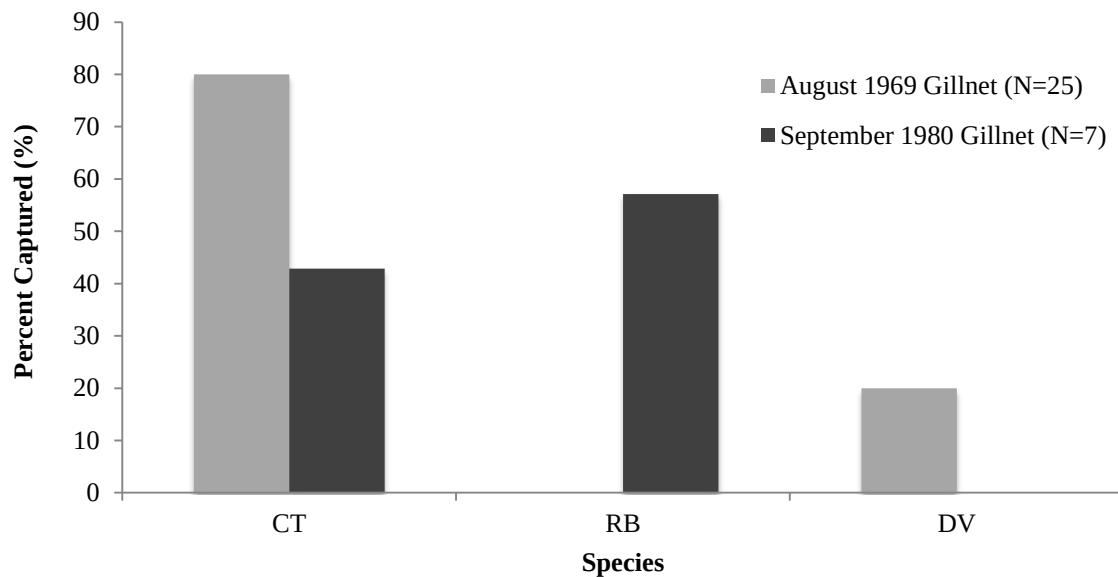


FIGURE 5. Percent cutthroat trout, rainbow trout and Dolly Varden captured in gillnets in Alice Lake in August 1960 and September 1980. Gillnet type (sinking or floating) and locations were not specified (Source: FLNRO files, Nanaimo).

Length and Weight

Unfortunately, the only information recorded during the 1969 gillnet sample indicated that 25 fish were caught. In 1980, three cutthroat ranging from 206 mm - 288 mm and averaging 241.0 mm and ~167 g were caught. Four rainbow trout ranging from 170 mm - 306 mm and averaging 240 mm in length and 192 g were also captured.

TABLE 5. Minimum, maximum, mean length and mean weight for cutthroat and rainbow trout and Dolly Varden captured in gillnets in Alice Lake 1980 (N=7) Note: because of low numbers of fish sampled, this data is subject to high variability and of little value in drawing conclusions on stock status in Alice Lake (Source: FLNRO files, Nanaimo).

Species	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
Cutthroat	3	206.0	288.0	241.0	166.8
Rainbow	4	170.0	306.0	240.3	192.1
Dolly Varden	5	No length or weight data			

One maturing female cutthroat 288 mm and 264 g, and two mature male cutthroat averaging 218 mm and 118 g were captured in 1980. One mature female rainbow 306 mm and 358 g, one maturing female rainbow 302 mm and 286 g, and two mature male rainbow averaging 177 mm and 62 g were caught in the 1980 gillnet set (Table 6).

TABLE 6. Number, range of fork length and mean fork lengths of immature and mature male and female cutthroat trout (N=3) and rainbow trout (N=4) captured in gillnets in Alice Lake 1980 (Source: FLNRO files, Nanaimo).

	Cutthroat		Rainbow		
	Females	Males	Females		Males
	Maturing	Mature	Mature	Maturing	Mature
n	1	2	1	1	2
Minimum Fork Length (mm)		206			170
Maximum Fork Length (mm)		229			183
Mean Fork Length (mm)	288	217.5	306	302	176.5
Mean Weight (g)	264.2	118.1	358.3	285.7	62.1

Catch Indicators

Total Catch

Twenty-five fish of which 80% were cutthroat and 20% were Dolly Varden were captured in gillnets in 1969. In 1980, seven fish, 43% of which were cutthroat were caught in gillnets in 1980 (Table 7). There is no information regarding the number of nets or their locations, the number of sets, or the soak times for either sample.

TABLE 7. Total catch of cutthroat trout, rainbow trout and Dolly Varden captured in Alice Lake in 1969 and 1980 (Source: FLNRO files, Nanaimo).

Species	1969	1980
Cutthroat	20	3
Rainbow	-----	4
Dolly Varden	5	
Total	25	7

Data Gaps

The only recent data for Alice Lake has come from the VILQ and there is no additional fisheries data such as angler creel surveys to provide further insight into the Alice Lake fishery (Table 8). Gillnetting data is >10 years old and the existing data doesn't provide critical stock status indicators such as fish length or age data. Lake and stream inventories and juvenile assessments in the tributaries are also >10 years old and there have never been snorkel surveys to assess spawning populations.

TABLE 8. Summary of data gaps for Alice Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Gillnetting		X	
Lake Inventory		X	
Stream Inventory (general)		X	
Fish Assessment (streams)		X	
Angler Creel Survey		X	
VILQ	X		
Water Quality/Lake Productivity			X
Level 1&2 WRP Surveys			X
Snorkel Surveys			X
Fishery Data and Angler Preferences			X
Acoustic Surveys			X

5.0 Fisheries Objectives and Management Strategies for Alice Lake

Existing Regulations

Alice Lake is covered by the general regional regulations of four trout but not more than 1>50 cm. There is no data on how often these goals are achieved. All wild trout and steelhead from streams and all Dolly Varden must be released.

The Marble (Link) River and tributaries between Victoria and Alice Lakes and the Benson River and tributaries are fly-fishing only. The remaining tributaries to Alice Lake are covered by the regional regulations of two fish from streams (must be hatchery) and mandatory release of all wild trout and steelhead from streams. There is a bait ban and single barbless hook restriction in all streams, all year.

Maximum Catch and Effort, Harvest and Yield at Current Regulations

We could not project maximum or optimum levels despite the close relationship between angler effort and total catch (Figure 6). The yield in 2011 and in 1986 when catch was at its highest recorded level yield is below what we've predicted using MEI and Ryder's simplified regression (Appendix 8).

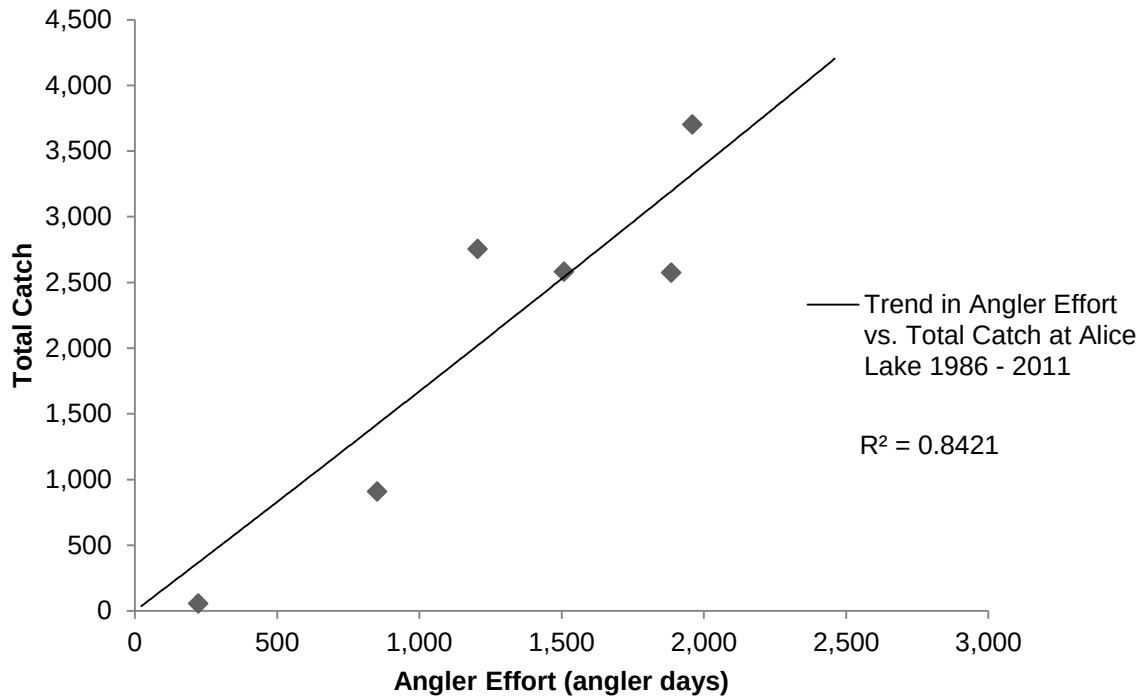


FIGURE 6. Relationship between angler effort vs. total catch and trend in angler effort and catch at Alice Lake 1986 - 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

It appears Alice Lake is under-fished based on the low yield and the fact that we could not project optimum angler effort and catch. However, angler success has declined in every VILQ survey year since 1992. In fact, despite angler effort being high in 2002, anglers caught fewer fish than in the previous survey year and angler success also declined that year. In 2011, angler effort, catch and success all declined by >10% from the previous survey.

The major data gap at this lake is the lack of stock status indicators. If we were to rely on the VILQ data, our conclusion would be a major decline in salmonid species. However, because of the low number of anglers sampled on lightly-fished lakes such as Alice Lake, catch and effort statistics have a high probability of error resulting in a wrong conclusion. Specifically, in the case of Alice Lake, only seven anglers responded to the mail-out VILQ in 2011. Fewer anglers sampled means higher variability in the data and catch and success estimates subject to error.

We've recommended that a gillnetting program be implemented immediately to gather stock indicator data and determine the status of cutthroat and rainbow in Alice Lake (Table 16; Chapter 1). Conservation regulations may be required after that sampling and may need to be strengthened depending on the results of the subsequent sampling and the results of the next VILQ.

1. Gillnetting should proceed in 2013 and stock status and catch data reviewed against existing 1980 data and means for Vancouver Island large lakes to determine if there are stock declines at Alice Lake.

2. Develop conservation regulations if necessary. We recommend the approach outlined in Chapter 1 for both species but we've moved the minimum size limit down because of the small size of maturing fish at Alice Lake. We recommend this size limit be confirmed during the gillnetting:
 - a. a minimum size regulation of 250 mm to allow fish to spawn once before entering the fishery; and,
 - b. a maximum size limit of 400 mm to protect immature and large fish but still allow anglers to catch a fish.
3. According to the VILQ a similar situation exists at Victoria Lake (Chapter 16). We recommend reviewing the data at that lake and determining if the same regulations are appropriate. Similar regulations at Alice and Victoria Lakes will make things easier for anglers moving between these areas.
4. The current harvest rate at Alice Lake is 25% which is already conservative, though we recommend moving to catch-and-release fishing if repeated gillnetting and the next VILQ indicate continued stock declines.
5. Fielden suggests high densities of coho juveniles in tributaries and we recommend reviewing the stocking program with DFO to determine if biostandards of 0.5 coho/m² (Envirowest Environmental Consultants, 1990) are being exceeded, and if monitoring suggests stocking in this watershed has been successful.

Operational Management Plan for Alice Lake

We've provided an operational management plan for Alice Lake in Table 9. Given the existing data gaps in stock status we've suggested implementing snorkel surveys on the Benson, Marble and Link Rivers to assess cutthroat and rainbow spawning, and that an angler creel survey precede or accompany any change in regulations (Figure 15; Chapter 1). If a roving angler creel is not possible, we recommend a box angler creel survey such that implemented at Upper and Lower Campbell Lakes (Michalski, 2011b). We also recommend a review of Fielden's (1989) report and detailed (Level 2 WRP) habitat assessments on lake tributaries to determine limiting factors, identify priorities and develop tributary enhancement and/or restoration plans.

TABLE 9. Operational Management Plan for Alice Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Assess stock status indicators; compare against 1980 data and VI large lakes data	2013 and 2016
	Conduct snorkel surveys on the Benson, Marble and Link Rivers to assess cutthroat and rainbow spawning, juvenile rearing densities, fish species compositions and size-age distributions.	2014 2015
Regulation Change (possible)	An out-of cycle conservation regulation may be necessary depending on results of the gillnetting survey; consider minimum size; slot limit or catch-and-release regulation.	2015
	Public consultation with Port Alice Fish and Wildlife Association and Region 1 Freshwater Fishing Regulations Committee (FFRAC).	2013-2015
Fisheries Assessments	Conduct an angler creel survey or box angler creel survey to determine actual angler effort, catch and harvest and gather stock status data on angler caught fish.	2015
Other – Coho Stocking	Determine if stocking is still occurring; review stocking rates with DFO; assess if this is a possible impact on Dolly Varden and trout fry.	2013
Habitat Assessment	Conduct WRP assessments to determine limiting factors, identify priorities.	2015
Habitat Restoration	Develop and implement restoration plans for Alice Lake tributaries.	2017
Fisheries Monitoring - VILQ	Evaluate changes in fisheries statistics every three years; review in conjunction with results of gillnetting assessments to determine if more restrictive regulations are required.	Ongoing

Chapter 3. Buttle Lake

Lake	Buttle
Planning Unit	Campbell Oyster
Watershed	Campbell
Surface Area (ha)	3,095
Mean Depth (m)	61.3
Key Tributaries	Thelwood, Price, Phillips Creeks; Ralph River
Freshwater Fish Species	Rainbow, Cutthroat, Dolly Varden
Limits to Production	Hydro, Forestry, Mining
Regional Priority*:	7
<u>Angling Statistics 2011</u>	
Angling Effort	2,924 angler days
Total Catch	6,752 fish
Angler Success	2.3 fish/angler day
Current Harvest Rate	25%
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	Mean length of cutthroat has remained stable, however, total catch in gillnets has declined substantially since 1960; although more rainbow trout have been observed in snorkel surveys recently. Mean length and weight of rainbow trout has declined since 1960 and total catch has declined by more than an order of magnitude in the same period, we identified a decline in modal length of this species.
Data Gaps	A hydroacoustic study would be beneficial and there are no stream electrofishing surveys; snorkel surveys should be continued every two years. We recommend an education program be developed in cooperation with watershed partners including an underwater fish viewing facility be developed on Thelwood Creek or Ralph River. There is also potential to illustrate fish habitat components and stream ecological processes in the Thelwood Valley and Ralph River campground. No restoration is recommended at this time.
Management Actions	Determine if there is gillnetting data available from NVI Mines; analyze data and compare results to determine if there are declines in stock status indicators for cutthroat and rainbow trout; develop regulations to decrease harvest if declines confirmed. If no declines, monitor with VILQ.
Operational Plan Priorities	Public awareness program; ongoing lake monitoring with Campbell River Fish and Game Association.
Potential Partners	NVI Mines, BC Parks, BC Hydro, Western Forest Products, Gold River Fish and Game Association

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Buttle Lake Watershed

General Information

Buttle Lake lies in a “U” shaped valley 223 m above sea level between Campbell River and Gold River in the mountains of Strathcona Park. This lake is located within the coastal western hemlock zone of the Campbell-Oyster PU and is the largest in a chain of lakes within the Campbell River watershed. Buttle Lake drains northward through a short channel into Upper Campbell Lake and the water levels of both lakes are controlled by BC Hydro at the Strathcona Dam.

Buttle Lake and much of its watershed have been within the Strathcona Provincial Park since 1911 and except for forest fires, this lake was largely undisturbed until dam construction in 1958, and mine construction in 1966.

Buttle Lake has a surface area of 3,095 ha, a perimeter length of 74.4 km, an average depth of 61.3 m, and a maximum depth of 120.7 m (Figure 1; Table 1). The lake has a secchi depth of 13 m, with a TDS of 40 ppm and was assessed by Provincial Fisheries staff in 1951, 1966, 1967, 1969, 1979, 1980, 1983 and 1997 (Table 1).

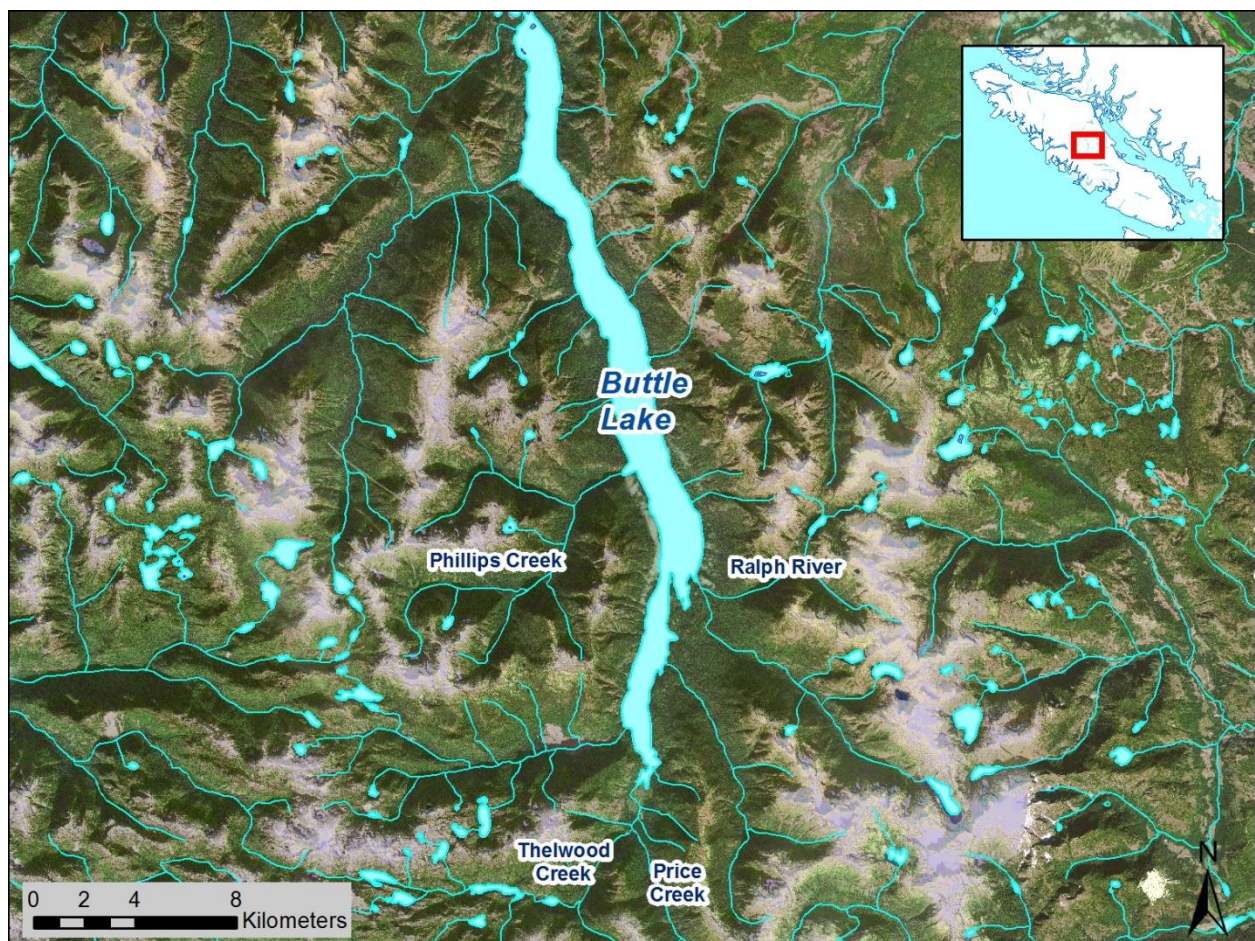


FIGURE 1. Map of Buttle Lake and tributaries; bathymetric profile of this lake is provided in Appendix 10. (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Buttle Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
Campbell Oyster	00362CAMB	3,095	74.4	120.7	61.3		40	13.0	1951, 1966, 1967, 1969, 1979, 1980, 1997

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Tributaries

We've provided a summary of the major tributaries to Buttle Lake in Table 2. Thelwood Creek is one of the most important cutthroat and rainbow trout spawning tributaries in the system with the Ralph River providing additional ~900 m of spawning and rearing habitat. The Wolf River and Henshaw and Phillips creeks are major spawning tributaries for rainbow trout (Reid, G., 2012, pers. com.).

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Buttle Lake (Source: Hatfield Consultants Ltd. 1982; FISS).

Tributary	Length (km)	Other Information
Wolf River	22.43	The Wolf system is relatively large but has an impassable falls ~200 m from the lake high water mark. The stream is poorly suited for spawning or fry rearing; the main fish usage in the accessible portion of this river would appear to be feeding and overwintering by larger juveniles and adult fish.
Ralph River	9.26	The mainstem is accessible to salmonids from the high water mark to ~900 m upstream at which point the Ralph is joined by Shepherd creek. From this confluence, Ralph River appears to be accessible for a further ~500 m; the gradient steadily increases upstream with small 1-2 m cascades. The total quality spawning habitat is limited in this creek. Some juvenile rearing likely occurs, but given flow and general absence of cover, most fry are probably displaced downstream shortly after emergence.
Phillips Creek	12.08	Phillips creek is accessible to salmonids for ~400 m from the lake high water mark. Most of the accessible portion is typified by boulder substrate and turbulent flow suitable for use by larger juveniles and adults. Some spawning (~100 m ²) is available above the high water mark; further suitable areas would be available during low lake levels. Fish usage is likely confined to some spawning; potential fry rearing areas are minimal and fry probably migrate lake-ward shortly after emergence.
Thelwood Creek	13.81	The lower reaches of Thelwood creek are accessible to fish from Buttle Lake from the Buttle Lake high water level to impassable falls and rapids ~2.7 km upstream. Hatfield Consultants estimated the amount of spawning area in Thelwood and Price creeks to be ~1,200 m ² and estimated the resident salmonid population at ~1,500. Below the impassable falls and rapids, the stream is formed of deep, bedrock controlled pools providing good habitat for rearing juveniles and overwintering adults. Below the deep pools, the creek flows over gravel-bottomed pool/riffle sequences suitable for spawning and glides. Further downstream and to its mouth, the channel is divided into several channels comprised of small-gravel substrate, more lower-flow pool areas and generally more diverse habitat features. Over the winter and early spring when lake drawdown approaches a maximum, ~1,200 m of additional stream channel exists between the lake high and low water marks. This portion of the stream is not

Tributary	Length (km)	Other Information
Henshaw Creek	13.47	available as stream habitat over summer when the channel is flooded. This creek is very important for rainbow trout spawning and initial rearing phases. This creek is accessible to fish from Buttle Lake for ~600 m; passage would become increasingly difficult until completely restricted by steep rapids and small falls. Bottom material is comprised mainly of cobble and boulders; only ~300 m ² is suitable for spawning while other fish activities in the stream would be restricted by the absence of instream and riparian cover and turbulent flow.
Price Creek	8.05	Price creek is a tributary to Thelwood creek. From its confluence with Thelwood creek upstream to higher gradient and small falls ~500 m upstream this creek provides some rearing and overwintering habitat (i.e. pools, LWD). Small areas are available for spawning. The lower reaches (~500 m) of Price creek are accessible to Buttle Lake fish and sampling by Hatfield Consultants suggest this creek is more important for cutthroat and Dolly Varden than for rainbow.

Species Composition

Native fish in Buttle Lake include cutthroat trout, rainbow trout, Dolly Varden, prickly sculpin, and threespine stickleback. Anadromous salmonids have never had access to the system upstream of a major waterfall near John Hart Dam.

Summary of Work and Reports

Fish and fish habitat studies have been conducted on several tributaries that enter Buttle Lake (i.e. McMyynn and Larkin, 1953; Sinclair, 1965; Butcher, 1981; Hatfield, 1982a and 1982b, Slaney, 1990, Lough et al, 1991, Hallam Knight Piesold Ltd., 2000, Golder, 2001). MOE has also performed several general habitat assessments and mapping surveys of Buttle Lake tributaries and some of these assessments include recommendations for habitat enhancement. Many of these reports can be found in the Ministry regional office in Nanaimo, and on-line through Ecocat (<http://www.env.gov.bc.ca/fish/>).

The Ministry has conducted annual snorkel surveys since 1991 to monitor rainbow trout stocks in five main Buttle Lake tributaries: Ralph and Wolf Rivers and Henshaw, Thelwood and Phillips Creeks. The provincial government and North Vancouver Island (NVI) Resources Ltd. have conducted a number of studies focused on assessing impacts from the mine. Many of these surveys include fish assessments and some of these reports, as well as reports from the Ministry snorkel surveys, can be found in the Ministry files in Nanaimo.

2.0 Limits to Fish Production

Water Withdrawal

The Strathcona Dam was constructed between 1955 and 1958 by the BC Power Commission and this dam, along with the Ladore and John Hart dams make up the Campbell River hydro-electric system. The Strathcona Dam raised the levels of both Upper Campbell and Buttle Lakes by 8.5 m and water level in the lakes now fluctuates ~9 m annually. Except during maximum reservoir draw-down, the two lakes usually have a common elevation. A study by the Fisheries Branch found only one fish marked in Buttle Lake suggesting limited movements of fish through these two lakes (FLNRO files, Nanaimo).

Logging

Logging in the area is minimal and riparian habitats of all spawning streams are intact because the lake is contained entirely within Strathcona Provincial Park.

Mining

Buttle Lake was subjected to long-term heavy metal contamination as a result of a copper/lead/zinc mine located at the south end of the lake adjacent to Myra creek. This mine began operating in 1966 and until 1984 mine tailings were deposited directly into the southern basin⁵ of Buttle Lake. Acid mine generation in the drainage basin released metals, especially copper, zinc and cadmium into Buttle lake via Myra Creek until 1983. Water chemistry analysis by MOE identified zinc and copper throughout the watershed and declines in rainbow trout, which are sensitive to zinc and cadmium toxicity, were documented on the basis of declining angling harvests and angler success in Buttle Lake (Deniseger et al, 1988). This fact, coupled with a lack of a similar decline in adjacent, limnologically similar but un-impacted Upper Campbell Lake, suggested that declines in fish numbers were due to the high heavy metal concentrations from tailings disposal in the Myra Creek watershed.

In 1983, a surface and groundwater collection and treatment system was installed at the mine and in 1984 an on-land tailings disposal system replaced the lake disposal system. The wastewater from ore extraction is now deposited into tailings ponds where it is treated with lime to precipitate heavy metals. The water is then directed into Myra creek, which is not accessible to fish, then into Buttle Lake. Gillnetting conducted by MOE in 1988 in Buttle Lake produced high catches (i.e. 265 fish/100 m) of which 45% were rainbow trout 250 mm - 300 mm, and 55% were Dolly Varden 260 mm – 340 mm. Based on these results it appeared that earlier trends towards increasing heavy metals levels had been reversed and the water quality of the lake was improving (Deniseger, et al, 1988).

3.0 Angling Statistics

Angler Effort

Angler effort averaged ~2,200 angler days/year in the mid-late 1980's (Figure 2). Since 1992, angler effort has increased at Buttle Lake reaching 4,500 angler days in 2002 and 5,852 angler days in 2006. In 2011, angler effort dropped to ~3,000 angler days. Angler effort has averaged ~3,700 angler days/year at Buttle Lake since 1986.

⁵ A 40 meter deep sill occurs approximately 8 km from the southern end of Buttle Lake and creates a well defined basin somewhat isolated from the rest of Buttle Lake.

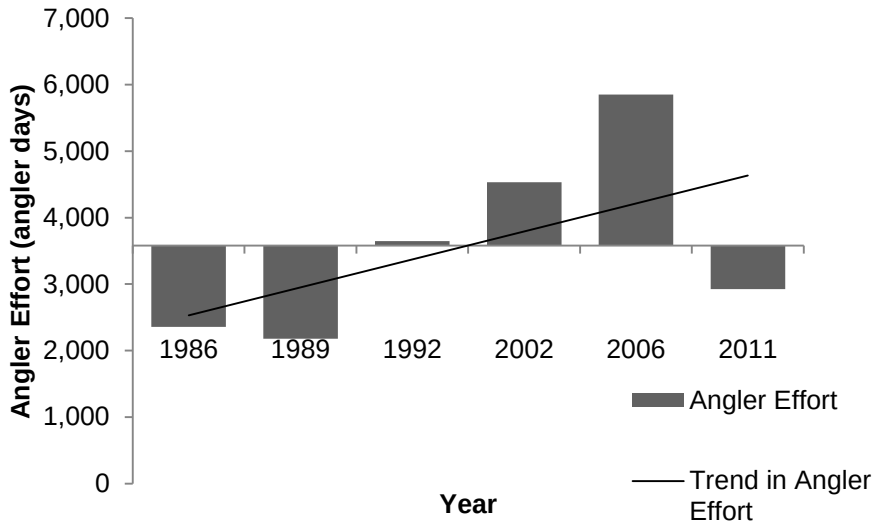


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Buttle Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Catch

Total catch increased by >30% from 1986 to 1989 (Figure 3). In 1992, angler catch was almost 10,000 fish and in 2002 catch increased to >11,000. By 2006, angler catch increased to ~15,500 fish but in 2011 catch dropped to ~7,000 fish. Angler catch at Buttle Lake has averaged ~10,000 fish/year over the 25 year VILQ survey period.

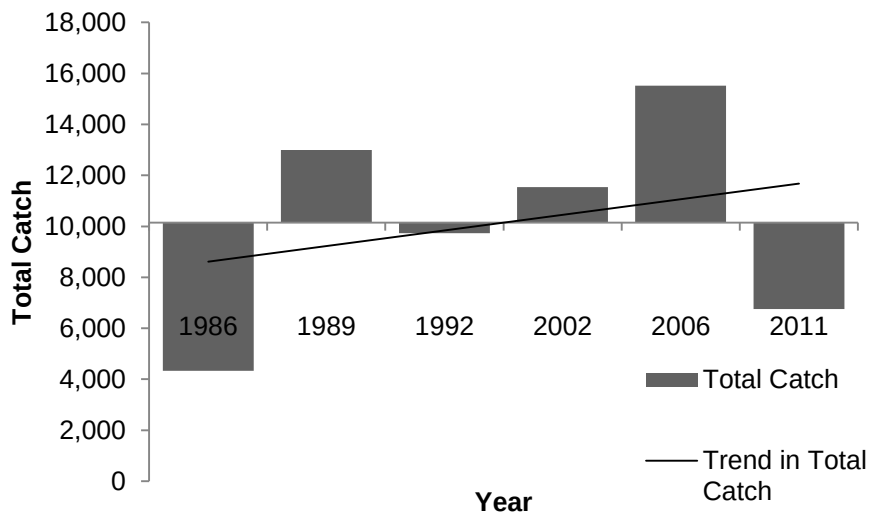


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Buttle Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Anglers caught ~7,400 cutthroat trout (47.7% of the total) and 6,250 rainbow trout (40.3% of the total) in 2006 (Table 3). A total of 1,875 Dolly Varden comprising ~12% of the catch were also caught that year.

In 2011, 3,856 cutthroat trout comprised ~57% of the total catch (Table 3). This catch of cutthroat was ~ ½ what it was in 2006. Catches of rainbow trout and Dolly Varden were considerably reduced in 2011 with only 2,576 rainbow trout (28.2% of the total) and 306 Dolly Varden (4.5% of the total) caught by anglers that year.

TABLE 3. Catch of rainbow and cutthroat trout at Buttle Lake 2006 and 2011 (Source: Andrews, 2007, Silvestri, 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	7,398	47.7	3,856	57.2
Rainbow	6,250	40.3	2,576	38.2
Dolly Varden	1,875	12.1	306	4.5
Total	15,523		6,738	

Angler Success

Angler success reached a high of almost 6 fish/day in 1989 then declined to between 2.5 and 2.6 fish/day from 1992 until 2006 (Figure 4). In 2011, angler success was ~2 fish/day and overall, angler success has averaged ~3 fish/day since 1986. This is above the regional success objective of 1.6 fish/day (Figure 4).

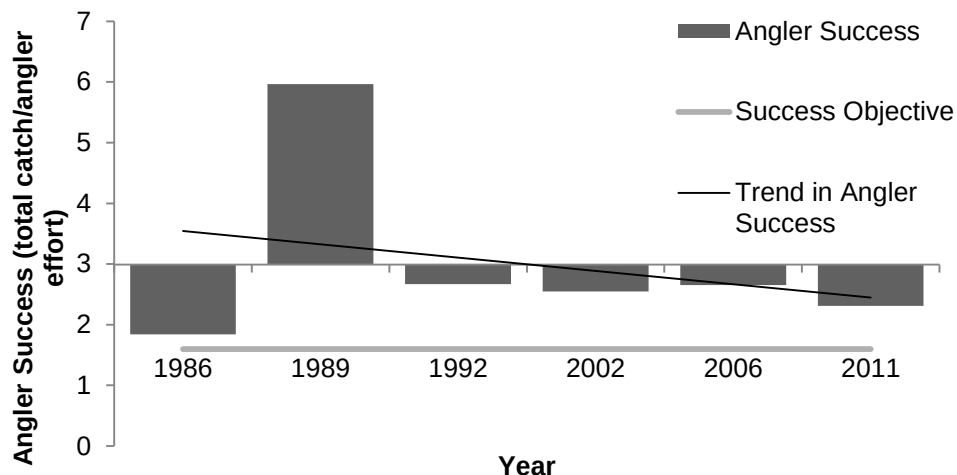


FIGURE 4. Angler success (total catch/total angler effort in angler days) compared to average angler success and the objective for angler success (1.6 fish/angler day) at Buttle Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Angler Creel Surveys

Actual angler success is likely well below the estimates provided by the VILQ. The Fish and Wildlife Branch (1979) conducted aerial boat and angler counts and angler creel surveys at Buttle Lake on May long-weekends in 1978 and 1979. Anglers caught more cutthroat than rainbow trout in those years, and harvest ranged from ~760 – 1,700 fish (Table 4). Angler success was <0.5 fish/day in both 1978 and 1979 (Fish and Wildlife Branch, 1979).

TABLE 4. Summary of angler harvest and angler success rate (for harvest) (fish/day) data collected during aerial angler counts and angler interviews at Buttle Lake Victoria Day (May) long weekends 1978 and 1979 (Source: FLNRO files, Nanaimo).

Year	Fisheries Statistics		Species (%)		
	Harvest	Harvest Success (fish/day)	Cutthroat	Rainbow	Dolly Varden
1978	1,704	0.42	44	36	20
1979	759	0.20	58	33	-----

Harvest

Anglers harvested 38% of their catch of cutthroat trout (2,818 fish) and ~31% of their catch of rainbow trout (1,909 fish) in 2006 (Table 5). Anglers also harvested ~2% of the Dolly Varden they caught (45 fish) despite the region-wide mandatory release regulation for this species.

TABLE 5. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Buttle Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	% Harvest	Catch	Harvest	% Harvest
Cutthroat	7,398	2,818	38.1	3,856	933	24.2
Rainbow	6,250	1,909	30.5	2,576	738	28.6
Dolly Varden	1,875	45	2.4	306	14	4.5
Total	15,523	4,772	30.7	6,738	1,685	25.0

There was a decrease in the overall harvest rate from ~31% in 2006, to 25% in 2011. In 2011, anglers harvested 24% (933 fish) of their cutthroat catch, ~29% (738 fish) of their rainbow catch and ~5% (14 fish) of their catch of Dolly Varden.

4.0 Stock Status Indicators

Relative Abundance

Buttle Lake has been sampled a number of times since the 1950's and we've presented the relative abundance of fish captured in gillnets in Figure 5. With the exception of samples taken in 1990 when Dolly Varden comprised most of the sample, rainbow trout have consistently outnumbered other species and have remained relatively constant in terms of numbers found in gillnet samples. Many samples were collected in the summer, although samples in the 1960's were collected during the spring and winter when Dolly Varden and cutthroat may have been spawning in the tributaries. This may explain the low numbers of these species in those

samples. Unfortunately, no information on the number of gillnets, locations or soak times were provided for any of the samples.

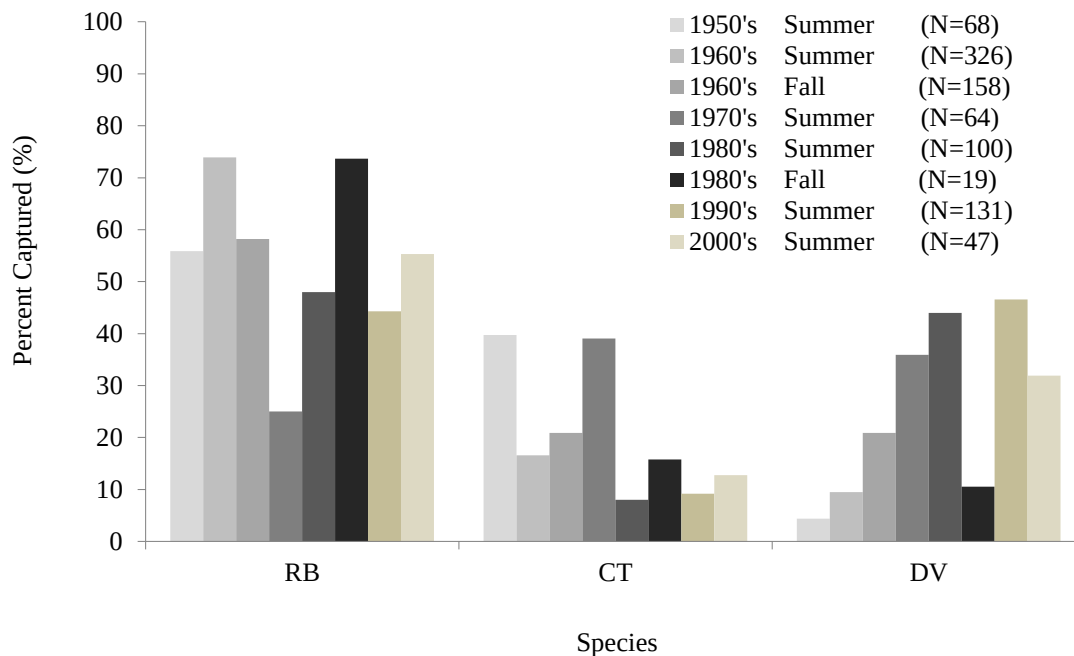


FIGURE 5. Percent cutthroat trout, rainbow trout and Dolly Varden captured in gillnets in Buttle Lake in June 1951; August 1954; June, July, August, October, December 1967; April 1968; June, July, August 1969; October 1969; May 1979; June 1984; June 1985; October 1987; June 1988; June 1989; June 1992; June 1993; June 1994; June 1995; July 1999; May 2001. No information on the number of gillnets was provided in any year (Source: FLNRO files, Nanaimo).

The numbers of cutthroat trout in gillnet samples have decreased since the 1980's. This finding is interesting given cutthroat trout are the most important species to the angler comprising ~50% and 60% of the catch in 2006 and 2011 respectively (Table 3, Table 4). It's not possible to draw any conclusions or links to the fishery as there may have been differences between the net locations and numbers of nets over the sampling years which may have affected the sampling. In addition, different species have been found to occupy different areas within Buttle Lake. In 1982, Hatfield Consultants found that rainbow trout had a greater relative abundance in the southern portion of the lake, with most rainbow trout congregating to the south and east of Myra Creek, while cutthroat trout were more abundant in the northern portion of Buttle Lake (Hatfield Consultants Ltd, 1982).

Snorkel Surveys

Annual snorkel surveys are conducted during rainbow trout spawning periods and the data are used by MFLNRO to monitor this species. Observations of rainbow trout made during snorkel surveys have increased over the years and particularly between 2006 and 2010. In the early 2000's for example, rainbow trout counts averaged ~4,000 fish for all tributaries. From 2008 until 2010, counts increased to ~8,000 but by 2012 the count declined to ~4,000 (Figure 6).

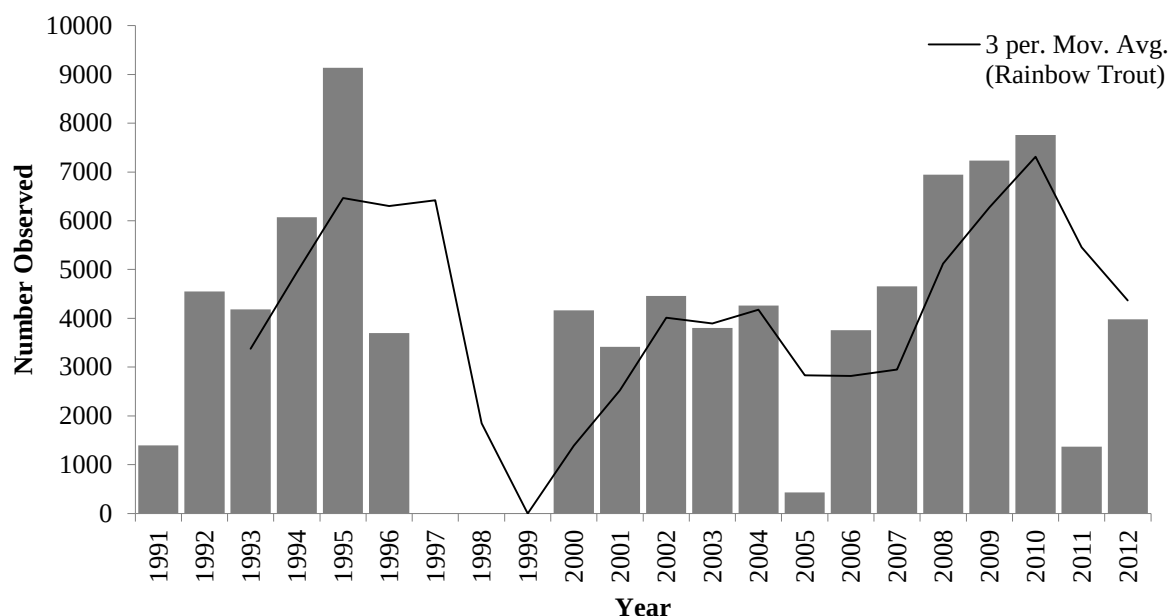


FIGURE 6. Total number of rainbow trout observed in snorkel surveys of the tributaries to Buttle Lake (Thelwood Creek (n=56988), Ralph River (n=16307), Wolf River (n=7302), Phillips Creek (n=4286), and Henshaw Creek (n=402), June 1991 – 2012 (N=85285). Trend line represents 3-year moving average. Note: no swims were conducted between 1997 and 1999. In 2005, only Phillips Creek and Wolf River were swum. In 2011, only Thelwood Creek, Philips Creek and Wolf River were swum. In 2012, only Thelwood Creek and Ralph River were swum (Source: Kevin Pellett, BCCF Nanaimo Snorkel Summaries of Buttle Lake; FLNRO files, Nanaimo).

Thelwood creek is the most important rainbow spawning tributary to Buttle Lake accounting for 66% of the total rainbow observed in snorkel surveys over the past ~2 decades (Table 6). Counts in this stream have ranged from 1,000 in 1991, to nearly 5,000 in 1995 and 2010, and have averaged ~3,100 fish annually. The Ralph River is also an important spawning area with counts ranging up to 2,620 fish and averaging ~1,000. Counts of rainbow in Wolf River and Phillips Creek average 609 and 306 respectively, while counts in Henshaw Creek range between 4 and 93 and average 40 fish/swim.

TABLE 6. Total number of rainbow trout observed in snorkel surveys of Thelwood Creek (n= 56,988), Ralph River (n=16,307), Wolf River (n= 7,302), Phillips Creek (n=4,286) and Henshaw Creek (n=402), June 1991 – 2012 (N=85,285) (Source: Kevin Pellett, BCCF Nanaimo Snorkel Summaries of Buttle Lake; FLNRO files, Nanaimo).

Year	Thelwood	Ralph	Wolf	Phillips	Henshaw
1991	1,000	300			98
1992	2,500	1,300		750	
1993	3,220	965			
1994	3,975	2,100			
1995	4,915	2,620	800	800	
1996	2,300	450	450	500	
1997					
1998					
1999					
2000	2,840	1,175		148	
2001	2,501	420	361	132	4
2002	3,374	724	228	111	24
2003	3,032	532	170	65	7
2004	2,590	910	576	109	78
2005			335	94	
2006	3,105	650			5
2007	3,921	690			42
2008	4,408	1,103	1,250	162	24
2009	4,128	1,181	1,210	624	93
2010	4,892	708	1,590	540	27
2011	1,123		140	106	
2012	3,164	479	192	145	
Total	56,988	16,307	7,302	4,286	402
Average	3,166	959	609	306	40

Ministry staff swam Thelwood Creek in 1998 and 1999 to enumerate spawning cutthroat trout in that system (Table 7). The highest number of spawning cutthroat trout were seen in April (mean = 72).

TABLE 7. Total number of cutthroat observed in snorkel surveys of Thelwood Creek (N=456) February 1998-June 1999 (Source: FLNRO files, Nanaimo).

Year	Date	Number Observed
1999	03-Feb	6
1998	27-Feb	69
1999	10-Mar	21
1998	01-Apr	87
1999	14-Apr	51
1998	30-Apr	77
1999	04-May	70
1999	28-May	38
1998	02-Jun	37

MJ Lough Environmental Consultants conducted an assessment of cutthroat trout spawning habitat in tributaries to Lower Campbell Lake in 2000⁶ (Lough, 2000). These investigators conducted snorkel surveys in 14 tributaries to the Ladore Reservoir and tributaries to the Strathcona Reservoir between March and May, 2000. Cutthroat trout redds were found in 6

⁶ Additional information on spawning in the Elk River is provided in the Upper Campbell Lake section of this report.

Strathcona tributaries when they were surveyed during late March and early April. Lough (2000) identified the Elk River and Thelwood Creek as among the most important spawning tributaries for cutthroat trout in this watershed (Figure 7).

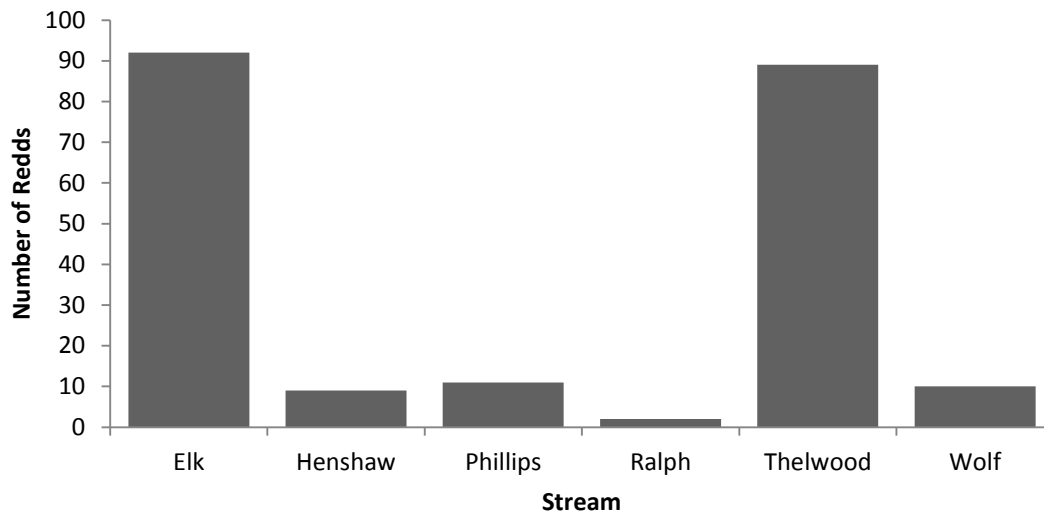


FIGURE 7. Number of cutthroat trout redds identified in each of the tributaries to the Strathcona Reservoir, as determined from field surveys during March and April 2000 (N=213); see the Upper Campbell Lake section of this report for more information on spawning in the Elk River (Reproduced from Lough, 2000).

Lough et al (2003) conducted snorkel surveys of tributaries to the Buttle, Upper and Lower and Comox Lake in response to Dolly Varden conservation concerns raised by the Ministry of Water, Land and Air Protection (MLAP) in 2003. Henshaw, Marblerock, Phillips and Price Creeks and Ralph, Thelwood and Wolf Rivers were assessed.

Lough et al (2003) found that spawning activity varied between streams but generally occurred between mid-October and early December, however, some adult migrants moved into the streams by mid-September. Peak counts in Thelwood and Price Creeks were in early November. This study, as well as a previous study by Lough and Hay (2001), found that Dolly Varden migrate from the lake into the small ephemeral spawning streams when flows are increasing and temperatures are declining (8°C-4°C). A total of 24 sexually mature Dolly Varden were sampled from the spawning population in the Thelwood River. Spawning males had a mean length of 35 cm and females had a mean length of 31 cm (Lough, et al, 2003).

Length and Weight

We've presented the minimum, maximum and mean length and mean weight of cutthroat and rainbow trout and Dolly Varden captured in gillnets in Buttle Lake by decade in Table 8 and individual data for each sample year, length frequency distributions and length weight relationships in Appendix 10.

The minimum size of cutthroat trout has ranged from 190 mm to 330 mm, the maximum size has ranged from 355 mm to 490 mm and the mean size has ranged from ~287 mm to 357 mm (Table 8). In the 1970's and the modal size of cutthroat was 230 mm but that increased to 390 mm in 2000's. Cutthroat trout have ranged from 215 g in the 1960's, to ~480 g in the 2000's.

The minimum size of rainbow trout has ranged from 150 mm in the 1970's, to 200 mm in the 1980's. The maximum size ranged from 290 mm in the 1960's, to 380 mm in the 2000's, while the mean size has ranged from 212 in the 1960's, to ~280 mm in the 1980's and the modal length has stayed relatively constant at ~220 mm. The mean weight of rainbow trout has ranged from 105 g to 380 g over the sampling period.

The minimum size of Dolly Varden has ranged from 140 mm to almost 200 mm, the maximum size has ranged from 245 mm to 445mm and the mean size has ranged from 222 mm to ~290 mm since the 1950's. The modal length of Dolly Varden has ranged from ~235 mm to 275 mm and the weight has ranged from <150 g to ~270 g over the past five decades.

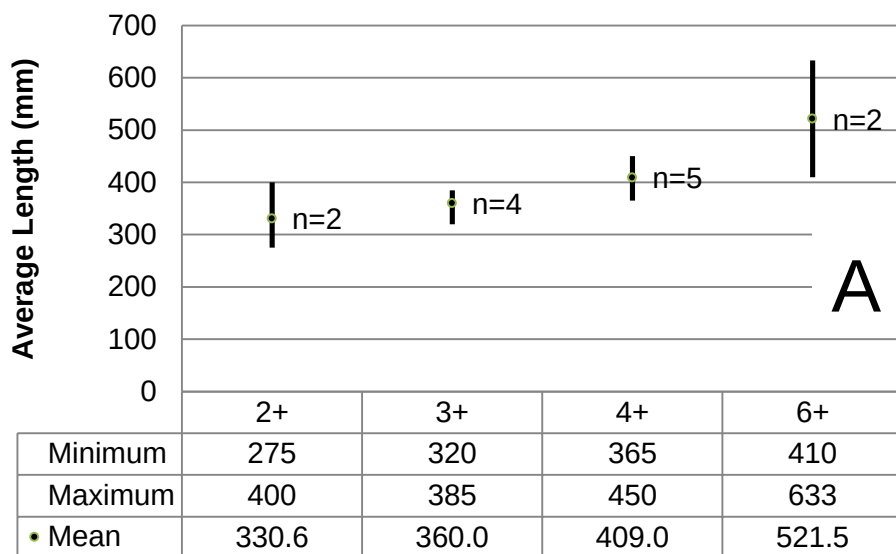
TABLE 8. Minimum, maximum, mean and modal length and mean weight for cutthroat and rainbow trout and Dolly Varden captured in gillnets in Buttle Lake by decade 1950 – 2000. Note, in the 1950's, 1960's and 1970's there were some years for which only total number of fish sampled and mean lengths were provided; see Appendix 10 for details on individual year totals) (Source: FISS; FLNRO files, Nanaimo).

Species		N	Length (mm)		Mean	Mode	Weight (g)
			Minimum	Maximum			Mean
Cutthroat	1950	26			357.0	-----	
	1960	11	240	355	295.0	305	215.0 - 610.0
	1970	43	190	430	286.7 - 301.0	230	
	1980	14	250	490	333.9	250	343.3
	1990	13	228	436	328.3	316	377.7
	2000	6	330	390	364.2	390	478.3
Rainbow	1950	37			266.0	-----	
	1960	471	165	290	212.0 - 221.0	220	105.0-380.0
	1970	39	150	310	215.0 - 247.0	200	
	1980	85	200	355	276.7	290	237.2
	1990	103	150	335	259.7	220	201.4
	2000	26	165	380	272.9	215	242.6
Dolly Varden	1950	3			222.0	-----	
	1960	34	195	245	220.0 - 253.0	-----	127.5
	1970	46	140	390	236.8	270	
	1980	60	174	390	272.2	250	258.2
	1990	87	190	445	289.0	234	317.0
	2000	15	175	335	279.3	275	267.8

In addition to reviewing lengths of fish captured in gillnets in Buttle Lake, we also wanted to determine if there was a difference in the mean lengths of fish captured by anglers. We found that anglers caught cutthroat trout that averaged 320 mm in the 1980's, vs. cutthroat that averaged 260 mm in the 1990's. Unfortunately, we only had data from the two decades to compare and so cannot make any statement regarding changes in size of cutthroat targeted by anglers (Appendix 10).

Age and Growth

Cutthroat trout caught in gillnets or angled in 1951 and 1954 were aged and we've provided summaries of the ageing data in Figure 8A. The mean size of the two 2+ cutthroat sampled was ~330 mm while the four aged 3+ cutthroat averaged 360 mm. Five aged 4+ cutthroat were sampled and they averaged ~400 mm. In 1951, one aged 6+ cutthroat was sampled and it was 410 mm, while in 1954, one aged 6+ cutthroat was sampled and it was 633 mm. Together these fish averaged 521 mm.



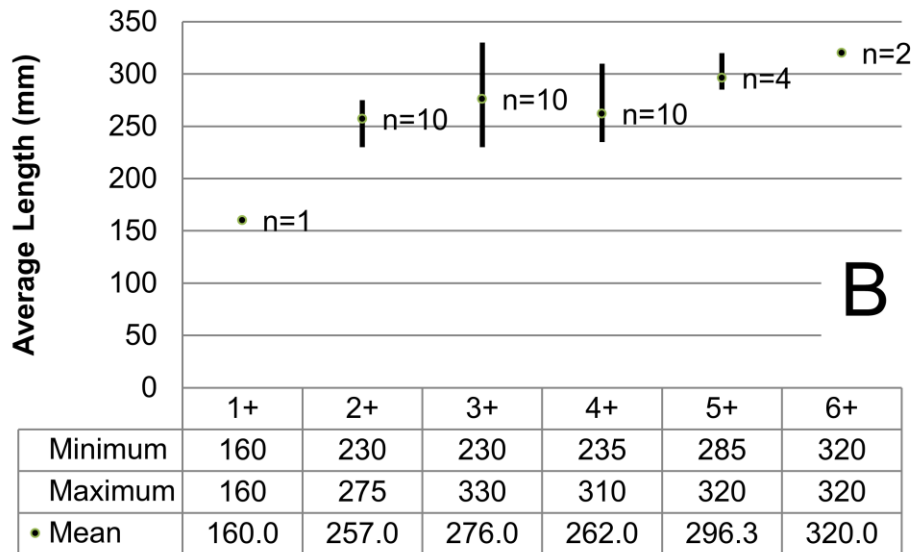


FIGURE 8. Length-at-age of (A) cutthroat sampled in gillnets in 1951 and 1954 (N=20) and (B) rainbow trout sampled in gillnets in (N=37) in Buttle Lake (Source: FLNRO files, Nanaimo).

There is considerable variability in the aging data – especially for 2+ cutthroat which range from 275 mm to 400 mm (Figure 8A). Given we don't see young fish during the Buttle Lake snorkel surveys it's likely that juveniles don't rear in the tributaries but recruit to Buttle Lake in the late summer when they are <60 mm and ~1+ year old. If this is the case, cutthroat 150 mm – 200 mm are likely 2+ years old, and fish 250 mm – 300 mm are 3+ years old which is consistent with the situation for other Vancouver Island large lakes (Appendix 9).

Thirty-seven rainbow trout were aged in 1951 (Figure 8B). One age 1+ fish was 160 mm while ten aged 2+ rainbow averaged 257 mm. Ten aged 3+ rainbow averaged 276 mm. The ten aged 4+ fish averaged 262 mm. There were four aged 5+ rainbow that averaged 296 mm and one aged 6+ fish that was 320 mm. Unfortunately, as with the cutthroat data, there is considerable variability in the rainbow trout aging data, especially for fish aged at 3+ (230 mm – 330 mm).

Only 3 Dolly Varden were captured and aged in 1951. The only age 1+ Dolly Varden was 165 mm while the age 2+ fish averaged 250 mm (Table 9).

TABLE 9. Age, fork length and mean fork length (mm) of Dolly Varden captured in gillnets in Buttle Lake in 1951 (N=3) (Source: FLNRO files, Nanaimo).

Age	N	Fork Length (mm)	Mean Fork Length (mm)
1	1	165	-----
2	2	180	250
		320	

Lough et al (2003) constructed a length-weight relationship of spawning Dolly Varden sampled from the Thelwood River in 2001 (Figure 9). Mature Dolly Varden (~280 mm - 300 mm) averaged ~200 g, while larger fish (i.e. up to 400 mm) averaged ~600 g.

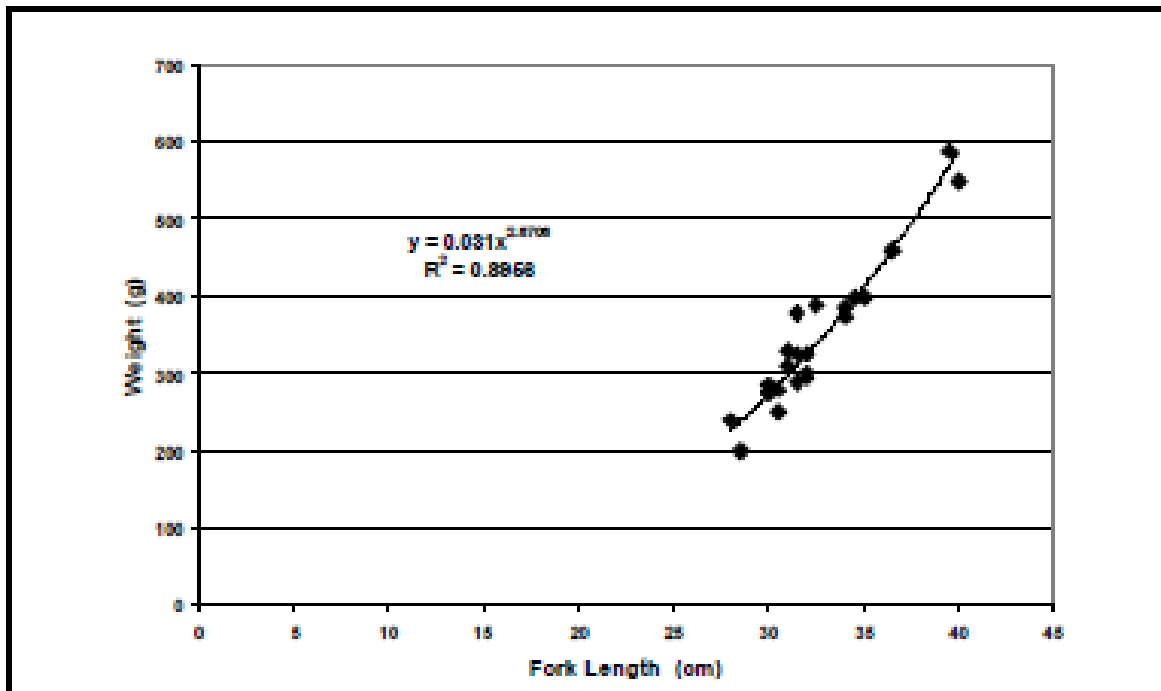


FIGURE 9. Length-weight relationship of spawning Dolly Varden sampled from the Thelwood River on November 1, 2001 (Reproduced from: Lough et al, 2003).

Catch Indicators

Total Catch

Individual data for gillnet catches for each sample year is provided in Appendix 10. Unfortunately, we're unable to compare catch indicators as no information on the number of gillnets used, the number of net sets or net locations, or soak times was provided for any sample.

Data Gaps

There is no data on angler preferences and no hydroacoustic surveys have been completed at Buttle Lake (Table 10). Lake and stream inventories, water quality and electrofishing surveys are >10 years old. Angler creel surveys and instant counts and gillnetting data are <10 years old and snorkel surveys are completed annually to monitor rainbow trout populations.

TABLE 10. Summary of data gaps for Buttle Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Lake Inventory		X	
Water Quality/Lake Productivity		X	
Stream Inventory (general)		X	
Level 1&2 WRP Surveys		X	
Fish Assessment (streams)		X	
Electrofishing Surveys (streams)		X	
Snorkel Surveys*	X		
VILQ	X		
Angler Creel Survey** & Instant Counts (effort)	X		
Angler Preferences			X
Gillnetting***	X		
Acoustic Surveys			X

*snorkel surveys of Buttle Lake tributaries are done annually by BC Conservation Foundation and the Ministry; surveys are currently funded by BC Hydro.

** a box creel has been run by Fish and Wildlife for 3 years; data on catch and harvest is on file.

***gillnetting may be done by NVI Mines; data is kept with the Mine.

5.0 Fisheries Objectives and Management Strategies for Buttle Lake

Existing Regulations

Buttle Lake is covered by the Region 1 general quota of four trout/char per day but not more than 1 > 50 cm. All wild trout and wild steelhead from streams and all Dolly Varden must be released. There is a single barbless hook regulation and bait ban for all streams all year.

Buttle Lake tributaries are fly fishing only except for Thelwood Creek which is closed all year.

Maximum Catch and Effort, Harvest and Yield at Current Regulations

We were unable to estimate maximum and optimum angler effort and catch as there is considerable variability in the relationship between these statistics ($R^2 < 0.5$) (Appendix 10). Current yield is well below predicted yield based on MEI (Appendix 8), and the harvest rate at Buttle Lake is ~25%.

Fisheries Objectives and Management Strategies and Operational Management Plan for Buttle Lake

Total catch at Buttle Lake declined by >10% and although angler success has remained somewhat constant over the past decade, angler success rate declined by ~10% between 2006 and 2011. In addition, although angler success exceeds the regional objective of 1.6 fish/day, the success rate at Buttle Lake has been below the long term average of 3 fish/day.

The mean length of cutthroat and rainbow trout captured in gillnets has remained stable over the past five decades and, with the exception of 2012, more rainbow trout have been observed in snorkel surveys in this decade compared to previous decades. It would be worthwhile to determine if the size of angler-caught fish of either cutthroat or rainbow trout has declined, and to collect more information on angler effort and determine if effort is different at different locations on this lake.

We recommend contacting NVI Mines to determine if there is recent gillnetting data that can be shared with the Ministry, monitoring the Buttle Lake fishery using the VILQ, establishing a partnership with Campbell River Fish and Game (CRF&GA) and implementing gillnetting surveys starting in 2015 (Table 16; Chapter 1), and angler creel and preference surveys in the future (Table 11). We also suggest implementing an angler education program to advise anglers of current regulations, and a general public awareness program in partnership with BC Parks to provide information on the stocks and fisheries of Buttle Lake.

1. Determine if there is gillnetting data available from NVI Mines; analyze data and compare results to Ministry data to update stock status information.
2. Implement a gillnetting survey in 2015 with volunteers from CRF&GA.
3. Conduct angler creel and angler preference surveys in the future with volunteers from CRF&GA.
4. Implement a public awareness program to advise anglers of regulations at Buttle Lake.
5. Implement an angler and public education program within Strathcona Park. This program should include signs outlining the life history characteristics of species found in the lake, characteristics of the Buttle Lake stocks and fishery. We recommend these signs be placed at all campgrounds, boat ramps, at the park entrance and at the Thelwood bridge. We also suggest an underwater fish viewing facility be constructed at either Thelwood Creek or Ralph River to increase public awareness of Buttle Lake fish species.

TABLE 11. Operational Management Plan for Buttle Lake.

Activity	Objective	Tentative Schedule
Monitor Fisheries Statistics	Monitor using VILQ; follow procedure outlined in Figure 15 Chapter 1 if there have been changes by >10% in three or more parameters for cutthroat and rainbow trout. If not, implement gillnetting surveys according to Table 16 Chapter 1.	2014
Long Term Monitoring	Implement gillnetting program to monitor Buttle Lake stocks with the Campbell River Fish and Game Association; design and implement angler creel and angler preference surveys in the future. We also suggest implementing an instant angler-count program to gain precision on angler effort.	2015
Education Program	Implement a public and angler awareness program in Strathcona Park; construct an underwater viewing facility at Thelwood Creek or Ralph River.	2017

Chapter 4. Comox Lake

Lake	Comox
Planning Unit	Campbell Oyster
Watershed	Puntledge
Surface Area (ha)	2,100
Mean Depth (m)	61
Key Tributaries	Upper Puntledge and Cruickshank Rivers, Comox and Rees Creeks
Freshwater Fish Species	Cutthroat Trout, Rainbow Trout, Dolly Varden, kokanee
Limits to Production	Water Withdrawal, Forestry
Regional Priority*:	2
<u>Angling Statistics 2011</u>	
Angling Effort	6,530 angler days
Total Catch	8,757 fish
Angler Success (catch/day)	1.3 fish/angler day
Current Harvest Rate	35%
Optimum Sustainable Effort	6,500 angler days/year
Optimum Sustainable Catch	8,000 fish
Angler Success at Optimum	1.2 fish/angler day
Stock Status	~ 90% of cutthroat trout captured in gillnets in 2009 and 2010 were <300mm and immature; mean size of immature cutthroat in Comox Lake is 225 mm. Rainbow trout and Dolly Varden are also present in the fishery; a hydroacoustic survey conducted in 2009 estimated at ~10 million fish with only age 1+ fish sampled.
Data Gaps	Juvenile densities in streams and on lake shoal habitats; densities of stocked coho in tributaries.
Management Objectives Summary	Monitor changes in the fishery and stock status to determine effects of regulations changes; implement juvenile assessments.
Operational Plan Priorities	Monitoring and tributary habitat enhancement where possible.
Potential Partners	Courtenay Fish and Game Association, BC Hydro, TimberWest, DFO

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Comox Lake Watershed

General Information

Comox Lake lies within the Coastal-Douglas Fir biogeoclimatic zone in the Campbell Oyster Planning Unit (PU) ~6 km west of Courtenay (Figure 1). This lake sits at an elevation of 138 m, has a surface area of 2,100 ha, a perimeter length of 41.4 km and is, on average, 61 m deep (Table 1). Much of the flow into Comox Lake is glacial in origin and while surface temperatures can exceed 20°C in the summer, hypolimnion temperatures remain between 5° - 6° C throughout the year (Ministry of Environment, 2009).

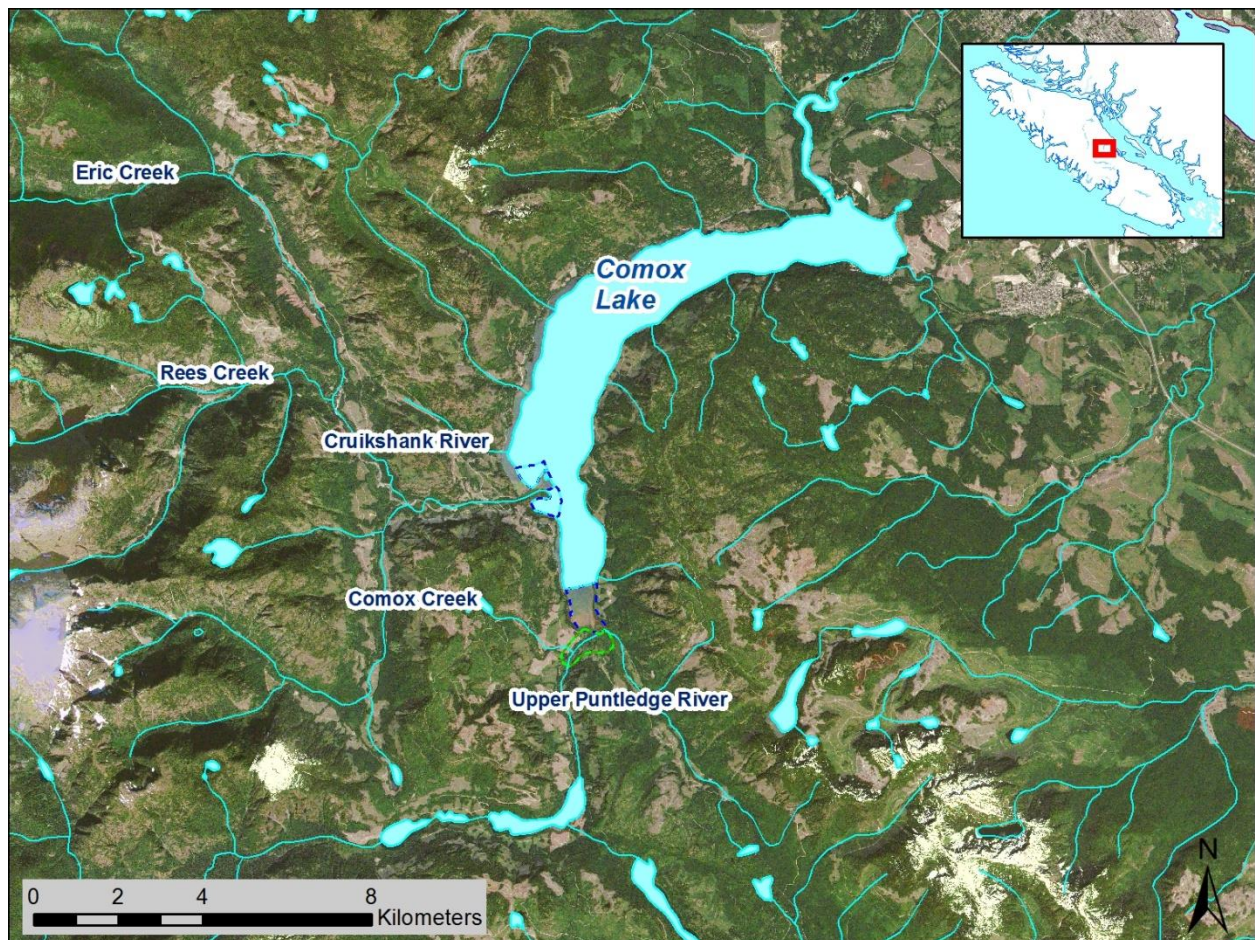


FIGURE 1. Map of Comox Lake and tributaries; bathymetric profile of this lake is provided in Appendix 11. (Source: FLNRO files, Nanaimo)

Comox Lake was assessed by Provincial Fisheries staff in 1948, 1951, 1975, 1980 and 1990 (Table 1). With a TDS of 22 ppm, Comox Lake is oligotrophic like all other large lakes in the region. Comox Lake has a pH of 7.1, and a secchi depth of 10 m.

TABLE 1. Location, size, depth and water quality parameters at Comox Lake (Source: FLNRO files, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
Campbell Oyster	01005COMX	2,100	40.7	109	61	7.1	22	10.0	1948, 1951, 1975, 1980, 1990

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Tributaries

Major tributaries to Comox Lake include the Cruikshank and Upper Puntledge River systems and Perseverance and Toma Creeks (Table 2). The Cruikshank and Upper Puntledge Rivers are both 4th order streams while Perseverance and Toma Creeks are small 3rd order tributaries. The 1st and 2nd order tributaries to these systems are unusable or inaccessible by fish due to excessive gradients (Russell, et al., 1990).

Most of the flow from the Cruikshank River and a significant portion of the Upper Puntledge is glacial in origin and a reconnaissance survey found that flow in the Cruikshank system varied between 20% – 30% of Mean Annual Discharge (MAD) (Russell, et al, 1990). Much of the Cruikshank and Upper Puntledge systems are relatively steep, high-velocity habitat contained by narrow, mountainous valleys and very few small, headwater tributaries that are available to lake resident fish for spawning and rearing (Russell et al., 1990). The Cruikshank tributaries of Comox, Rees and Eric Creeks along with the Upper Puntledge River are of considerable value to the system for rearing cutthroat and recent investigations by Lough et al (2011a) revealed the Upper Puntledge River is also a valuable spawning habitat for cutthroat trout. The Upper Puntledge River above Comox Lake may also be the main spawning tributary for Dolly Varden and kokanee salmon (Russell et al., 1990).

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Comox Lake (Source: Russell et al., 1990; Griffith, 1995).

Tributary	Stream Order	Length (km) and/or Drainage Area (km ²)	Other Information
Comox Creek	3 ⁰	~ 7 km to barrier	Gradient varies from 1.6% to 3%.
Cougar Lake Tributary	2 ⁰	~ 3 km	Gradient ~ 10%
Cruikshank River	4 ⁰	~ 17 km to barrier; 214 km ²	Gradient varies between <1%-8%.
Eric Creek	3 ⁰	~ 6 km to barrier	Gradient varies between 1.9%-2.7%
Kweishun Creek	2 ⁰	~ 2 km	Gradient ~ 7%
Perseverance Creek	3 ⁰	22 km ²	1 ⁰ and 2 ⁰ tributaries to this creek are unusable or inaccessible due to excessive gradients (Russell, et al., 1990).
Rees Creek	3 ⁰	~ 5 km to barrier.	Gradient varies between 1%-4%
Toma Creek		22 km ²	1 ⁰ and 2 ⁰ tributaries to this creek are unusable or inaccessible due to excessive gradients (Russell, et al., 1990).
Upper Puntledge River	4 ⁰	~ 13 km to barrier; 96 km ²	Gradient varies between <1%-1.6%.

Species Composition

Cutthroat and rainbow trout, Dolly Varden, steelhead, Chinook and kokanee salmon are found in Comox Lake as are coast range sculpin and threespine stickleback. Historically, the upper watershed appears to have been primarily the domain of summer steelhead, Chinook salmon and resident trout and char, while winter steelhead, coho and other anadromous salmonids were apparently restricted to the lower watershed (Rimmer et al, 1994). Both the Cruikshank and Upper Puntledge River systems contain cutthroat, rainbow, Dolly Varden, sculpins and stickleback.

From 1921 until 1954 the lake was stocked with cutthroat trout, rainbow trout, Atlantic salmon and brook trout. Puntledge River steelhead fry were released into the Cruikshank system in 1982 and 1985 (Russell et al., 1990). DFO stocks coho salmon, which are not thought to have been present historically in Comox Lake (Rimmer et al, 1994) into the lake and tributaries, with the exception of Comox Creek and the Upper Puntledge River.

Summary of Work and Reports

Comox Lake was surveyed in 1948 and 1951 by the B.C. Game Department and again in 1975 by Fish and Wildlife Branch; data collected is provided in two reports available in the Fish and Wildlife files in Nanaimo. Over the years, MOE completed three detailed habitat inventory and fish assessments of Comox Lake and tributaries. In 1977, Caw documented fish habitat in Cruikshank River and tributaries, in 1989, Russell et al (1990) conducted habitat surveys and fish assessments of the same streams, and in 1995 Griffith completed a detailed watershed assessment including conducting fish assessments in a number of Comox Lake tributaries.

Between 2009 and 2011 the Courtenay and District Fish and Game Protective Association (CDF&GPA) funded and assisted Ministry staff in implementing a fish and fisheries assessment of Comox Lake. Detailed reporting of this study is provided in Michalski, 2011a. As part of this

study, Johnner and Sebastian completed a hydroacoustic survey in 2009 to assess the pelagic fish population of Comox Lake.

Lough and Associates conducted a detailed assessment of cutthroat trout spawning including identifying peak spawning times and locations in Comox Lake tributaries and estimating the cutthroat escapement in 2011. Results of this study can be found in Lough et al, 2011b, while results of the follow-up monitoring conducted in 2012 can be found in the Fish and Wildlife files in Nanaimo. Electrofishing assessments by Lough and Associates and funded by the Fish and Wildlife Compensation Program (FWCP) of BC Hydro were ongoing at the time of this report. A final project report from this study will be available on the BC Hydro web site at:

http://www.bchydro.com/about/sustainability/environmental_responsibility/compensation_programs.html?WT.mc_id=rd_bcrp

Some Water Survey of Canada (WSC) data is available for the Cruikshank (08HB074) and the Lower Puntledge River just below the dam (8HB007) (Russell, et al, 1990). In 2011, the Environmental Protection Division of MOE concluded a detailed water quality survey at the lake and this report is available on-line at:

<http://www.env.gov.bc.ca/wat/wq/comox/comox-overview-may2011.pdf>

2.0 Limits to Fish Production

Water Withdrawal

An impoundment dam was constructed at the outlet of Comox Lake in 1868 to supply water and power to Canadian Collieries and the coal mines in central and eastern Vancouver Island. The dam was replaced in 1912 and reconstructed in 1956 and 1982 by BC Hydro. The present structure is a 10 m high, 100 m wide concrete and earthen-filled dam and the diversion dam is a 3.5 m high, 30 m long, concrete structure. Both dams were furnished with rebuilt fish ladders in 1955-56, and the main dam was raised by five meters in 1981 to accommodate maximum water levels.

Water levels in Comox Lake are now controlled by the Comox Dam which is operated according to the BC Hydro Water Use Plan (WUP) for the Puntledge River System (BC Hydro, 2002). The Bridge Coastal Fish and Wildlife Restoration Program reviewed the impact of the dam in 1994 and concluded that the current spring drawdown strands fish and reduces access to tributary and wetland habitat, and that the dam has caused a loss of instream, lake, riparian and upland habitats. A fishway into Comox Lake was installed as part of the original dam construction and although extensive use by fish has not been documented, the sporadic occurrence of Chinook and chum salmon in Comox Lake tributaries testifies to its occasional use.

Water Licences and Operational Constraints

The formal agreement between DFO and BC Hydro has been informally modified in attempts to benefit both fisheries and power generation. From November through February, the minimum flow below the diversion dam is in effect and provides barely adequate coverage for summer-run Chinook spawning, but is insufficient for steelhead to ascend Stotan Falls (FLNRO files, Nanaimo). From March to June, BC Hydro provides flow below the diversion and draws down Comox Lake if refill forecasts are favourable. From June to August, flows below the diversion are to minimize pre-spawning adult injuries at Stotan and Nib Falls. BC Hydro normally reduces

flows to reduce draws on Comox Lake and lowers flow into the Puntledge River after mid-August when summer-run Chinook have completed their in-migration.

Logging

Extensive logging continues around the watershed and in the higher elevation of both the Cruikshank and Upper Puntledge Rivers. Logging also continues in the higher elevation areas of both the Cruikshank and Upper Puntledge Rivers. There is evidence of sand and silt from logging and road building throughout the length of the Cruikshank and these impacts may account for the depressed juvenile cutthroat trout production suggested by Russell, et al (1990). Direct impacts from logging in the Upper Puntledge watershed are probably reduced because of the buffering effects of Blue Grouse and Willmar Lakes which are located higher in the system. The Upper Puntledge downstream of these lakes has many log jams throughout its length and at least one of these log jams may impede fish migration.

Fish Stocking

DFO established a hatchery on the Puntledge River near Courtenay in 1977, and constructed a spawning channel adjacent to the powerhouse in 1990 to build a fall-run of Chinook and coho salmon, and steelhead stocks (Sigma Engineering Ltd 1990).

An agreement between DFO and MOE on stocking levels and locations was reached in November, 1989. This agreement stipulates a coho stocking strategy for the Comox Lake watershed and specifies that Forbush and Willemar Lakes be stocked with <1,500 fry/ha; Comox Lake spring out-plants be reduced; and Comox Creek be dropped from all coho colonization stocking plans and identified as a cutthroat trout sanctuary (Law, 1989). As of 2010, coho stocking in Rees Creek, the Cruikshank and Upper Puntledge River was continuing. In 2010 and 2011, there were several coho releases totalling ~1.3 million fish each year but in 2012 numbers of coho releases were reduced to ~800,000 (Miller, D., 2012, pers. com.). Also in 2012, DFO agreed to a request by the Fish and Wildlife Branch to discontinue coho stocking in the Upper Puntledge River system.

Stream Habitat

Although some reaches of Comox and Rees Creeks and the Upper Puntledge River lack some important habitat components such as LWD, the most important factor limiting fish production in Comox Lake tributaries is nutrients (Caw, 1977; Michalski, 2011a). Russell et al (1990) provides a comparison of theoretical vs. actual fry production and, based on associated water quality data, also maintains that under-seeding of important streams in the Comox Lake watershed is due to a lack of nutrients.

Nutrients

Comox Lake is a naturally oligotrophic lake and nutrients are likely the major constraint to fish production. There are low levels of nitrate-nitrogen and phosphorous and low conductivity and total alkalinity in both Comox Lake and the Cruikshank River (Larkin and Vernon, 1948; Binns, 1982; Russell et al, 1990).

3.0 Angling Statistics

Angler Effort

Angler effort has varied between ~4,500 angler days in 1986, and 8,500 angler days in 1989 (Figure 2). In 2006 and 2011, angler effort was close to the long-term average of 6,400 angler days.

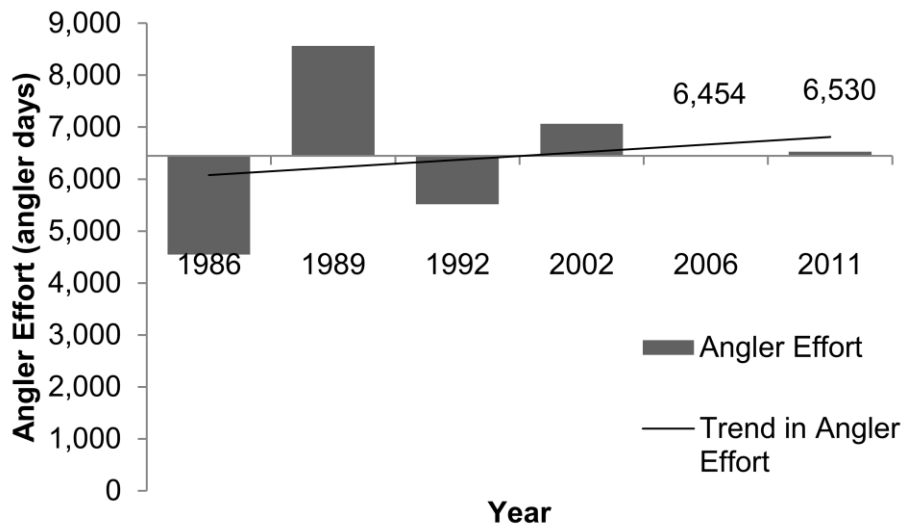


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 at Comox Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Volunteers participating in the CDF&GPA study conducted instant angler counts from April, 2009 until October, 2010 and based on that data angler effort at Comox Lake was estimated at ~5,600 angler days/year in 2009 and 2010 (Figure 3) (Michalski, 2011a). This is similar to the 6,454 angler days predicted by the VILQ for 2006 (Figure 2).

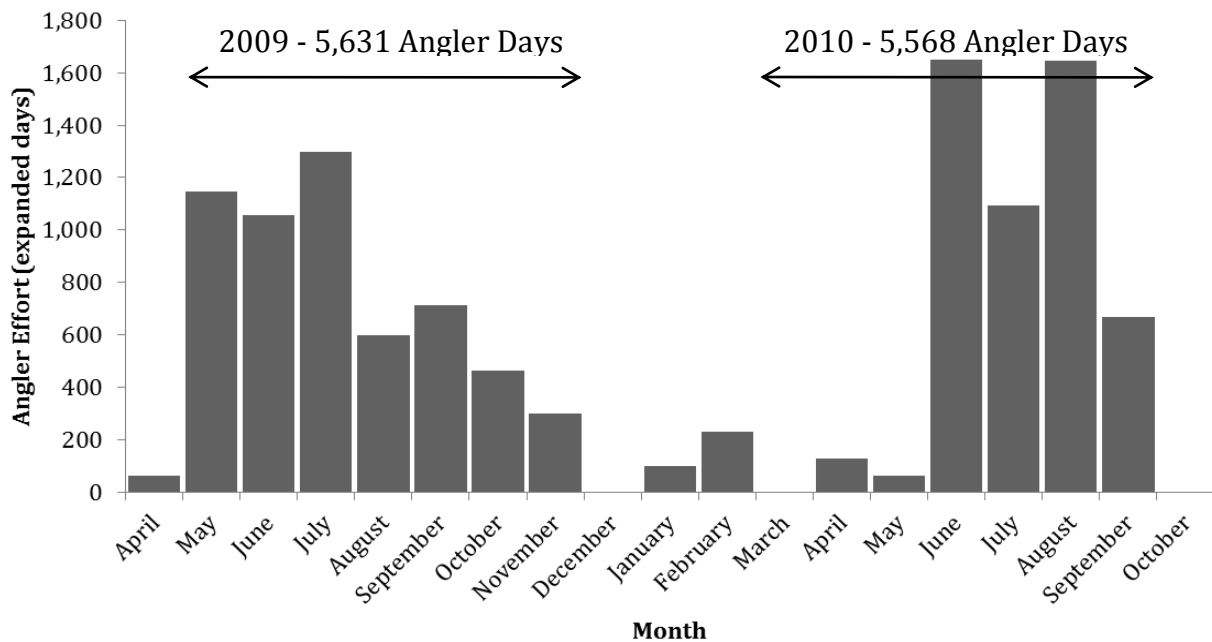


FIGURE 3. Expanded angler effort at Comox Lake April 2009 – October 2010. Expanded angler effort calculated using instantaneous angler counts conducted by Courtenay Fish and Game Club volunteers (Source: FLNRO files, Nanaimo).

Catch

Total catch at Comox Lake has varied from a low of ~5,000 fish in 1986, to 9,500 fish in 2002 (Figure 4). Catch dropped to 7,600 fish in 2006 but rose to ~8,000 fish in 2011 which is roughly the average catch over the 25 year VILQ. Overall, there is an increasing trend in angler catch at Comox Lake.

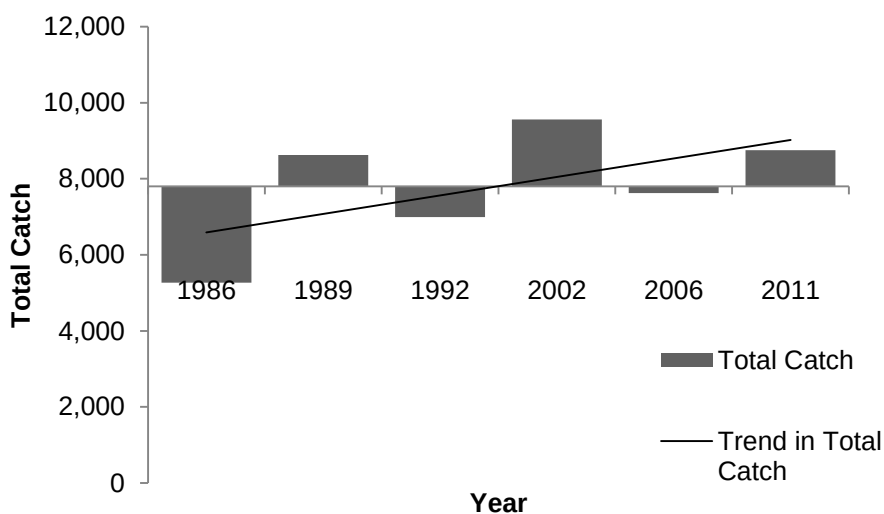


FIGURE 4. Total catch by year compared to average catch from 1986-2011 and trend in catch at Comox Lake 1986 – 2011 (Source: Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

According to the VILQ in 2006, 66% of the angler catch (~5,000 fish) was cutthroat trout, 23% (1,750 fish) was rainbow trout, and 11% (841 fish) was Dolly Varden (Table 3). In 2011, the catch of cutthroat was roughly the same at ~5,000 fish but the species comprised only 58% of the catch. That year, rainbow trout comprised ~33% of the catch (2,868 fish), and Dolly Varden comprised ~9% of the catch (807 fish).

TABLE 3. Catch of rainbow and cutthroat trout at Comox Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	5,034	66.0	5,082	58.0
Rainbow	1,750	23.0	2,868	32.8
Dolly Varden	841	11.0	807	9.2
Total	7,625		8,757	

We've provided angler catch data collected during the CDF&GPA study in Table 4. In 2009, cutthroat trout comprised 96% of the angler catch, and fish classified as trout comprised 4% of the catch. In 2010, cutthroat trout comprised 56%, while rainbow trout comprised 31% and fish classified as trout comprised the remaining 13% of the angler catch.

TABLE 4. Total and percent of catch by species at Comox Lake April 2009 – October 2010 (Source: angler interviews conducting following instantaneous counts conducted by Courtenay Fish and Game Club April, 2009 – October, 2010; FLNR files, Nanaimo).

Species	2009		2010	
	Catch (# of fish)	Percent of Total	Catch (# of fish)	Percent of Total
Cutthroat	87	96	25	56
Rainbow	0	0	14	31
Trout	4	4	6	13

Angler Success

According to the VILQ, angler success at Comox Lake has been stable at ~1.2 fish/day over the 25 year survey period (Figure 5). In 1986, angler success was about average at 1.2 fish/day but the success rate fell in the late 1980's to ~1 fish/day. Since that time, angler success increased to a high of almost 1.4 fish/day in 2002, then declined to 1.2 fish/day in 2006, and increased to ~1.3 fish/day in 2011. Overall, the trend in angler success at Comox Lake is increasing although it is still below our regional success objective of 1.6 fish/day.

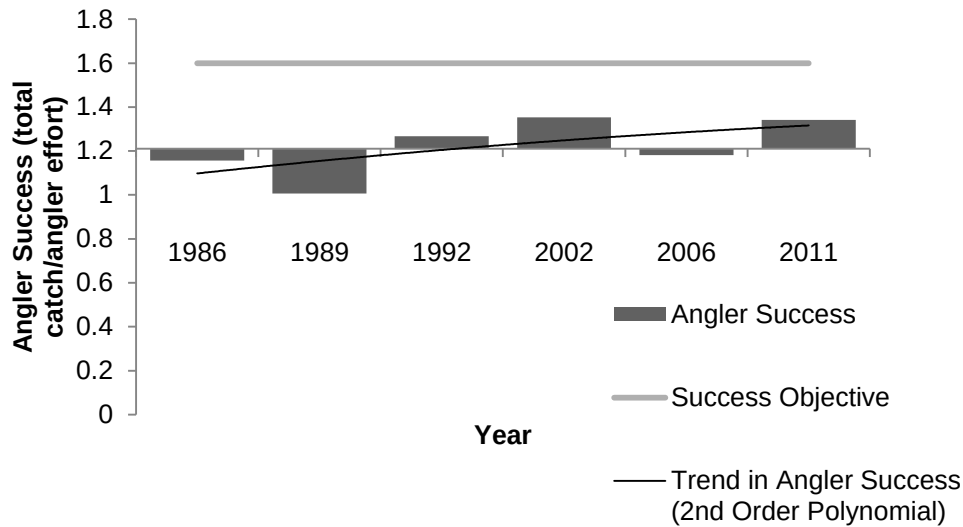


FIGURE 5. Angler success (total catch/total angler effort in angler days) compared to average angler success and the objective for angler success (1.6 fish/angler day) at Comox Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Estimates of angler success from the angler creel survey conducted during the CDF&GPA study suggest a much lower angler success rate does the VILQ. Angler success rates estimated from the angler creel survey data suggest an angler success of 0.64 fish/day in 2009, 0.38 fish/day in 2010 and an average angler success of ~0.52 fish/day over the 2-year survey (Table 5).

TABLE 5. Total catch, observed effort (instantaneous angler counts) and angler success (catch/angler day) by year from April, 2009 – October, 2010; note only catch by Fish and Game Club members that occurred on instant count days included. (Source: instantaneous counts and angler interviews conducted by Courtenay Fish and Game Club April, 2009 – October, 2010 and angler logs kept by Courtenay Fish and Game Club May – October, 2009; FLNRO files, Nanaimo).

Year	Total Catch	Observed Effort	Angler Success (catch/angler day)
2009	91	142	0.64
2010	46	120	0.38
Total	137	262	0.52
Average Angler Success	0.51		

Harvest

According to the VILQ, the harvest rate at Comox Lake was ~42% in 2006 and ~35% in 2011 (Table 6). However, harvest rates calculated from data collected by volunteers participating in the CDF&GPA study indicates that overall, anglers harvest 82% of their total catch and 90% of their cutthroat trout catch (Table 7).

TABLE 6. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Comox Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	% Harvest	Catch	Harvest	% Harvest
Cutthroat	5,034	2,386	47.4	5,082	1,949	38.4
Rainbow	1,750	693	39.6	2,868	1,142	39.8
Dolly Varden	841	91	10.8	807	-----	0.0
Total	7,625	3,170	41.6	8,757	3,091	35.3

TABLE 7. Total and percent of catch and harvest of each species caught by anglers and Courtenay Fish and Game Club Members at Comox Lake April, 2009 – October, 2010 (angler interviews conducting following instantaneous counts conducted by Courtenay Fish and Game Club April, 2009 – October, 2010 and angler logs kept by Courtenay Fish and Game Club May – October, 2009; FLNRO files, Nanaimo).

Species	Catch	Harvest	Harvest Rate (%)
Cutthroat	92	83	90
Rainbow	6	1	17
Trout	9	4	44
Total	107	88	82

In addition to finding high harvest rates of cutthroat trout generally, the CDF&GPA study also found that anglers were harvesting a high percentage of small (<300 mm) cutthroat trout (Figure 6; Appendix 11). In fact, almost 70% of the cutthroat harvested by anglers at Comox Lake were <300 mm. Cutthroat trout from large lakes on Vancouver Island mature at ~320 mm (Figure 9; Chapter 1) and the mean fork length of spawning cutthroat trout at Comox Lake is 390 mm (Lough, et al, 2011). As a result, most of the cutthroat trout harvested by Comox Lake anglers are immature.

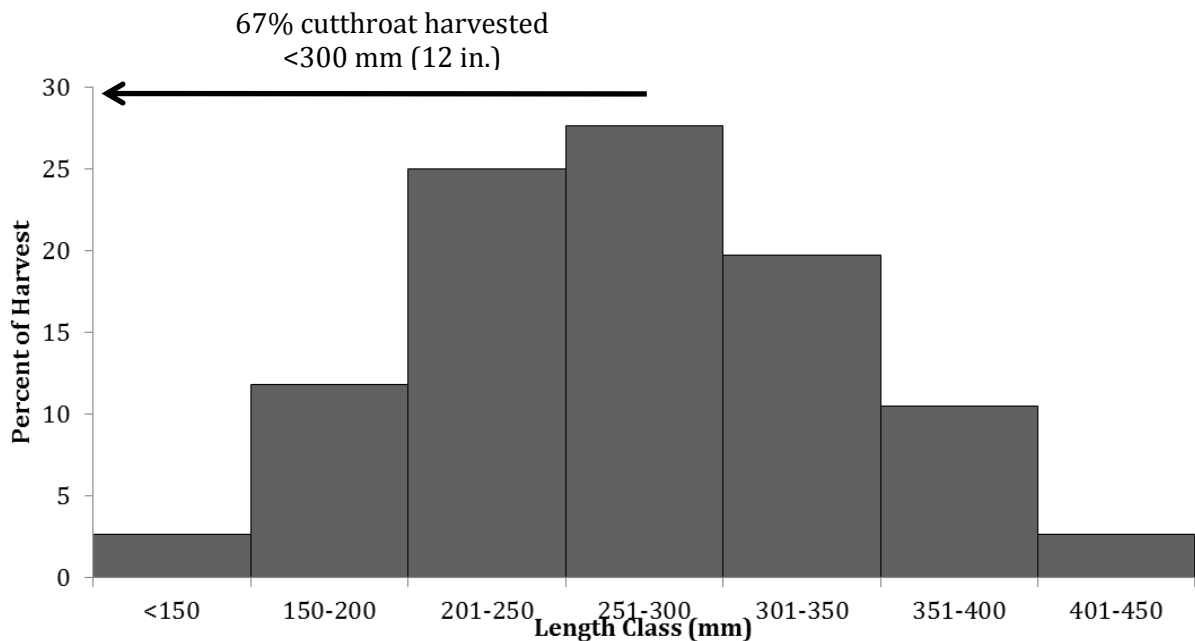


FIGURE 6. Length frequency diagram of cutthroat trout harvested by anglers at Comox Lake April, 2009 – September, 2010 (N=76); note that cutthroat trout in Vancouver Island large lakes mature at ~320 mm (see Figure 9, Chapter 1 for details) (Source: Michalski, 2011a).

4.0 Stock Status Indicators

Relative Abundance

Kokanee salmon, cutthroat and rainbow trout and Dolly Varden were sampled in gillnets in 1948, 1951, 1953, 2009 and 2010 and we've presented the relative abundance of these species in Figure 7. Gillnetting samples in 1948 revealed a predominance of kokanee and Dolly Varden with small numbers of cutthroat trout and smaller numbers of rainbow trout. Almost 50% of the gillnetted fish sampled in 1948 were kokanee, followed by 30% Dolly Varden, and 20% cutthroat trout.

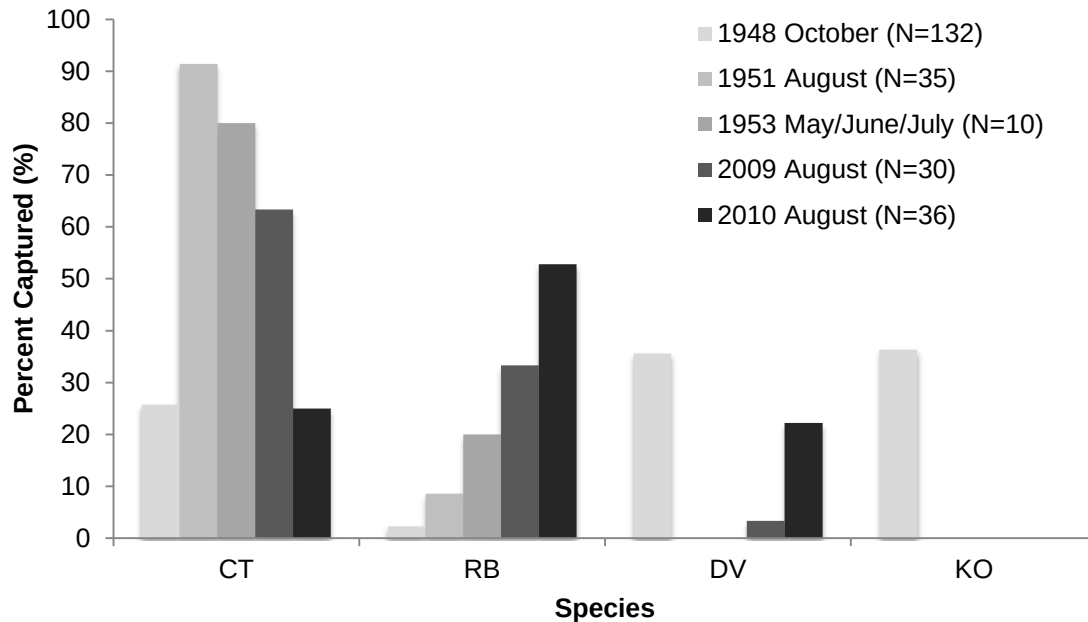


FIGURE 7. Percent cutthroat trout, rainbow trout, Dolly Varden char and kokanee captured in Comox Lake by gillnets in 1948, 1951, 1953, 2009 and 2010 (N=243) (Source: FISS and FLNRO files, Nanaimo).

In 1951 almost 90% of the sample of 35 fish was comprised of cutthroat trout with 10% of the sample comprised of rainbow. The proportion of cutthroat trout have decreased in the samples starting in 1951 when this species comprised ~80% of the sample, to 2009 when cutthroat comprised 60% of the sample and 2010 when cutthroat comprised only 20% of the sample. Conversely, the proportion of rainbow in the gillnetting samples has increased with that species comprising ~20% of the 1953 sample, 35% of the 2009 sample, and ~50% of the 2010 sample. It's likely that steelhead stocking by the Ministry, and releases of rainbow trout from the CDF&GPA trout pond located adjacent to Comox Lake have contributed to the increased numbers of rainbow trout in the lake.

Snorkel Surveys

Lough et al (2003) conducted snorkel surveys of the lower three km of the Cruickshank and the Upper Puntledge River, Kweishun and Comox and Rees as part of an investigation into the life history characteristics of Dolly Varden (Table 8). Swimmers found a few Dolly Varden adults had moved into the river by mid-September. In larger rivers such as the Cruickshank, Dolly Varden gather into aggregations of 10 - 15 fish near prospective spawning areas in the weeks prior to spawning. As spawning time approaches, these fish enter the small streams or proceed to the upper reaches of the mainstem. In the Comox Lake system, the spawning period probably ends toward the end of November but the last of the spawners probably remain in some areas like Rees Creek until early December (Lough et al, 2003).

TABLE 8. Peak counts of Dolly Varden spawners and redds observed during snorkel surveys from September 13 to November 26, 2001 (Reprinted from Lough, et al, 2003).

Stream	Peak Number of Spawners	Redds	Date
Comox Creek	0	0	Oct 29/01
Cruickshank River	5	1	Oct 29/01
Rees Creek	72	78	Nov 6/01

Length and Weight

We've provided a summary of length and weight data of fish captured in gillnets in Table 9 and detailed fish sampling data including length frequency distributions and length weight relationships in Appendix 11. Although the mean size of cutthroat has remained between 240 mm - 300 mm, the maximum size of this species declined from 560 mm in the 1950's, to 425 mm in 2000 and the modal length has shifted from 280 mm in the 1940's, to 210 mm in the 2000's. The mean weight of cutthroat has also decreased from ~400 g in the 1950's to 185 g in the 2000's. Also of concern is the percentage of larger cutthroat (>300 mm) captured in gillnet samples over the years. In the 1948 sample, cutthroat >300 mm comprised ~25% of the gillnet sample, whereas in the 2009, sample cutthroat >300 mm comprised ~2% of the sample (Appendix 11).

TABLE 9. Minimum, maximum, mean length and mean weight for cutthroat and rainbow trout and Dolly Varden captured in Comox Lake by gillnets by decade 1940 - 2000 (Source: FISS; FLNRO files, Nanaimo; Michalski, 2011a; Ministry files, Nanaimo).

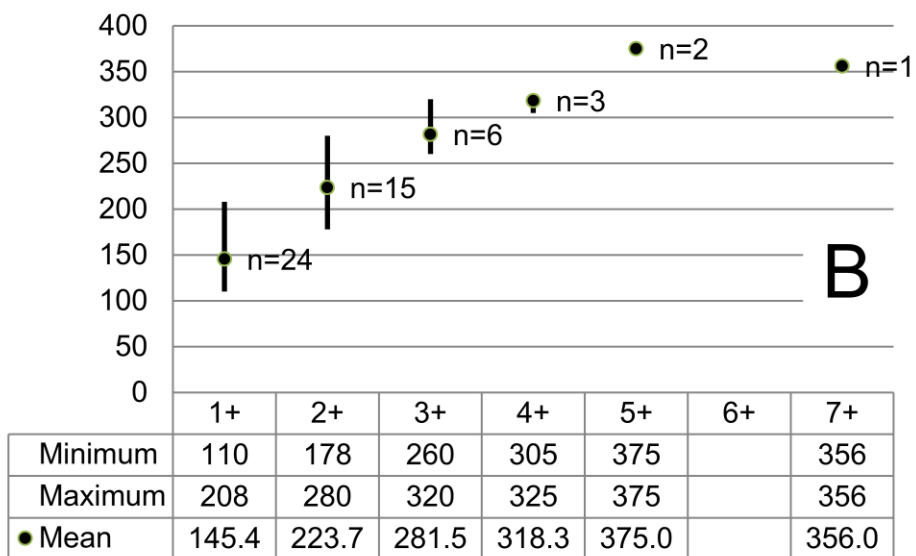
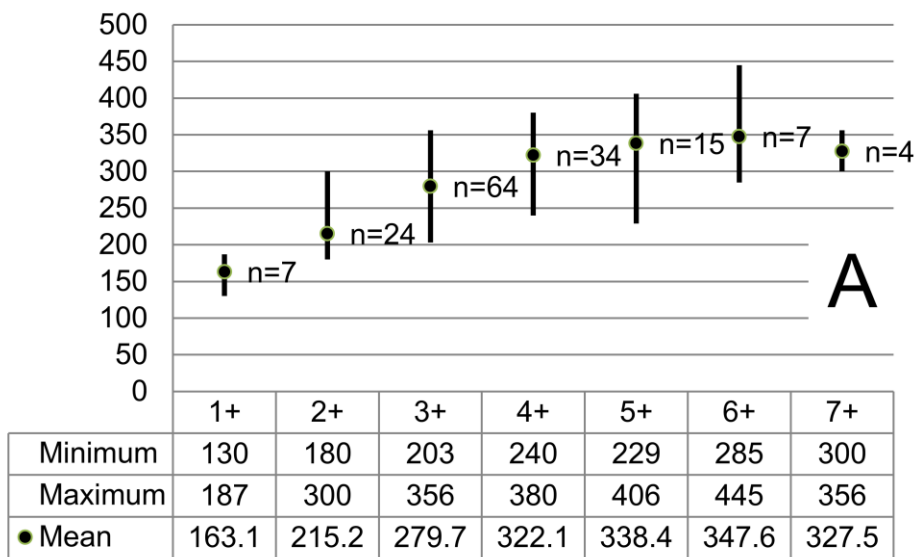
Species	Decade	N	Length (mm)				Weight (Mean) (g)
			Minimum	Maximum	Mean	Mode	
Cutthroat	1940	34	208	355	276.5	280	-----
	1950	40	165	560	313.5	255	407.5
	2000	28	130	425	239	210	185.0
Rainbow	1940	3	230	250	243.3	250	-----
	1950	5	155	330	255.4	-----	210.2
	2000	29	110	375	199.8	130	108.8
Dolly Varden	1940	47	195	380	254.4	210	-----
	2000	9	150	340	239.7	250	169.4

Although the minimum size of rainbow trout has decreased from 230 mm to 110 mm since the 1940's, the maximum size has increased from 250 mm in the 1940's, to 330 mm in the 1950's, to 375 mm in the 2000's. The mean size of this species has decreased over the decades from 243 mm to ~200 mm. The modal length has also shifted from 250 mm in the 1940's, to 130 mm recently, while the mean weight has decreased from ~210 g in the 1950's, to 108 g in the 2000's. Note the small sample sizes in the 1940's and 1950's make it difficult to draw comparisons to earlier decades.

The minimum size of Dolly Varden decreased from 195 mm in the 1940's to 150 mm recently, while the maximum size has decreased from 380 mm in the 1940's to 340 mm in the 2000's (Table 6). The mean size of this species has remained somewhat constant at between 240 mm and 250 mm over the past 50 years, while the modal length has increased from 210 mm in the 1940's, to 250 mm in the 2000's. Note that only nine Dolly Varden were captured in the 2009 and 2010 gillnet samples.

Age and Growth

We've presented length-at-age analyses for cutthroat trout captured in gillnets and by anglers in 2009 and 2010 in Figure 8A. Seven 1+ cutthroat were caught ranging from 130 mm - 187 mm and averaging 163 mm, 2+ cutthroat ranged from 180 mm - 300 mm and averaged 215 mm, 3+ cutthroat ranged from 203 mm - 356 mm and averaged ~280 mm, and 4+ cutthroat ranged from 240 mm - 380 mm and averaged 322 mm. Age 5+ cutthroat ranged from 229 mm - 406 mm and averaged 338 mm, age 6+ cutthroat ranged from 285 mm - 445 mm and averaged 348 mm. There were also four cutthroat aged at 7+ which ranged from 300 mm - 356 mm and averaged ~328 mm.



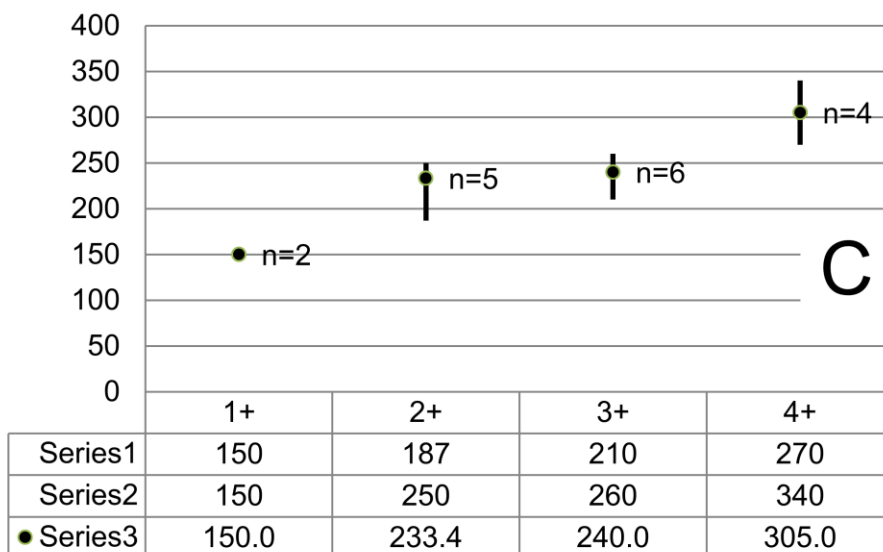


FIGURE 8. Length-at-age of (A) cutthroat trout (N=155), (B) rainbow trout (N=51), and (C) Dolly Varden (N=17) caught by anglers and in gillnets in 2009 and 2010 in Comox Lake (Source: FLNRO files, Nanaimo; Lough, 2009; Lough, 2010).

Fifty-one rainbow trout were also captured and aged in 2009 and 2010 (Figure 8B). Age 1+ rainbow ranged from 110 mm - 208 mm and averaged 145 mm, age 2+ rainbow ranged from 178 mm - 280 mm and averaged ~224 mm, age 3+ rainbow ranged from 260 mm - 320 mm and averaged ~282 mm, while age 4+ rainbow ranged from 305 mm - 325 mm and averaged ~318 mm. Two age 5+ rainbow averaging 375 mm, and one age 7+ rainbow 356 mm were also caught.

A total of 17 Dolly Varden were caught in 2009 and 2010 and aged. Age 2+ fish ranged from 187 mm - 250 mm and averaged 233 mm, age 3+ fish ranged from 210 mm – 260 mm and averaged 240 mm and age 4+ fish ranged from 270 mm – 340 mm and averaged 305 mm (Figure 8C).

Mean Age

Unfortunately, only four cutthroat were aged in the samples from the 1950's so we couldn't compare the mean age between decades. The mean length of the 157 cutthroat sampled from 2009 to 2010 was ~285 mm and the mean age was 3+ (Table 10). The mean length of the 52 rainbow trout sampled was 214 mm and the mean age was 2+ while the mean length of the 17 Dolly Varden captured was ~240 mm and the mean age was 2+.

TABLE 10. Mean length (mm) and mean age of cutthroat and rainbow trout and Dolly Varden captured in gillnets and by anglers in Comox Lake in 2009 and 2010 (Source: FISS; FLNRO files, Nanaimo; Lough, 2010, Lough, et al, 2011).

	N	Mean Length (mm)	Mean Age
Cutthroat	157	284.6	3+
Rainbow	52	214.4	2+
Dolly Varden	17	239.7	2+

Catch Indicators

Total Catch

Unfortunately, no information on the number of gillnets or the number of net sets or soak times was provided from the earlier gillnet samples so we can only compare total catch (Table 11) and relative proportion of the catch (Figure 7) between samples. Both comparisons show a decrease in the numbers of cutthroat and Dolly Varden, and an increase in the number of rainbow trout at Comox Lake over time.

TABLE 11. Total catch of cutthroat and rainbow trout and Dolly Varden captured in gillnets in Comox Lake 1948 – 2010 (Source: FISS; FLNRO files, Nanaimo).

Species	1948	1951	1953	2009	2010
Cutthroat	34	32	8	19	9
Rainbow	3	3	2	10	19
Dolly Varden	47	-----	-----	1	8
Total	84	35	10	30	36

Data Gaps

The detailed fisheries and stock assessment completed on Comox Lake in 2009 – 2011 provided recent fisheries and stock status data (Table 12). No angler preference survey was completed during this study, however, which is an important data gap given there was a change in regulations in 2012. In addition, electrofishing data is required to confirm the length of residence of juvenile fish in Comox Lake tributaries, and to determine coho stocking densities to establish if there are density-related impacts to wild cutthroat trout as a result of stocking practices.

TABLE 12. Summary of data gaps for Comox Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	< 10 years	>10 years	No data
Gillnetting	X		
Angler Creel Survey	X		
VI Lakes Questionnaire	X		
Snorkel Surveys	X		
Acoustic Surveys	X		
Electrofishing (streams) (not complete)	X		
Juvenile age, weight, density		X	
Lake/Limnology	X		
Stream Habitat Inventory	X		
Angler Preferences			X
Water Quality/Lake Productivity	X		
Kokanee Assessment	X		

5.0 Fisheries Objectives and Management Strategies for Comox Lake

Existing Regulations

The Fish and Wildlife Branch implemented a mandatory release of all cutthroat <300 mm in 2012. The rationale for this regulation was based on the results of the CDF&GPA study which established that anglers were harvesting high numbers of immature cutthroat trout. The objective of the minimum size limit is to insure that cutthroat will spawn at least once before entering the fishery.

The Ministry also extended the mandatory bait ban and single barbless hook and mandatory release of cutthroat >50 cm to cover the entire year. The extension of the maximum size limit ensures protection of remaining large cutthroat trout.

The region-wide regulation of 4 trout/day is still in effect at Comox Lake. The Cruikshank River is closed all year as are all tributaries to the Puntledge River. All wild trout and wild steelhead from streams and all Dolly Varden must be released.

Maximum Catch and Effort at Current Regulations

The maximum angler effort is ~13,000 days and the maximum catch is 10,500 fish while the optimum angler effort is ~6,000 angler days and the optimum catch is 8,000 fish (Figure 9). Note these values are based on VILQ data collected before the minimum size limit and year-long extension of the maximum size limit were implemented. The new regulations should result in a higher optimum sustainable effort and catch in addition to providing larger sized cutthroat for the angler.

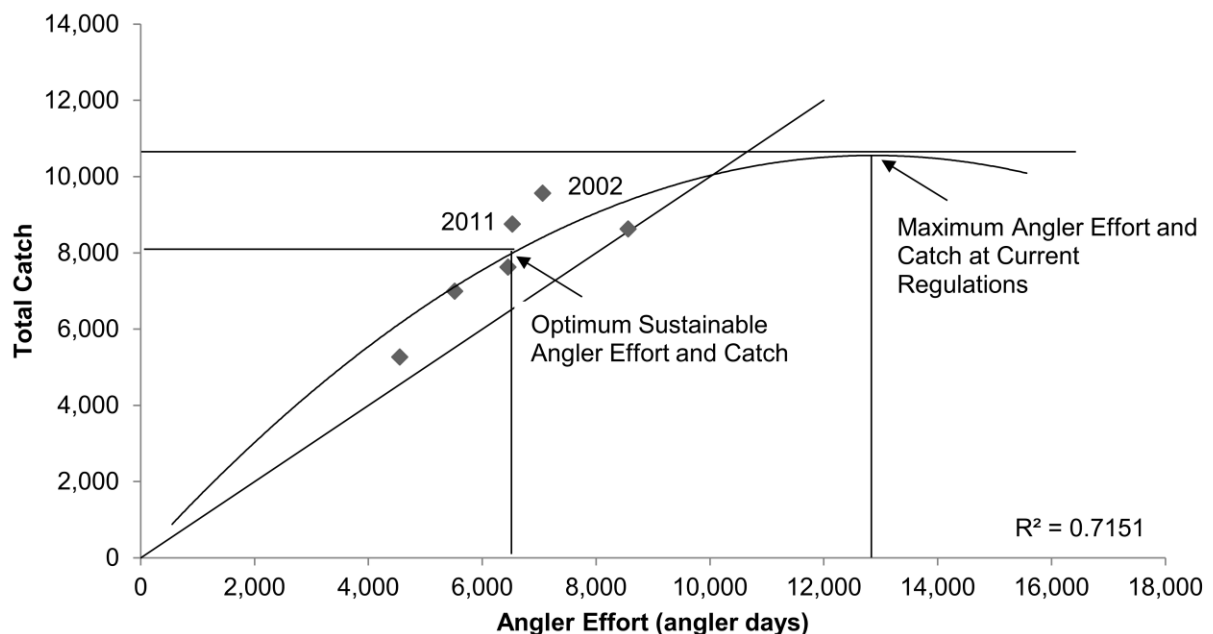


FIGURE 9. Angler effort (angler days) vs. total catch at Comox Lake 1986 – 2011 and maximum angler effort and catch and optimum sustainable angler effort and catch at current regulations (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

Angler success based on the VILQ has been stable over the years, albeit below our regional target of 1.6 fish/day. However, the actual angler success based on angler creel survey data is much lower at <0.5 fish/day and until the implementation of the new regulations in 2012, anglers were harvesting high numbers of immature fish. Also of concern is the decrease in the percentage of larger cutthroat trout (>300 mm) in gillnets over the past 50 years. In the 1940's, cutthroat >300 mm comprised ~25% of the sample while in 2009, fish this size comprised only ~2% of the sample (Appendix 11). In addition, rainbow trout comprise increasingly large proportions of gillnet samples and the Ministry is extremely concerned about the large numbers (~1 million/year) of coho being stocked into Comox Lake and tributaries. Impacts from this activity are well known (Glova and Mason, 1977; Tripp and McCart, 1983) and could impact the success of the new angling regulations.

1. Monitor the Comox Lake fishery with an angler creel survey in 2013/14 and again in 2016 to determine changes in angler catch and success. Determine if there is a need for additional regulations following the 2016 survey.
2. Conduct an angler preference survey as part of all angler creel surveys. There is a data gap regarding this particular aspect of the Comox Lake fishery which must be filled in view of the recent regulations change.
3. We recommend instant angler counts be conducted in 2013/14 and again in 2016 along with the angler creel surveys to monitor angler effort at Comox Lake.
4. Repeat the gillnet assessment in 2014 and compare stock status indicators.
5. Conduct snorkel surveys to monitor cutthroat trout escapement and mean size. Complete surveys can be done once every three years and index reach surveys can be completed annually if funds permit (see Lough, et al, 2011 for procedures).
6. Conduct electrofishing in Comox Lake tributaries to establish ages of juvenile fish rearing in tributaries and determine densities of stocked coho salmon. Additional studies such as a shoal assessment of Comox Lake should also be implemented to confirm the age and size of cutthroat trout recruiting to the lake.
7. Review the results of the VILQ to determine if fisheries statistics show changes in angler effort, catch, success and harvest compared to previous VILQ surveys. The VILQ can again be used as the primary monitoring tool for Comox Lake once changes to stocks and the fishery as a result of the new regulations are established.
8. MFLNRO requested that DFO discontinue coho stocking in the Upper Puntledge River and to review the stocking numbers in Comox Lake tributaries. DFO agreed to stop stocking the Upper Puntledge and has agreed to assess coho stocking success as part of a recently-funded FWCP project. We recommend the Ministry, CDF&GPA and DFO jointly review stocking practices and assessment results and, based on that review, determine long-term management objectives that benefit all salmon and trout species in the watershed.

Operational Management Plan for Comox Lake

We've summarized the operational management plan for Comox Lake in Table 13. A more detailed management plan is outlined in Michalski, 2011a.

TABLE 13. Operational Management Plan for Comox Lake.

Activity	Objective	Tentative Schedule
Fishery/Regulations	Monitor changes in the fishery since implementation of regulations changes in 2012.	2013/14
Monitoring		2016/17
Fish Stock Assessment	Conduct gillnetting assessment and gather data on angler-caught fish to compare stock status and catch data from 2009-2010 study.	2014
	Conduct snorkel surveys at index reaches and compare to 2012 results.	Annual
	Conduct electrofishing survey to determine numbers of juvenile trout in Comox Lake tributaries; conduct shoal assessment to establish age of cutthroat juvenile recruitment to Comox Lake.	2013/2014
Habitat Enhancement	Investigate feasibility of fertilizing tributary streams and/or increasing rearing habitat with addition of LWD, boulders etc. to increase nutrients and habitat for juvenile fish.	Potential with DFO study
VILQ	Evaluate changes in fisheries statistics every three years.	Ongoing

Chapter 5. Cowichan Lake

Lake	Cowichan
Planning Unit	Nanaimo Cowichan
Watershed	Cowichan
Surface Area (ha)	6,204
Mean Depth (m)	50.1
Key Tributaries	Sutton, Nixon, Cottonwood and Robertson Creeks
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden, kokanee
Limits to Production	Forestry, Urbanization at mouths of Key Tributaries
Regional Priority*:	1
<u>Angling Statistics 2011</u>	
Angling Effort	12,447 angling days
Total Catch	15,273 fish
Angler Success (catch/day)	1.2 fish/angler day
Current Harvest Rate	20%
Optimum Sustainable Effort	11,000
Optimum Sustainable Catch	12,000
Angler Success at Optimum	1.1 fish/day
Stock Status	Stable for cutthroat and Dolly Varden; unknown for rainbow
Data Gaps	Fecundity for cutthroat trout; genetic studies to determine life history types for rainbow trout in Cowichan Lake and Cowichan River; bathymetric map to assist with definition of rearing areas for juvenile trout.
Management Objectives Summary	Restrictive regulations to increase catch and angler success
Operational Plan Priorities	Gillnetting surveys every two years; habitat restoration of key streams; monitoring of prescriptions and stock status with Valley Fish and Game.
Potential Partners	Valley Fish and Game Association, TimberWest,

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Cowichan Lake Watershed

General Information

Cowichan Lake is located ~70 km northwest of Victoria and 31 km west of Duncan and lies in the Coastal Douglas Fir Zone in the Nanaimo-Cowichan PU (Figure 1). With a surface area 6,204 ha, Cowichan Lake is the 2nd largest lake on Vancouver Island (Table 1). The lake is situated at an elevation of 164 m, has a maximum depth of 152 m and a mean depth of 50 m. Cowichan Lake is ringed by 1,500 m high hills and drains a watershed of ~300 km². The Cowichan River, which is the lake outlet, leaves the eastern end of Cowichan Lake and flows east ~45 km down the Cowichan Valley and into Cowichan Bay and the Georgia Strait. The area drained by the lake and river is ~600 km².

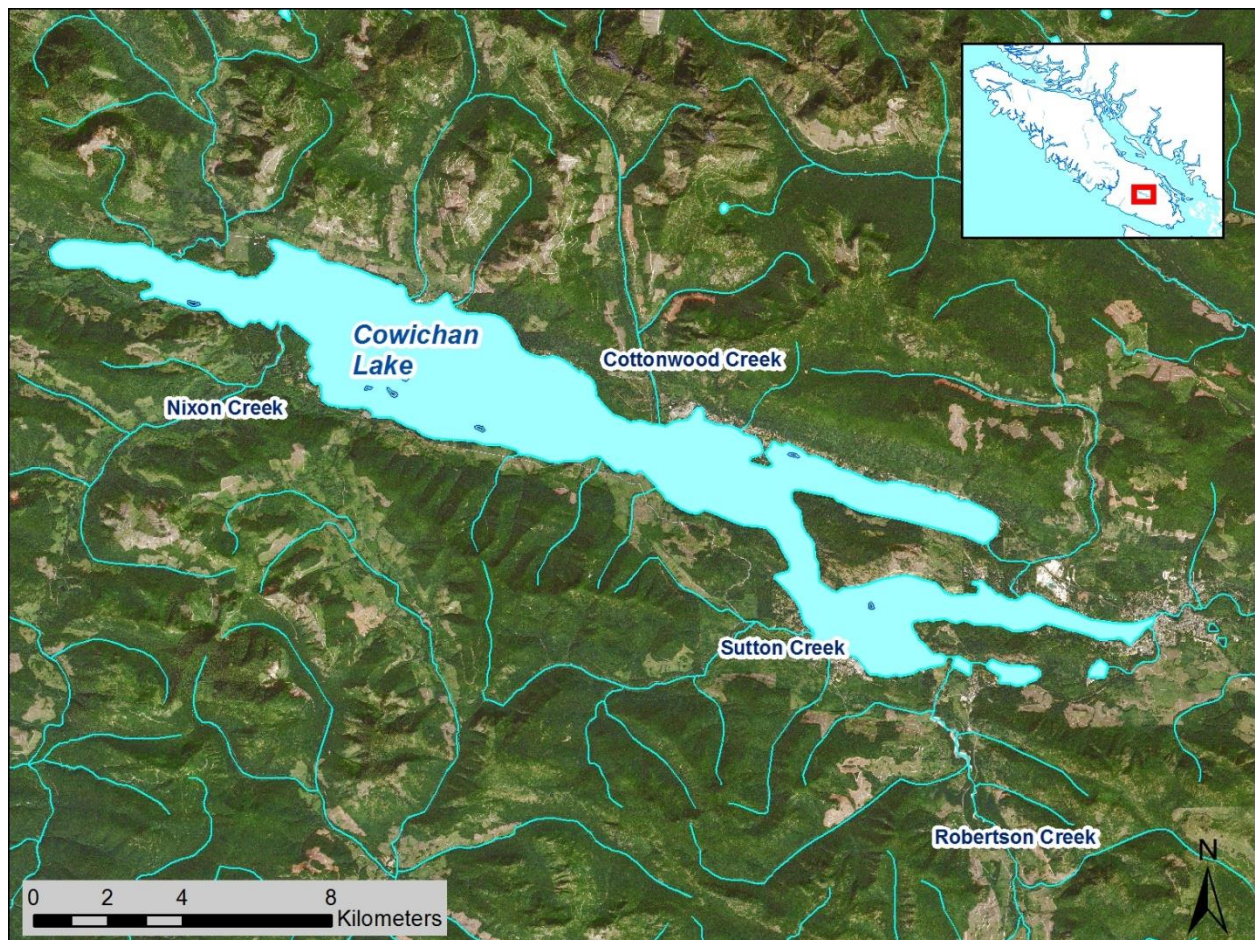


FIGURE 1. Map of Cowichan Lake and tributaries; a bathymetric profile of this lake is provided in Appendix 12. (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Cowichan Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
Nanaimo Cowichan	00408COWN	6,204	109.7	152	50.1	7.4	53		1950, 1953, 1960

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Tributaries

There are 30 tributaries to Cowichan Lake; only seven of which are major streams and these enter at widely separated points around the lake (Table 2). Four of these streams (Meade, Cottonwood, McKay and Shaw Creek) enter along the north shore of the lake, and three (Robertson River, Sutton and Nixon Creek) enter from the south. Each of these seven streams drains the surrounding highlands and are typical mountain streams with long, gravelly reaches and swift, cold water (Carl, 1952). During the rainy season these tributaries are subject to flooding and shifting of gravel and boulders. There is also a tendency of substrate to form bars across the tributary mouths. During the dry season, the flow of most streams is much reduced with the result that considerable portions of the lower reaches of some streams are completely dry or consist of isolated pools connected by water flowing beneath the gravel (Carl, 1952). Possible groundwater entering Cottonwood and Shaw Creeks may limit summer fish production (Table 2).

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Cowichan Lake (Source: Burns, 1984).

Tributary	Order	Length (km) and/or Drainage Area (km ²)	Other Information
Meade Creek	3	5.4 km	Steep, non-buffered, winter discharge fluctuation and bedload may limit production; lacks winter habitat; possibility that falls at ~4.9 km; 2m falls at head of canyon.
Cottonwood Creek	3	9.5 km	Production may be limited by cold summer temp. And high fall-winter discharge fluctuation; 4m falls at ~2km greatest vertical leap ~ 2m; 6 small falls <1m at 1.5 km; 2m falls at 4 km.
McKay Creek	2	7 km	Drains southern tail of Vancouver Island range; steep, non-buffered; summer cold and low nutrients; high fall-winter discharge fluctuations; 3m falls at 1.2 km; 5m falls at 2.5 km, 8m falls at 5 km.
Shaw Creek	3	25 km	Largest tributary to the lake, no fish found in Middle Fork above 1.2 km, production limited by cold summer temp (<10°C) and high fall-winter flow fluctuation; 2.5 m falls at 3 km on mainstem, series of cascades at 5 km, 3 m falls in Middle Fork 1.2 km above confluence with mainstem, rapidly increasing gradient and decreasing channel size in W. Fork 9 km above confluence with mainstem.
Robertson River	3	16 km	Productive length estimated at 11 km because 10 m

Tributary	Order	Length (km) and/or Drainage Area (km ²)	Other Information
Sutton Creek	3	11.6 km	falls at ~1 km on mainstem, falls and/or rapidly increasing gradient on some tributaries. Large, low nutrient, cold mountain stream with several important tributaries, extensive logging, flow and turbidity respond rapidly with precipitation, extensive gravel extraction in lower reaches; mainstem limited by summer drying, low nutrients and bedload instability. Productive length estimated at 10 km. High discharge fluctuations, cold summer temp, low nutrients; gradient increases at 10km; 2m cascade at ~0.6 km; 7m falls at ~0.7 km; 3 m falls at ~0.6 km on South Sutton; 5 m falls at 100m on 1 st west tributary; series of falls total ~25m at 250m on 2 nd tributary. Productive length estimated at 7.5 km. Subject to extreme discharge fluctuation; 5 th largest lake tributary, responds quickly to rainfall and carries large amounts of sediment, production may be limited by low nutrients, violent fall-winter discharge fluctuation, unstable channel and substrate, lower 2 km dries by mid-July most years; rapidly increasing gradient at 10 km in mainstem and 5 km in Raymond creek; 3m cascade at 300m in 2 nd west tributary.
Nixon Creek	3	15.8 km	

Numerous secondary and smaller streams flow directly into Cowichan Lake and, like some of the major streams, these smaller systems possess a variety of obstructions and barriers to the upstream migration from the lake of adult cutthroat trout and Dolly Varden (Griffith, 1989).

Species Composition

The Cowichan watershed supports an abundance and diversity of anadromous and resident salmonids. Anadromous species include Chinook, coho and chum salmon, steelhead and cutthroat trout while resident species include brown trout, which were introduced into the Cowichan River in the mid-1970's, Dolly Varden, rainbow and cutthroat trout, and kokanee salmon. Other species include the Cowichan Lake or Vancouver lamprey, Pacific lamprey, prickly sculpin and threespine stickleback.

Cowichan Lake contains cutthroat trout, rainbow trout, Dolly Varden and kokanee salmon. Brown trout and brook trout (*Salvelinus fontinalis*) are also reported in the lake (Rutherford et al, 1988) but have not been verified. The lake and tributaries are used by spawning and rearing steelhead trout, and coho salmon (Griffith, 1989).

An assessment by Griffith (1989) found the most abundant and widely distributed species in Cowichan Lake tributaries were coho salmon followed by rainbow trout, cutthroat trout, Dolly Varden and brown trout. This assessment also found the greatest numbers of cutthroat trout and Dolly Varden in the Robertson River and Sutton and Nixon Creeks which are located on the south side of the lake. A cursory review of habitat data by Burns (2002) suggests that average gradients of south-side streams are lower than for streams such as Meade, Cottonwood, McKay and Shaw which are located on the north side, and this gradient difference may explain the

dissimilarity in cutthroat distribution between the two sides of the lake. Griffith (1989) did not find evidence of Dolly Varden in major stream systems on the north side of the lake, however, in 2006, Michalski and Jancowski confirmed Dolly Varden presence in Sutton, Cottonwood and Nixon creeks, and the Robertson River.

Griffith (1989) conducted electrofishing assessments and found cutthroat and Dolly Varden in streams on the south side of the lake, however, he noted the absence of both species at sample sites in all the major tributaries on the north side of the lake. Where cutthroat presence was identified, densities tended to be low (Griffith, 1989). Coonskin Creek was the only stream sampled on the north side found to contain significant numbers of cutthroat fry, while Stanley Creek below the outlet of Cowichan Lake also contained high densities of cutthroat fry. Despite finding limited areas of cutthroat production, Griffith (1989) found evidence of widespread hybridization of cutthroat and rainbow trout at streams around the lake. He noted that some degree of blended characteristics in cutthroat and rainbow fry populations was observed at nearly all sites he sampled (Griffith, 1989).

Summary of Work and Reports

A number of assessments of Cowichan Lake and its tributaries have been conducted including a limnology assessment in 1952 by Carl, and water quality monitoring studies of the Cowichan River between 1985 and 2003 by MOE (Pommen, 2004). Fish assessments have focused on salmon production plans (i.e. Burns and Tutty, 1987; Burns, 2002), and on identifying enhancement opportunities for cutthroat trout and Dolly Varden (e.g. Michalski and Jancowski, 2006; Griffith, 1989; Tripp, 1989). In 1989 and 1990, MOE conducted angler creel surveys at Cowichan Lake to determine effort and total catch over the late summer period. In 1988, Rutherford et al. conducted a detailed investigation into stock levels and life history attributes of Cowichan Lake kokanee, and from 1988 until 2004, DFO conducted a series of Chinook salmon escapement studies on the Cowichan River. These studies were published as part of the Canadian Manuscript Report Series available through Fisheries and Oceans Canada.

In 2009, the Fish and Wildlife Branch received funding from the Habitat Conservation Trust Fund (HCTF) to conduct a fish and fisheries assessment of Cowichan Lake. The Ministry partnered with the Valley Fish and Game Club (VF&GC) to implement instant angler counts and angler creel surveys to assess Cowichan Lake fisheries, and conduct gillnetting and electrofishing surveys to assess the status of Cowichan Lake fish stocks. Summaries of some of the study findings are provided here and a final report will be available from the Fish and Wildlife Branch in 2014. A hydroacoustic and trawl survey to assess the Cowichan Lake kokanee population was completed by Johnner and Sebastian (2011) as part of the Ministry/VF&GC study.

2.0 Limits to Fish Production

Water Withdrawal

The Town of Lake Cowichan and the Cowichan Valley Regional District (CVRD) both have water licenses to remove water from Cowichan Lake for waterworks purposes (2,408 dam³/a) (Epps, 2011). There are also a number of domestic licenses allowing individuals to withdraw water for domestic use (including drinking water), and irrigation purposes, and there are a number of water licenses for domestic and irrigation purposes on the Cowichan River and Cowichan Lake (Epps, 2011). DFO holds water licenses for conservation purposes.

Of the water required for industrial purposes, almost 90% is held by Catalyst Paper in two licences which account for 68% of the water licences in the entire area. One licence supplies industrial water to the pulp and paper mill in Crofton and allows 62,000 dam³ of water storage on Cowichan Lake. A flow control weir is located at the lake outlet to affect water storage. During much of the year, dam flood gates may be partially or fully opened to provide unimpeded access to the lake, however, associated velocities are often high, and there may be limited periods when the weir is actually passable to smaller fish such as juveniles moving upstream (Griffith, 1989). Stored water is released according to a rule curve which specifies a minimum release of ~7 m³/s from June 1 – October 15 and opening and closing of the weir gates is overseen by committee comprised of government, industry and private stakeholders.

Logging

The area around Cowichan Lake and extending to the Cowichan Valley was at one time heavily forested with extensive stands of Douglas fir, cedar, hemlock and Sitka spruce. By 1952, however, Carl noted that practically the whole lake was girdled with a deforested belt extending from the lake to an altitude of ~ 450 m and, to a great extent, the timber cover had been removed by logging and subsequent burning of slash with the result that a great part of the watershed was denuded of large trees (Carl, 1952). In 1989, McKean pointed out that although the forestry industry provided the economic base in this area for many decades, the available timber supply had declined and it appeared unlikely that operations in the Cowichan Lake area would continue at the levels of the previous decades (McKean, 1989). Despite McKean's prediction, logging continues in the Cowichan Lake watershed.

Development

The upper Cowichan Valley includes the Village of Lake Cowichan and several communities around Cowichan Lake. In 1981, the population of the area was ~30,000 (McKean, 1989) and by 2001, the population of this area more than doubled reaching 73,948 (BC Ministry of Citizens' Services, 2009). By 2020, population is projected to reach 93,223 and over the next 25 years to increase by 30% to 106,360 (BC Ministry of Citizens' Services, 2009). Development restrictions and habitat protection mandates will be important in this watershed given the large extent of private land ownership around the lake, and the limited numbers of tributaries including Nixon, Sutton, Cottonwood, Coonskin and Stanley Creeks and the Robertson River critical for salmon and trout production.

Fish Stocking

Griffith (1989) and Ptolemy (1990) raised concerns about coho stocking and its impact on cutthroat at sites in most of the larger streams of the Cowichan watershed. Griffith (1989) noted that if stream densities of coho juveniles were to be increased, the Cowichan system would probably be close to the point where cutthroat recruitment could be affected. He further suggested that agencies should take a critical look at how coho enhancement was being conducted, and what the ultimate effects of this activity might be with respect to over-recruitment of streams and related impacts on trout production. It's not known whether Griffith's concerns were ever brought to the attention of DFO.

Stream Habitat

Griffith (1989) performed a habitat assessment of tributaries to Cowichan Lake and concluded there was ample habitat of good quality in the streams containing the majority of cutthroat production. He also noted that a lack of water during low flow periods is the major constraint to potential fish production, particularly in streams on the south side of the lake. He pointed out that not only does reduced wetted width reduce overall capacity for fish, but also that there are reductions in deeper habitats specifically required by parr. He noted that high densities and wide distributions of coho and rainbow trout, coupled with low flows were the principal factors limiting the production of cutthroat and Dolly Varden in the tributaries to Cowichan Lake.

In 2006, Michalski and Jancowski conducted overview and Level 1 Watershed Restoration Program (WRP) fish habitat assessments and fish inventories of Sutton, Cottonwood and Nixon creeks, and the Robertson River and found poor instream cover in the form of LWD and LWD/boulders, high concentrations of fines and bedload, and low wetted area as the main factors limiting fish production.

Nutrients

With a TDS estimated at 53 ppm, Cowichan Lake is typical of other large coastal lakes in that it is oligotrophic. It is also deep with nearly 85% of the lake's total surface area ≥ 20 m, and depths <10 m representing only ~6% of the total surface area (Rutherford, et al, 1988). In his biolimnology assessment, Carl (1953) indicated that Cowichan Lake had limited primary and secondary production.

Epps (2011) recommended a number of water quality objectives⁷ for parameters including dissolved oxygen and chlorophyll *a* for the protection of aquatic life, and total suspended solids objectives for the protection of drinking water. She notes these objectives are required to ensure that inputs from residential, timber harvesting, and recreation do not impair water uses in the Cowichan watershed.

3.0 Angling Statistics

Angler Effort

Angler effort at Cowichan Lake has averaged ~16,500 over the past 25 years (Figure 2) and in 2011 was 2nd only to Elk Lake with respect to angler effort at all regional lakes (Silvestri, 2013 in prep.). However, there has been a declining trend in angler effort at Cowichan Lake since 1992. That year angler effort exceeded 25,000 angler days and accounted for almost $\frac{1}{4}$ of all the angler effort in the Nanaimo Cowichan PU. Since then, angler effort declined to ~15,000 angler days in 2002, and to ~12,000 angler days in 2006 and 2011.

⁷ Water quality objectives are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia as part of the Ministry of Environment's (MoE) mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the future.

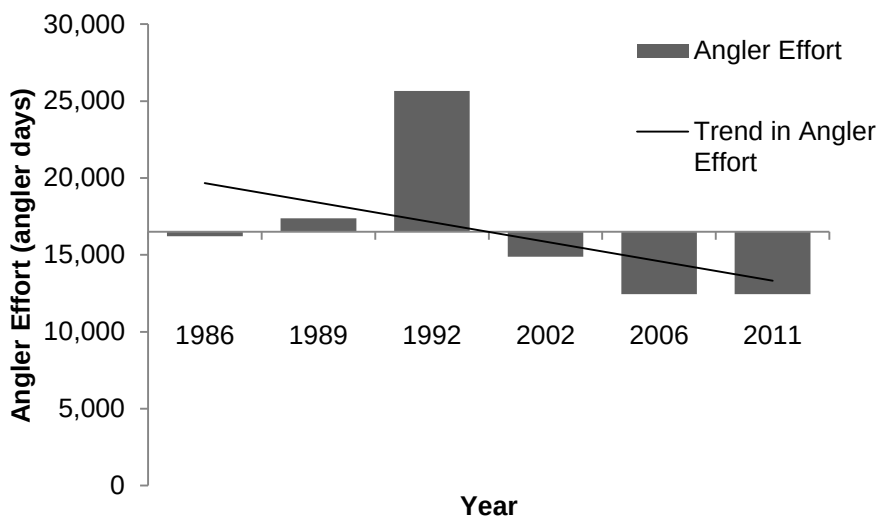


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 at Cowichan Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Instant angler counts conducted as part of the Ministry/VF&GC study provided the data used to estimate angler effort of ~15,200 angler days in 2010 (Figure 3) (Michalski, 2014 in prep). Although angler counts were conducted for only part of the year in 2009 and 2011, data was extrapolated using the 2010 results to estimate ~15,800 angler days in 2009, and ~12,700 angler days in 2011. These estimates are consistent with the VILQ which estimated 12,447 angler days in 2011 (Table 2; Silvestri 2013 in prep.).

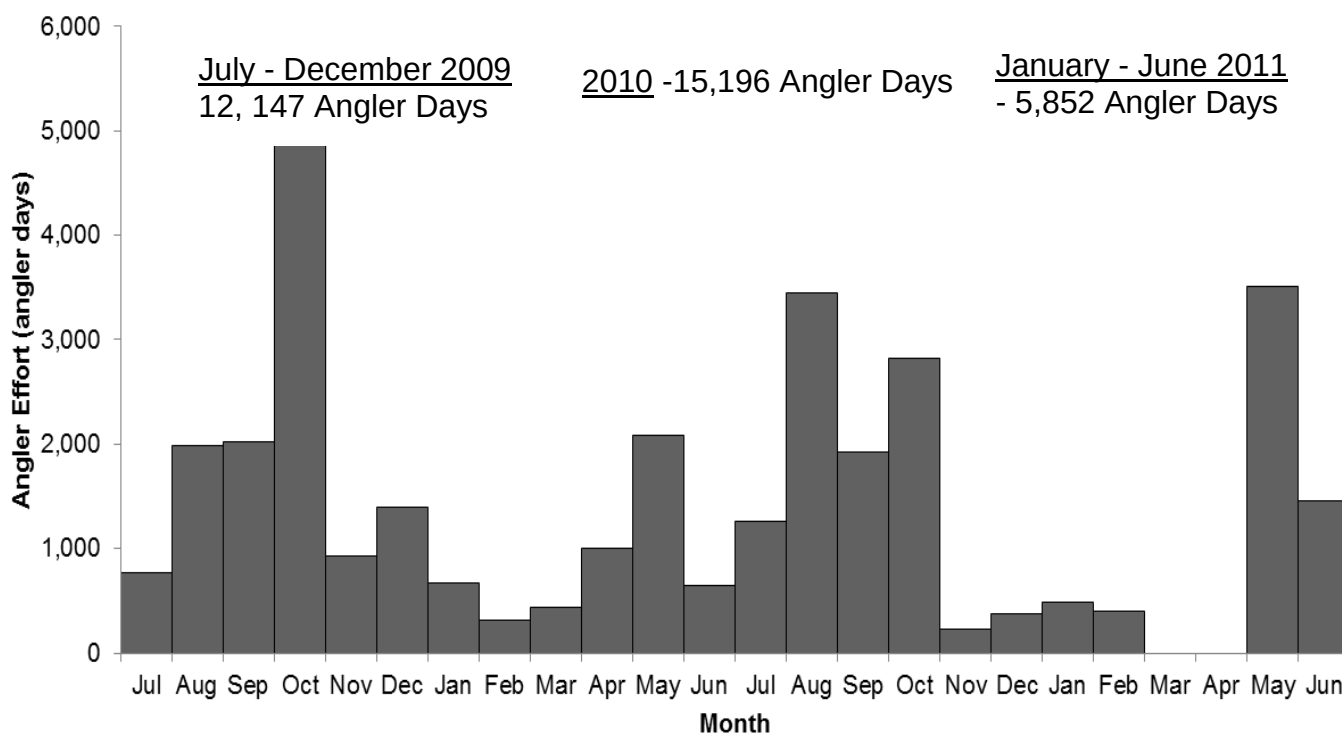


FIGURE 3. Expanded angler effort at Cowichan Lake July, 2009 until June, 2011. The expanded angler effort was calculated using instantaneous angler counts conducted by the Valley Fish and Game Club. We estimate the angler effort for all of 2009 at ~15,800 angler days, and for all of 2011 at ~12,700 angler days; see the Appendix 12 for raw data and calculations (Source: Source: Michalski, 2013).

Catch

Total catch at Cowichan Lake has varied from a high of >20,000 fish in 1992, to a low of ~11,000 fish in 2006 (Figure 4). Over the past 20 years, anglers at Cowichan Lake have caught an average of ~16,000 fish per year. The lowest catches on record have occurred since 2002 although in 2011, total catch increased to 15,000 fish which is still just less than the long-term average of ~16,000 fish. The trend in total catch mirrors that of total angler effort over the survey period.

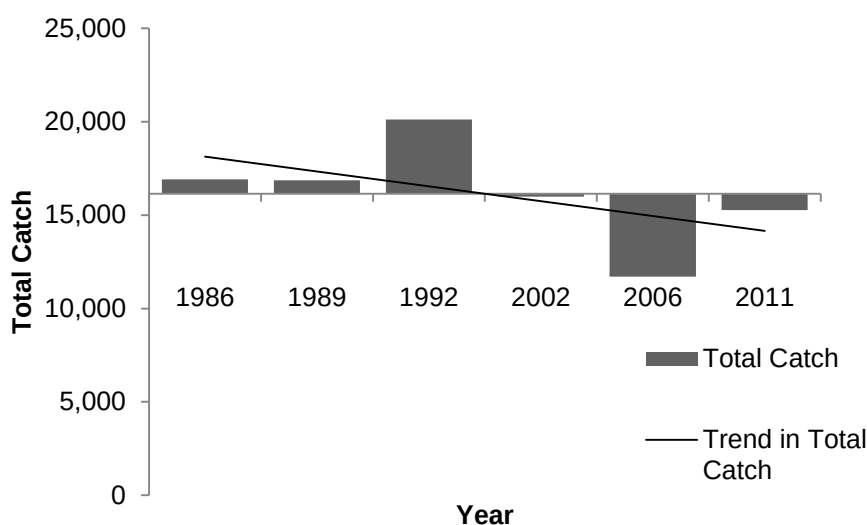


FIGURE 4. Total catch by year compared to average catch from 1986-2011 and trend in catch at Cowichan Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Angler creel assessments were conducted by MOE in 1989 and 1990. In 1989, anglers caught roughly equal numbers of cutthroat and rainbow trout while in 1990, anglers reported catching more cutthroat trout (68%) than rainbow trout (32%) (Table 3) (Griffith, 1989; Stewart, 1990).

TABLE 3. Percent of total catch of cutthroat and rainbow trout and Dolly Varden by anglers in 1989 (n=61) and 1990 (n=77) at Cowichan Lake (N=138) (Griffith, 1989 and Stewart, 1990).

Species	Percent of Total Catch		
	1989	1990	Average
Cutthroat Trout	59	68	63
Rainbow Trout	41	32	37
Dolly Varden	0.2	12	7

Although data from the 2011 VILQ suggests 60% of the catch at Cowichan Lake is cutthroat trout (Table 4), data collected during angler creel surveys conducted during the Ministry/VF&GC study suggest that 78% of the catch is cutthroat trout (Table 5) (Michalski, 2014 in prep.).

TABLE 4. Catch of rainbow and cutthroat trout at Cowichan Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri, 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	7,000	39.1	9,008	59.1
Rainbow	4,545	0.8	5,973	39.2
Dolly Varden	91	100	251	1.6
Total	11,636	0.0	15,231	100.0

TABLE 5. Percent of total catch of cutthroat and rainbow trout and Dolly Varden by anglers in 2009, 2010, 2011 at Cowichan Lake (N=179) (Source: angler interviews conducted following instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011; FLNRO files, Nanaimo).

Species	Percent of Total Catch			
	2009	2010	2011	Average
Cutthroat Trout	72.4	78.9	83.9	78.4
Rainbow Trout*	27.6	20.0	16.1	21.2
Dolly Varden	0.0	1.1	0.0	0.4

Angler Success

The average long term angler success rate at Cowichan Lake is 1 fish/day and there has been an increasing trend in this statistic over the past 25 years (Figure 5). Angler success is still below the regional objective of 1.6 fish/day, however. Angler success has varied from <1 fish/day in 1989 and 1992, to just over 1 fish/day in 2002. In 2006, angler success was 0.9 fish/day and in 2011 it was ~1.2 fish/day.

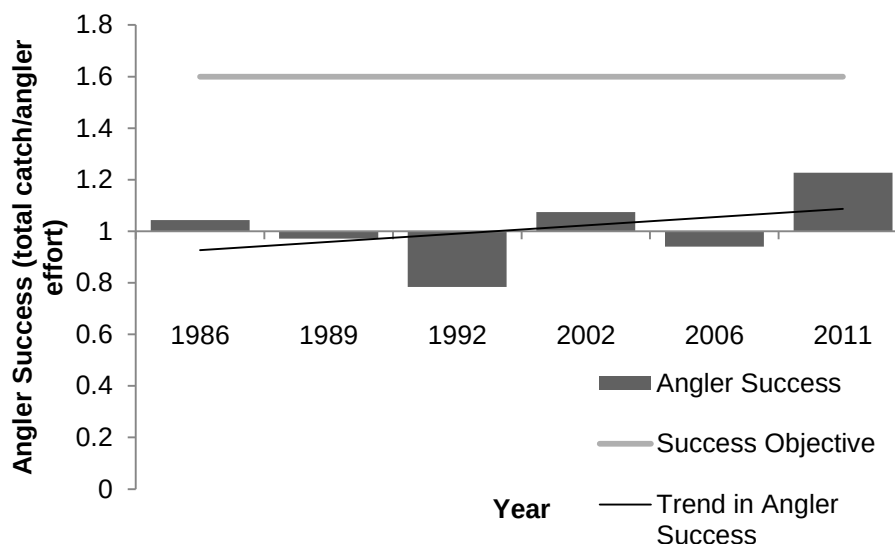


FIGURE 5. Angler success (total catch/total angler effort in angler days) compared to average angler success and the objective for angler success (1.6 fish/angler day) at Cowichan Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Angler success calculated using angler creel survey results from the Ministry/VF&GC study is substantially lower than that estimated by the VILQ. Angler success calculated using angler

creel survey and instant angler count data suggests that angler success actually averages ~0.3 fish/day (Table 6), as opposed to 1.2 fish/day estimated by the VILQ (Figure 5).

TABLE 6. Total catch, observed angler effort from instant counts and success (total catch/observed effort) at Cowichan Lake 2009, 2010, 2011 (Source: angler interviews and instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011; FLNRO files, Nanaimo).

Year	Total Catch	Observed Effort	Success (catch/angler day)
2009	58	234	0.25
2010	90	277	0.32
2011	31	87	0.36
Total	179	598	0.30
Average Success	0.31		

Derbies

Derbies at Cowichan Lake run almost weekly throughout the winter months and provide anglers with the opportunity to catch some of the largest cutthroat trout on the West Coast. Much of the angler effort in October and throughout the winter months until roughly Easter is attributed to derby effort, and much of this angler effort is from local anglers.

In 1989 and 1990 the Ministry conducted angler creel surveys at Cowichan Lake derbies and the angler effort and catch data collected is presented in Table 7. Angler success averaged 0.55 fish/day in 1989, and 0.56 fish/day in 1990. Data did not include a derby in October at which angler success was 0.67 fish/day. In 1989, Burns provided information on an additional derby including an overall success rate of ~1.2 fish/day. He cautioned that many anglers did not report in and he suggested that angler success rate was more likely closer to ~0.6 fish/day.

TABLE 7. Summary of angler effort (angler days), total catch and success (catch/angler day) of Cowichan Lake creel studies completed in 1989 and 1990. Angler days were determined by dividing effort in hours by 2.5 which is the average number of hours anglers spend fishing Cowichan Lake (Source: Stewart, 1990; note from Burns in FLNRO files, Nanaimo).

Month	Effort (hours)		Effort days*		Catch		Success (catch/angler day)	
	1989	1990	1989	1990	1989	1990	1989	1990
July	236.5		94.6		89		0.94	
August	695.5	540.2	278.2	216.1	116	155	0.42	0.72
September	48.0	550.2	19.2	220.1	6	124	0.31	0.56
October		73.6		29.4		12		0.41
-derby		647.0		258.8		174	~0.6*	0.67

*Not all anglers reported in and it is assumed that anglers not reporting in did not catch fish which reduced the angler success to ~0.6 fish/angler day.

Volunteers, contractors and Ministry staff attended weigh-ins for 23 derbies held on Cowichan Lake between October 2009 and March 2012 as part of the Ministry/VF&GC study. The number of anglers weighing fish at each derby ranged from 2 anglers to 33 anglers with an average of 15 anglers weighing fish at each event (Table 8).

TABLE 8. Total number of derbies monitored, number of calendar days during which derbies occurred, total, range of number of derby participants and average number of anglers/derby at Cowichan Lake October, 2009 – March

2012; derbies were monitored by Valley Fish and Game Club volunteers, contractors and Ministry staff (Source: FLNRO files, Nanaimo).

Year	Derbies Monitored	Total Number of Calendar Days	Total Number of Anglers	Range of Number of Anglers	Average Number of Anglers/Derby
2009	4	6	50	7-20	13
2010	12	15	179	2-26	15
2011	3	6	78	13-33	26
2012	4	5	45	5-23	11
Total	23	32	353	2-33	15

Anglers weighed in 573 fish at the 23 derbies monitored between October, 2009 and March, 2012 (Table 9, Table 10). Approximately 95% of fish (544 fish) were cutthroat trout, ~5% (26 fish) were rainbow trout and <1% (3 fish) were Dolly Varden.

TABLE 9. Total number of cutthroat and rainbow trout and Dolly Varden weighed-in at 23 derbies conducted from October 2009 until March 2012 at Cowichan Lake. Weigh-ins were monitored by volunteers from the Valley Fish and Game Club, contractors and Ministry staff (Source: FLNRO files, Nanaimo).

Year	Cutthroat	Rainbow	Dolly Varden	Total
2009	71	6	----	77
2010	278	16	1	295
2011	153	3	2	158
2012	42	1	-----	43
Total	544	26	3	573

TABLE 10. Total number of derbies monitored, total number of anglers, total number, range and average number of cutthroat trout weighed-in per derby from October 2009 until March 2012 at Cowichan Lake. Weigh-ins were monitored by volunteers from the Valley Fish and Game Club, contractors and Ministry staff (Source: FLNRO files, Nanaimo).

Factor	Number
Number of Derbies	23
Total Number of Anglers	366
Total Cutthroat Weighed-In	544
Range of Cutthroat Weighed-In	6 - 66
Average Number Weighed-In/Derby	24

Four hundred and seventy-six cutthroat trout ranging from 160 mm - 650 mm were weighed at derbies between 2009 and 2012 (Table 11). The mean length of these fish was 397.2 mm, and the modal length was 400 mm.

TABLE 11. Total number and minimum, maximum, mean and modal length of cutthroat trout weighed-in at scales and released during derbies held October, 2009 until March 2012 at Cowichan Lake. Note, only weight was provided for fish caught during the Caycuse Family Derby held April 2, 2010. I estimated the length of these cutthroat trout using a length-weight relationship for cutthroat trout in Vancouver Island large lakes (Appendix 12). Weigh-ins were monitored by volunteers from the Valley Fish and Game Club, contractors and Ministry staff (Source: FLNRO files, Nanaimo).

Number of Fish	Length (mm)		Mean	Mode
	Minimum	Maximum		
Weighed-In				
476	160.0	650.0	397.2	400.0
Released				
38	140.0	635.0	476.7	500.0

Harvest

According to the VILQ, harvest rates at Cowichan Lake in 2006 were ~24% and in 2011 were ~20% (Table 12). However, harvest rates calculated from angler creel surveys conducted during the Ministry/VF&GC study were much higher. This study found that overall, the harvest rate for all species was ~40%, while the harvest rate for cutthroat trout specifically was ~44% (Table 13).

TABLE 12. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Cowichan Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	7,000	1,795	25.6	9,008	1,810	20.1
Rainbow	4,545	977	21.5	5,973	1,197	20.0
Dolly Varden	91	0	0.0	251		0.0
Total	11,636	2,772	23.8	15,231	3,007	19.7

TABLE 13. Total catch and harvest and harvest rate (percent) of cutthroat and rainbow trout, "trout" and Dolly Varden by anglers in 2009, 2010, 2011 at Cowichan Lake (Source: angler interviews conducted following instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011; FLNRO files, Nanaimo).

Species	Total Catch	Total Harvest	Harvest Rate (%)
Cutthroat	139	61	44
Rainbow	28	3	11
Trout	9	7	78
Dolly Varden	1	0	0
Total	177	71	40

In general, anglers at Cowichan Lake (not including derbies) harvest cutthroat trout that range in size from <150 mm - 600 mm (Figure 6) (Michalski, 2014, in prep.). Most of the cutthroat harvested are 250 mm - 400 mm, however, ~50% are <350 mm and ~45% are <330 mm.

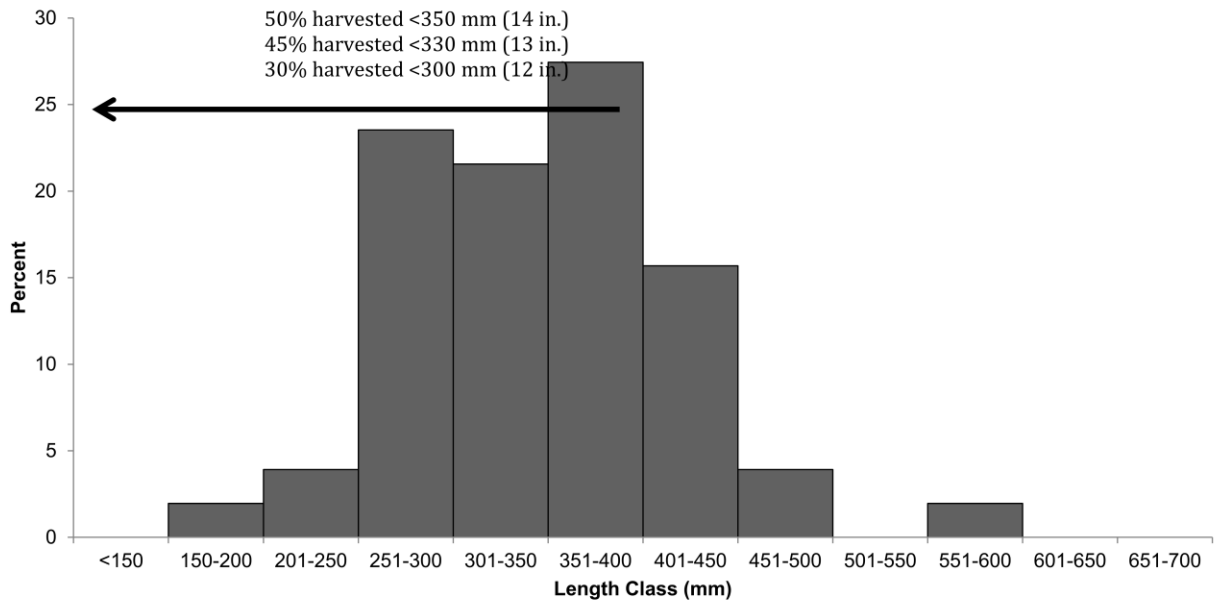


FIGURE 6. Length frequency analysis of cutthroat trout harvested by anglers at Cowichan Lake July, 2009 – June, 2011 (N=126) (Source: angler interviews conducted following instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011; FLNRO files, Nanaimo).

Anglers participating in derby fisheries harvest larger cutthroat trout than anglers participating in the general fishery (Figure 7) (Michalski, 2014, in prep.). More than 80% of cutthroat weighed at derby scales are between 300 mm - 500 mm. Approximately 90% of all cutthroat harvested at derbies are >300 mm, 83% are >330 mm and 74% are >350 mm.

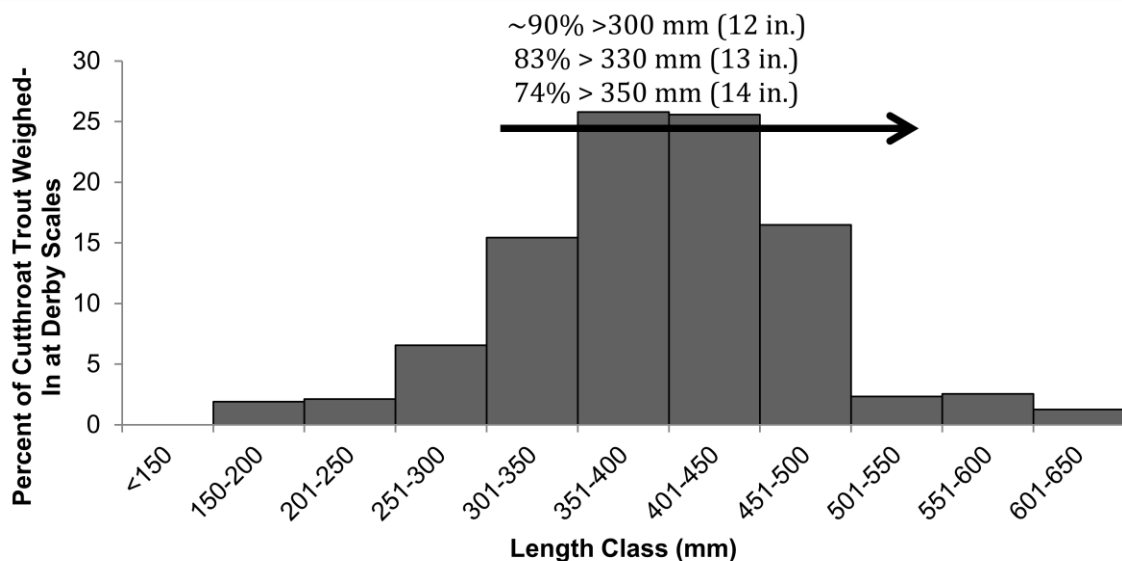


FIGURE 7. Length frequency diagrams of cutthroat trout weighed-in at derbies (n=473). (Source: Interviews and sampling conducted by Valley Fish and Game Club volunteers, contractors and Ministry staff at Cowichan Lake October 2009 – March, 2012; FLNRO files, Nanaimo).

Rainbow trout comprise ~21% of the fishery at Lake Cowichan and most fish are caught in March (25%), and September and October (20% each) (Figure 8). Most rainbow trout are

released by anglers with the exception of some rainbow which are harvested during derby fisheries (Michalski, 2014, in prep.).

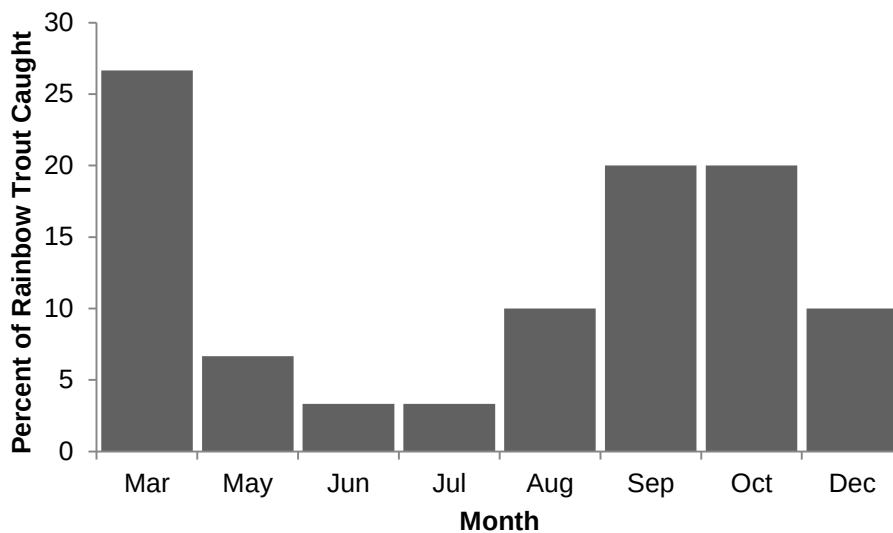


FIGURE 8. Percent of rainbow trout caught by month at Cowichan Lake July, 2009 until June, 2011 (N=30). (Source: angler interviews conducted following instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011; FLNRO files, Nanaimo).

4.0 Stock Status Indicators

Relative Abundance

We've shown the proportion of cutthroat and rainbow trout, Dolly Varden and kokanee salmon collected in gillnets between 1950 and 2009 in Cowichan Lake and tributaries in Figure 9. In 1989, ~90% of fish caught were cutthroat, and in 2009 ~75% of the fish caught were cutthroat trout. No Dolly Varden were caught in the 1989 sample, however, 13% of the 2009 gillnet sample was Dolly Varden.

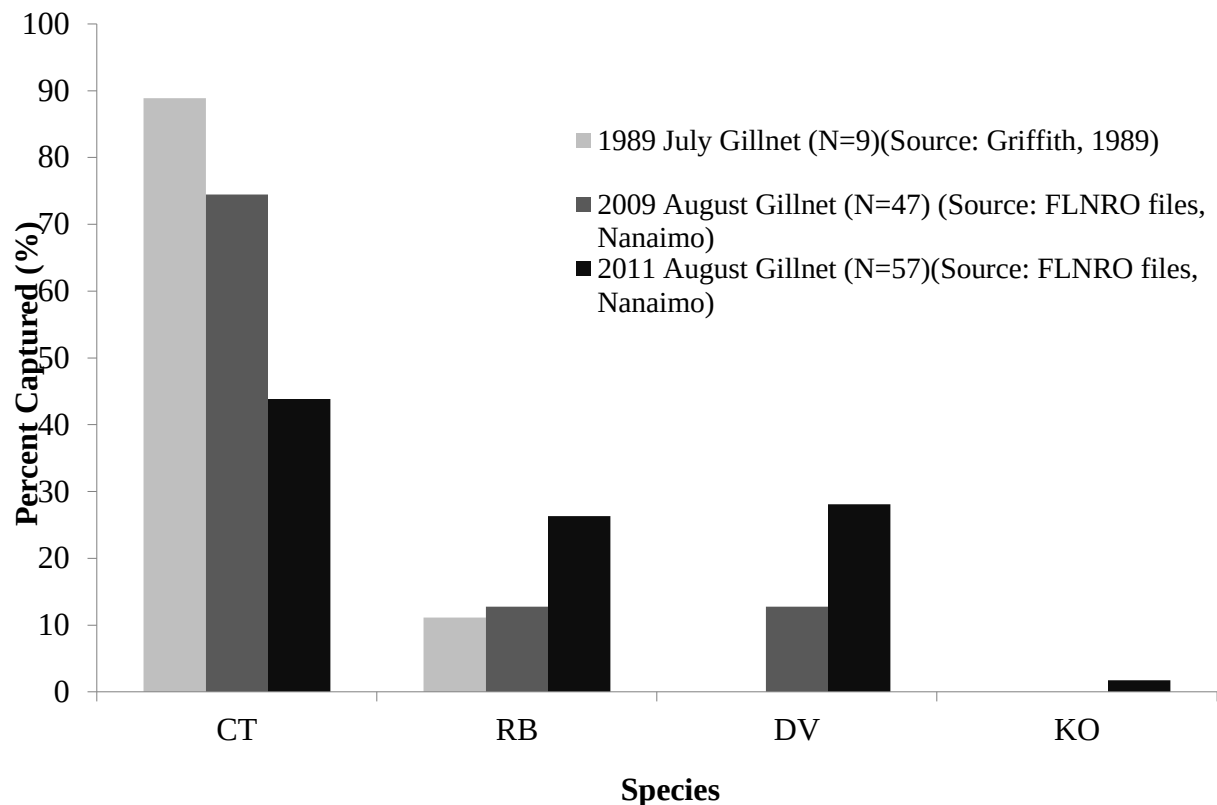


FIGURE 9. Percent cutthroat trout, rainbow trout, Dolly Varden and kokanee salmon captured in Cowichan Lake by gillnet in 1989 (N=9); 2009 (N=47) and 2011 (N=57) (Source: Griffith 1989; and FLNRO files, Nanaimo).

Net traps were set by the Cowichan Lake Education Center in 1996 and 1998. Both years of sampling found almost equal proportions of rainbow and cutthroat trout. A total of 101 fish were caught by net trap in 1996 and this sample consisted of 35% cutthroat, 28% rainbow, 24% kokanee and 14% Dolly Varden (Table 14). In 1998, 536 fish were caught and this sample consisted of 35% cutthroat, 20% rainbow, and 45% kokanee.

TABLE 14. Total number of cutthroat and rainbow trout, Dolly Varden and kokanee captured in net traps by the Cowichan Lake Education Centre in 1996 (n=101) and 1998 (n=536) (Source: FLNRO files, Nanaimo).

Species	1996	1998
Cutthroat	35	186
Rainbow	28	108
Dolly Varden	14	----
Kokanee	24	242
Total	101	536

We've presented the minimum, maximum and mean lengths of cutthroat trout captured in net traps in 1996 and 1998 in Table 15. Age 1+ cutthroat trout captured in the traps early in the year and larger, older (likely 3+ year old) fish were captured later in the year suggesting that cutthroat recruit from the tributaries to the shoals at 1+ years, and stay in these habitats until they are >300 mm when they likely move into deeper, pelagic habitats.

TABLE 15. Minimum, maximum and mean length (mm) of cutthroat trout captured in net traps in Cowichan Lake 1996 – 1998 (N=221) (Source: MFLNRO files, Nanaimo).

Month	Length (mm)			
	N	Minimum	Maximum	Mean
April	3	99.0	136.0	117.7
May	156	84.0	346.0	143.5
June	27	85.0	370.0	153.6
November	35	150.0	390.0	228.4

Snorkel Surveys

A snorkel survey of the Cowichan River has been conducted annually in July since 1976. The original objective of this snorkel survey was to enumerate rainbow trout which were reported by a local resident as declining (Reid, G., 2013 pers. com.). Over the years, this snorkel survey has also become the method used to track trends in brown trout numbers and information on snorkel counts for this species can be found in Appendix 12.

Snorkel counts of rainbow trout have increased steadily over the past 30 years (Figure 10). In 2008, swimmers counted >500 rainbow trout and in 2009 swimmers counted >400 rainbow trout. On average, swimmers observe ~300 adult rainbow over the ~20 km stretch between Cowichan Lake and Stoltz Crossing. More rainbow trout are observed in snorkel counts early in July, vs. later in the month.

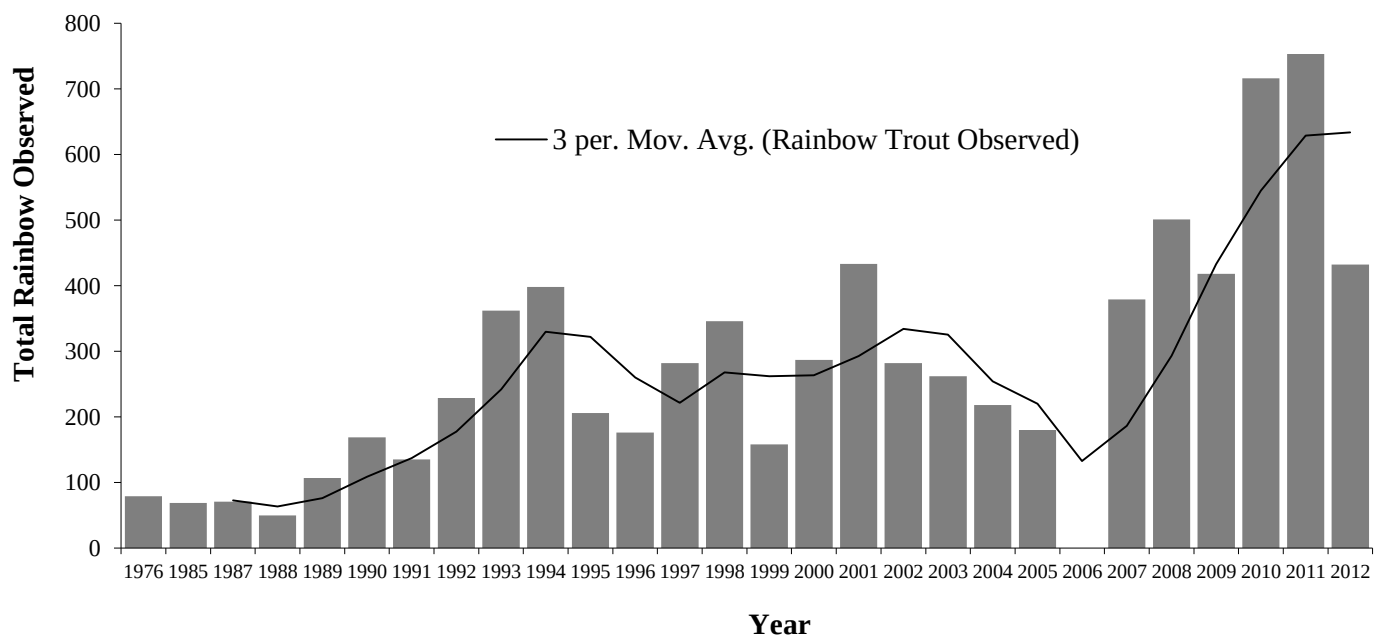


FIGURE 10. Total number of rainbow trout observed in snorkel surveys of the Cowichan River 1976 – 2012. All swims were conducted during the month of July, except for in 1995, 2011 and 2012 when the swim took place in August. Snorkel swims were completed in sections 1-3 from 1976 to 1992 and in sections 1-4 from 1993 to 2010. The 2011 and 2012 swims were completed in sections 1-2 only. Note: no swim was conducted in 2006 (Source: FLNRO files).

Cutthroat trout are observed in the annual rainbow trout snorkel surveys and we've provided a summary of these observations in Appendix 12. We've also provided the results of snorkel surveys conducted in the spring over a number of years in an attempt to enumerate spawning cutthroat trout in the Cowichan River. Lough and Associates conducted a number of snorkel surveys in tributaries to Cowichan Lake and we've provided summaries of these assessments in Appendix 12 while complete results of these studies can be found in Lough et al (2012a) and Lough et al (2011a). In short, these studies found that cutthroat spawning activity in the Cowichan watershed occurs from the end of March until May, and peak spawning occurs between 4°C and 6°C (Lough, 2012a).

Length and Weight

Cowichan Lake was sampled from the 1950's until the 1980's using various methods including gillnets, net traps and angling. Gillnets were set in 1980 and 2000 and we've presented minimum, maximum, mean and modal length and mean weights of cutthroat, rainbow trout and Dolly Varden sampled by this method in Table 17.

In the 1980's, cutthroat trout ranged from 180 mm - 424 mm, and averaged 210 mm. The modal length that decade was 180 mm. At present, cutthroat range from 113 mm - 525 mm and average ~295 mm. The modal length now is 260 mm, and the mean weight is ~320 g.

TABLE 17. Minimum, maximum, mean length and mean weight for cutthroat and rainbow trout and Dolly Varden captured in gillnets in Cowichan Lake 1980 and 2000 (Source: FISS; FLNRO files, Nanaimo; Michalski, 2014, in prep.).

Species	Decade	N	Length (mm)				Weight (Mean (g))
			Minimum	Maximum	Mean	Mode	
Cutthroat	1980	9	180	424	210.5	180	-----
	2000	59	113	525	296.7	260	319.6
Rainbow	1980	1	260	260	260	-----	-----
	2000	21	180	374	246.2	240	196.2
Dolly Varden	2000	22	100	420	286.6	225	372.2

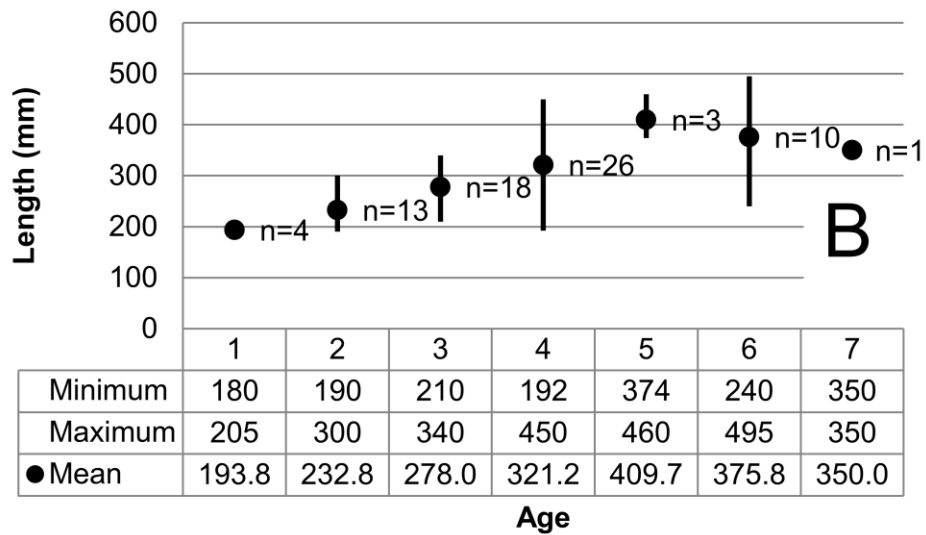
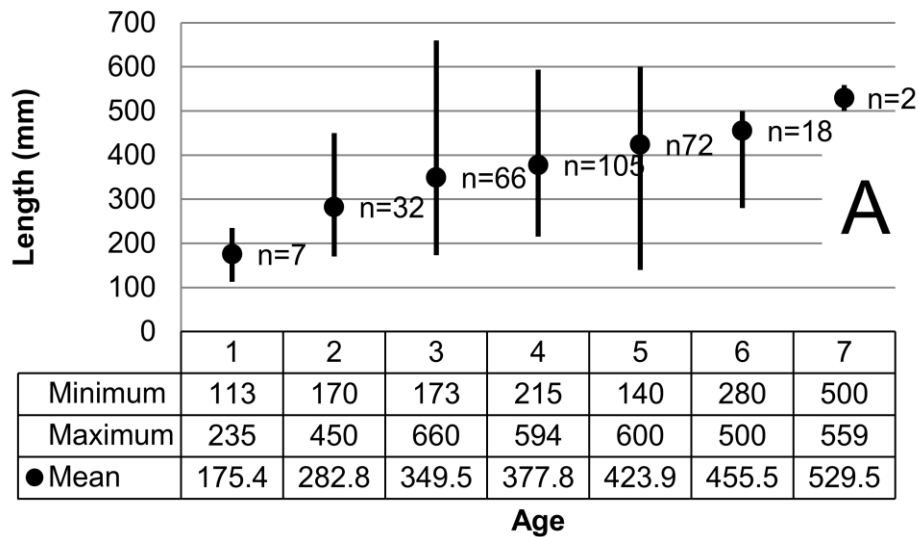
Only one rainbow trout was captured by gillnetting in the 1980's (Table 17). In the 2000's 21 rainbow trout were netted and these fish ranged from 180 mm - 374 mm and averaged ~245 mm. The modal length of rainbow trout is now 240 mm, and the mean weight is ~195 g.

Twenty-two Dolly Varden were captured in gillnets in this decade. These fish ranged from 100 mm - 420 mm and averaged ~285 mm. The modal length of this species is 225 mm, and the mean weight is 372.2g (Table 17).

Age and Growth

We've presented ageing data from fish scales sampled from angling and gillnets in Figure 11. Age 1+ cutthroat range from 113 mm – 235 mm and average ~175 mm, 2+ cutthroat range from 170 mm – 450 mm and average ~283 mm, 3+ cutthroat range from 173 mm – 660 mm and average ~350 mm, and 4+ cutthroat range from 215 mm – 594 mm and average 278 mm (Figure 11A). Age 5+ cutthroat range from 140 mm – 600 mm, age 6+ fish range from 280 mm

– 500 mm and average 456 mm and 7+ cutthroat range from 500 mm – 559 mm and average ~530 mm.



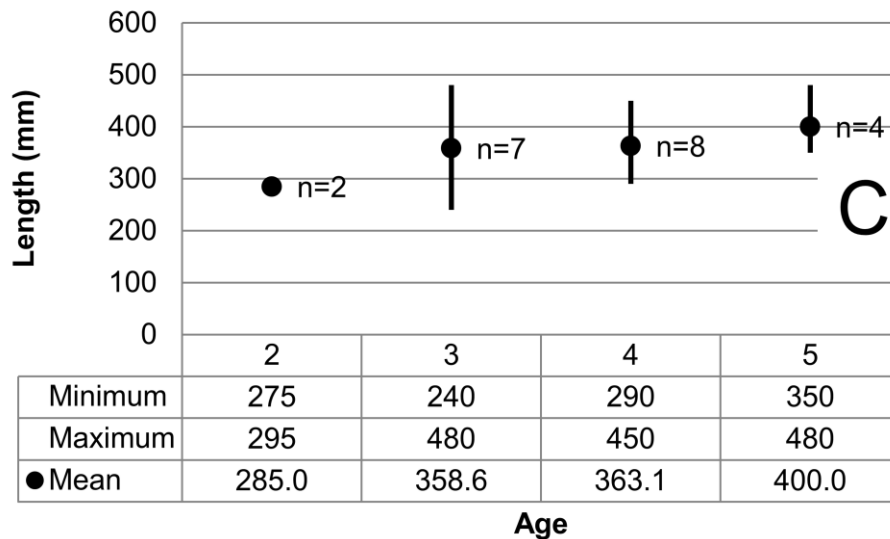


FIGURE 11. Length-at-age of (A) cutthroat trout (N=302) caught by anglers in 1989 and 1990 and 2009 – 2012, and in gillnets in 2009 and 2011 (N=302); B) rainbow trout (N=75) caught by anglers in 1989 and 1990 and 2009 – 2012, and in gillnets in 2009 and 2011 and (C) Dolly Varden (N=21) caught by anglers in 1989 and 1990 and 2009 – 2012, and in gillnets in 2009 and 2011; angling data in the 2000's includes fish sampled during derbies (Source: Michalski, 2014, in prep.).

Age 1+ rainbow trout sampled in Cowichan Lake range from 180 mm – 205 mm and average ~194 mm, 2+ fish range from 190 mm – 300 mm and average 233 mm, 3+ rainbow range from 210 mm – 340 mm and average 278 mm and 4+ rainbow range from 192 mm – 450 mm and average 321 mm (Figure 11B). Age 5+ rainbow trout range from 374 mm – 460 mm and average ~410 mm, and 6+ rainbow range from 240 mm – 495 mm and average 375.8 mm. Only one 7+ rainbow trout has been sampled in Cowichan Lake and it was 350 mm.

Age 2+ Dolly Varden range from 275 mm – 295 mm and average 285 mm, 3+ Dolly Varden range from 240 mm – 480 mm and average 359 mm, 4+ Dolly Varden range from 290 mm – 450 and average 363 mm and 5+ Dolly Varden range from 350 mm – 480 mm and average 400 mm (Figure 11C).

Mean Age and Length

We've provided mean age and length and catch data by decade for cutthroat and rainbow trout caught by anglers since the 1980's in Table 18. Anglers have caught increasing numbers of older and larger cutthroat trout over the decades. In contrast, anglers caught younger and, on average, smaller rainbow trout between 1980 and 1990.

TABLE 18. Mean age of cutthroat and rainbow trout captured in Cowichan Lake by decade by decade by anglers. Data sets with fewer than 10 fish have not been included (Source: FLNRO Files, Nanaimo; Michalski, 2014, in prep.).

Cutthroat			
Year	1980	1990	2000
N	36	52	168
Mean Age	3.3	3.8	4.4
Mean Length	313.5	382.6	422.4
Rainbow			
Year	1980	1990	
N	25	23	
Mean Age	4.3	3.9	
Mean Length	332.4	299.1	

Catch Indicators

The numbers of cutthroat and rainbow trout and Dolly Varden captured in gillnets in 2009 and 2011 are provided in Table 19. Although fewer cutthroat were captured in the 2011 assessment compared to that conducted in 2009, more than double the number of rainbow trout and Dolly Varden were captured in 2011 compared to 2009.

Table 19. Total catch of cutthroat and rainbow trout and Dolly Varden captured in gillnets in Cowichan Lake in 1984 (N=1), 1989 (N=9), 2009 (N=47) and 2011 (N=56) (Source: Michalski, 2014, in prep.).

Species	2009	2011
Cutthroat	35	25
Rainbow	6	15
Dolly Varden	6	16
Total	47	56

Juvenile Fish

We've provided population estimates for juvenile trout and salmon captured by electrofishing in Cowichan tributaries as part of the Ministry/VF&GC study in 2012 in Appendix 12. Michalski (2014, in prep.) noted very high densities of coho in sampled sites which supported Ptolemy's 1990 review of Griffith's 1989 electrofishing assessment of Cowichan Lake tributaries. In his review, Ptolemy noted that coho fry abundance in most sampled sites was extremely high; perhaps too high for their own maximum growth performance and survival, not to mention the increased mortality of cutthroat fry. Ptolemy (1990) also pointed out that marginal growth of coho was usually seen from late July until mid-August, and that typically extreme densities of 400+ fish per unit (FPU) were estimated with some sites containing up to 713 FPU. These high densities of coho in stream habitat may be why cutthroat trout parr are found on lake shoals as opposed to in tributaries (Table 20; Appendix 12) (Michalski, 2014, in prep.).

TABLE 20. Number and minimum, maximum and mean length of cutthroat trout captured by electrofishing (N=27) conducted by Fish and Wildlife Branch staff in August 2012 and in net traps in Lake Cowichan April, May, June and November 1996 and November 1998 (N=221) by the Cowichan Lake Educational Centre (Source: FLNRO Files, Nanaimo; Michalski, 2014, in prep.).

Month	Life Stage ¹	N	Length (mm)		
			Minimum	Maximum	Mean
<u>Electrofishing</u>					
August	Fry	25	40	89	47.6
August	Parr	2	98	150	124.0
<u>Net Trap</u>					
April	Parr	3	99	136	117.7
May		156	84	346	143.5
June		27	85	370	153.6
November		35	150	390	228.4

¹ Estimated size of cutthroat trout at emergence is ~25mm; growth of 0+ up to ~85 mm growth of 1+ up to ~145 mm (Carlander, 1969)

Data Gaps

The detailed fisheries and stock assessment completed on Cowichan Lake in 2009 – 2011 as a result of the joint Ministry/VF&GC study resulted in fisheries and stock status data and eliminated many previous data gaps on this system, however additional data would provide more clarity on fish life history characteristics (Table 21). For example, information on cutthroat fecundity would be useful for developing management objectives, and a genetic study on Cowichan Lake and Cowichan River rainbow trout may provide insight into how movements of this species affect the lake fishery for this species. A more detailed bathymetric map would provide better insight into locations of kokanee spawning and shoal locations critical to the survival of young cutthroat trout.

TABLE 21. Summary of data gaps for Cowichan Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	< 10 years	>10 years	No data
Gillnetting			
Fecundity			X
Angler Creel Survey	X		
Derby Data	X		
Angler Preferences	X		
VI Lakes Questionnaire	X		
Snorkel Surveys	X		
Acoustic Surveys	X		
Electrofishing (streams)	X		
Limnology	X		
Bathymetry		X	
Stream Habitat Inventory	X		

5.0 Fisheries Objectives and Management Strategies for Cowichan Lake

Existing Regulations

Current regulations at Cowichan Lake include a daily catch quota of two trout but none >50 cm and there is a bait ban and single barbless hook regulation from November 15 – April 15 on the lake. As with all Region 1 waters, Dolly Varden must be released.

There are a number of regulations on the Cowichan River including no fishing from the Cowichan Lake weir to the Greendale trestle, November 15-April 15, a year-long closure of tributaries above and including Holt Creek, fly fishing only in some locations and no fishing downstream of the Mile 66 trestle.

Regional regulations apply to the remaining Cowichan Lake tributaries including a daily catch quota of 4 from streams but not more than 1 >50 cm (2 hatchery steelhead >50 cm allowed) and 2 from streams (must be hatchery). All wild trout and wild steelhead from streams and all Dolly Varden must be released.

Angler Preference Surveys

A total of 123 anglers provided opinions on the Cowichan Lake fishery during the 2009 angler creel survey conducted as part of the Ministry/VF&GC study. Only 12% of anglers said the angling at Cowichan Lake is excellent, most anglers (~46%) said the angling is good and 37% said angling is poor.

TABLE 21. Percent of responses by anglers during an angler preference survey at Cowichan Lake conducted during the July 2009 – December 2009 angler creel surveys by Valley Fish and Game Club volunteers, contractors and Ministry staff (Source: Michalski, 2014, in prep.).

Question and Response				
1. How do you rate fishing in Cowichan Lake? (N=123)				
Excellent (n=15)	Good (n=56)	Poor (n=46)	No answer (n=6)	
12.2	45.5	37.4	4.9	
2. Why do you fish Cowichan Lake? (N=123)				
Catch fish to eat (n=59)	Catch large fish (n=30)	Catch many fish (n=28)	No answer (n=6)	
48.0	24.4	22.8	4.9	
3. Which species do you prefer to catch? (N=123)				
Cutthroat (n=57)	Rainbow (n=55)	Dolly Varden (n=1)	No Answer (n=10)	
46.3	44.7	0.8	8.1	

Forty-eight percent of anglers said they fish Cowichan Lake to catch fish to eat while about equal numbers (~23%) said they fish to catch large fish, or to catch many fish (Table 21). About equal numbers (~45%) like to fish for cutthroat as like to fish for rainbow, while <1% said they fish for Dolly Varden.

When asked if they would be in favour of regulations changes to improve the fishery and conserve stocks, 18% of anglers said they were happy with the current regulations (Table 22). Approximately 16% said they would support catch-and-release regulations, while 13% said they would support reducing the number of fish killed. This is an interesting response given that 48% of the anglers participating in this survey also said they fish the lake to catch fish to eat.

TABLE 22. Percent of responses to a question regarding regulations changes as part of the angler preference survey at Cowichan Lake conducted during the July 2009 – December 2009 angler creel surveys by Valley Fish and Game Club volunteers, contractors and Ministry staff (Source: Michalski, 2014, in prep.).

If new regulations were implemented to improve the fishery and conserve fish stocks, which regulation would be acceptable to you? (N=121)					
Size Limits (n=40)	Reduce Number of Fish Killed (n=16)	Season/Area Closure (n=3)	Catch & Release (n=22)	Happy with Current Regulations (n=22)	No Answer (n=21)
33.1	13.2	2.5	15.7	18.2	17.4

Maximum Catch and Effort at Current Regulations

Data from the VILQ suggests the high level of angler effort and total catch in the early 1990's approached the maximum angler effort and catch at Cowichan Lake (Figure 12). In addition, even at decreased levels of angler effort and catch in 2011, optimum sustainable angler effort and catch was exceeded as it had been every other year of the VILQ. When catch and harvest approaches the maximum or crosses the equilibrium line, angler catch rates decline and angler effort decreases as anglers leave the fishery. At Cowichan Lake, anglers have left the fishery and in 2006 and 2011, angler effort was the lowest in the 25 year history of the VILQ.

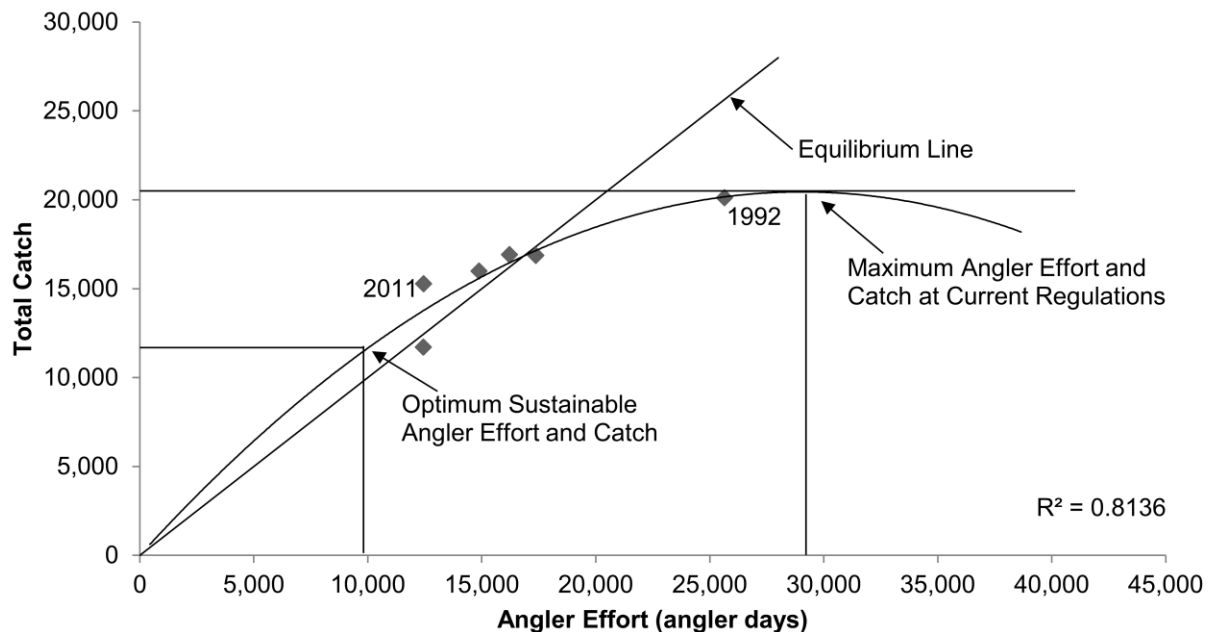


FIGURE 12. Angler effort (angler days) vs. total catch and maximum angler effort and catch at the current regulations, and maximum sustainable angler effort and catch at Cowichan Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

Some anglers are catching larger cutthroat than in the past and derby anglers have good catch rates, however, we are concerned that high angler effort and catch in the past may have impacted fishing opportunities for the general population at Cowichan Lake. According to the VILQ, even at the optimum angler effort and catch, angler success is ~1 fish/day which is below

the regional target of 1.6 fish/day. This is a concern considering the angler success in the general fishery according to angler creel surveys is actually closer to ~0.3 fish/day. In addition, almost 40% of anglers surveyed said angling at Cowichan Lake is poor. This is a problem given the importance of this lake to the regional fishery.

In addition to concerns regarding angler success, we are troubled that high numbers of immature cutthroat are being harvested at Cowichan Lake. The results of the angler creel surveys conducted as part of the joint Ministry/VF&GC study suggest that ~45% of cutthroat harvested are <330 mm (Figure 6). Given cutthroat trout in Vancouver Island large lakes mature at ~320 mm, almost half the cutthroat trout harvested at Cowichan Lake are immature.

Gillnetting results suggest that rainbow trout are not a dominant part of the Cowichan Lake system and anglers do not have high encounter rates with this species. According to the results of our snorkel surveys it appears that rainbow may be in the Cowichan River and not available to the angler during the summer months when most of the general (non-derby) fishery occurs. We don't have any information on the life histories of rainbow trout in the Cowichan system and this is a gap which should be addressed to better understand the Cowichan Lake fishery. In addition, we've suggested looking into methods to improve fishing for rainbow trout during the summer including the possibility of introducing sterile fish into a lake embayment.

1. According to the VILQ angler success is ~1 fish/day and although this is below our regional objective for angler success, angler effort and catch is currently at the optimum levels for this lake. We recommend considering additional conservation regulations such as reducing the catch quota to 1 fish/day, or introducing catch-and-release if angler success drops by 10% in the next VILQ survey.
2. Implement a minimum size limit of 300 mm to protect immature cutthroat and allow them to spawn once before recruiting to the fishery.
3. Monitor cutthroat stock status by repeating spawner assessments every 3 years (see Lough, 2012a for details). This frequency will provide data for every generation and can be compared over time. Spawner numbers should be compared to catch data from angler creel surveys, also completed every three years, or angler catch data from the VILQ.
4. Repeat gillnet assessments every 3 years to compare changes in stock status parameters.
5. Fecundity is a critical data gap and studies to determine cutthroat fecundity should be included in the next gillnet assessment of Cowichan Lake.
6. Monitor derby fisheries using instant angler counts, angler creel surveys and data collection at derby weigh-ins especially during peak cutthroat spawning periods in April and May.
7. Conduct genetic analysis of lake and river rainbow trout to determine the life-history type of Cowichan rainbow trout; design a stock monitoring program for rainbow trout stocks contributing to the fishery in Cowichan Lake.
8. Investigate ways to improve angling opportunities for shore anglers including releasing sterile rainbow trout into an embayment such as at the Gordon Bay Provincial Park campsite.
9. A more detailed bathymetric map of Cowichan Lake would allow for a more complete delineation of shoal habitat which is critical for spawning kokanee salmon and rearing cutthroat trout.
10. We support the recommendations by Johner and Sebastian (2011) who suggested implementing successive years of kokanee assessments to reflect the natural

fluctuations in fish abundance between cohorts, size-at-age, growth rates and species composition.

11. Partner with DFO and review management objectives for stocking coho in Cowichan Lake tributaries. Conduct carrying capacity studies at major cutthroat trout spawning tributaries to determine if coho stocking is appropriate and, if so, to what level. Determine the extent of coho salvage being conducted in the watershed and review the need for, and implications of this practice.
12. Review and prioritize existing recommendations for habitat enhancement projects (e.g. Michalski and Jancowski, 2006; Griffith, 1989) and implement projects with the assistance of the VF&GC and local stewardship groups where possible.
13. Implement public and angler awareness programs on topics such as the ecology of Cowichan Lake fish species, and Cowichan Lake fishing regulations.

Operational Management Plan for Cowichan Lake

We've presented the operational management plan for Cowichan Lake in Table 23. A more detailed plan will be provided in the Cowichan Lake fish and fisheries assessment report being compiled by the Fish and Wildlife Branch. This plan will be available from the Fish and Wildlife Branch at the MFLNRO office in Nanaimo in late 2014.

TABLE 23. Operational management plan for Cowichan Lake.

Activity	Objective	Tentative Schedule
Fish Stock Assessment	Conduct gillnetting assessment and compare stock status and catch data to previous assessments. Conduct snorkel surveys at index reaches and compare to previous counts and angler catch data. Conduct electrofishing survey to determine numbers of juvenile trout in tributaries and compare to theoretical production model; conduct shoal assessment if possible to confirm age of cutthroat juvenile recruitment to Cowichan Lake. Conduct genetic analysis to determine life history type of Cowichan rainbow trout.	2014 and every 3 years 2015 and every 3 years 2015 2015+
Fisheries Monitoring	Conduct angler counts and angler creel surveys; conduct angler preference survey during angler interviews. Monitor angler success rate to ensure fisheries management objectives are being met; monitor catch and fish length and weight at derby weigh-ins	2014 and every 2-3 years
Habitat Enhancement	Conduct habitat assessment to document rearing habitat available in the Cowichan Lake watershed (see Michalski and Jancowski (2006) and Griffith (1989) for priorities. Conduct Level 2 WRP Assessment and develop restoration prescriptions for high priority streams. Suggest also evaluating if LWD placement on lake shore is a possibility to increase habitat for rearing juvenile cutthroat trout.	2015
VILQ	Evaluate changes in fisheries statistics every three years	2015 and every 3 years

Chapter 6. Elsie Lake

Lake	Elsie
Planning Unit	West Coast
Watershed	Stamp/Somass
Surface Area (ha)	1,107 (at full storage)
Mean Depth (m)	7.8
Key Tributaries	Ash and Upper Ash Rivers, Ramsay Creek
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden
Limits to Production	Water Withdrawal, Logging
Regional Priority*:	11
<u>Angling Statistics 2011</u>	
Angling Effort	738 angler days
Total Catch	2,450 fish
Angler Success	3.3 fish/angler day
Current Harvest Rate	21%
Optimum Sustainable Effort	3,000 angler days
Optimum Sustainable Catch	5,800
Angler Success at Optimum	1.9 fish/angler day
Stock Status	Rainbow trout are the primary species in the lake, with some cutthroat and Dolly Varden. Current information suggests the stocks are stable and can sustain more angler effort while maintaining current catch rates.
Data Gaps	Snorkel surveys, stream assessments, creel and angler preference surveys
Management Objectives	Wild stock conservation of cutthroat and rainbow trout.
Operational Plan Priorities	Develop protective regulations based on gillnet assessments carried out every three years starting in 2011. Develop regulations aimed at improving angler success and size of fish caught by anglers and increasing spawning escapements.
Potential Partners	BC Hydro, BC Parks, Port Alberni Fish and Game Association, Ark Resort, First Nations; Nuu-chah-nulth Tribal Council, Pt. Alberni, Mowachaht

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Elsie Lake Watershed

General Information

Elsie Lake is located ~40 km northwest of Port Alberni and lies in steep, mountainous terrain within the Coastal Western Hemlock zone in the West Coast PU (Figure 1) (Lewis and Ganshorn, 2005). The mean depth of Elsie Lake is 8 m, the maximum depth is 30 m, pH is 6.9 and dissolved oxygen is 8 mg/l (Table 1) (Perrin and Harris, 2006; FLNRO files, Nanaimo). The lake is oligotrophic and has a high water transparency with secchi depth readings of 9 m (Table 1) (Perrin and Harris, 2006).

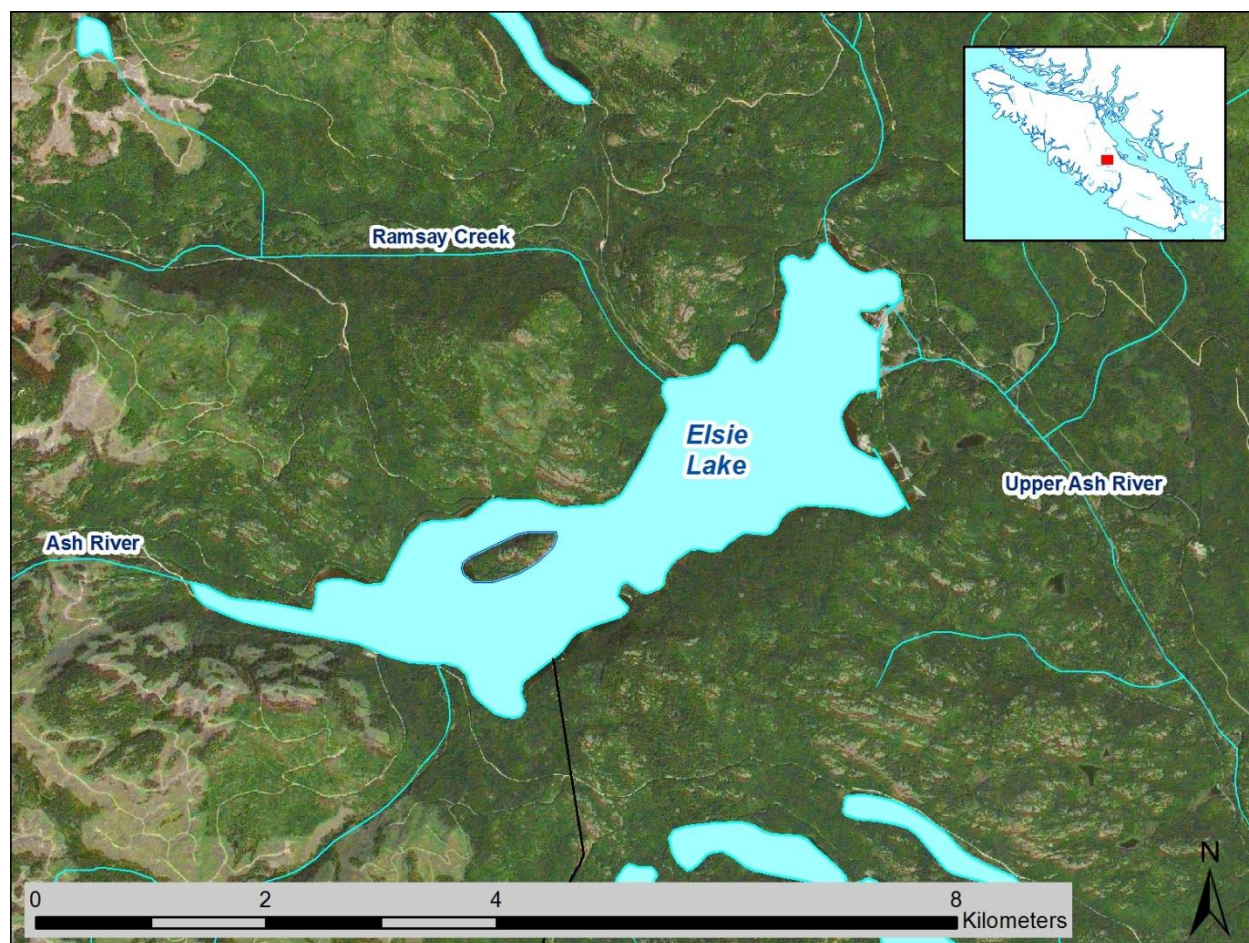


FIGURE 1. Map of Elsie Lake and tributaries; a bathymetric profile of this lake is provided in Appendix 13. (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Elsie Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
West Coast	00133ALBN	672 & **1,107	28.3	20.7	7.8	6.9	32	9.0	1969, 1980

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

**surface area increases to 1,107ha at full storage (Hirst, 1991a).

Elsie Lake was originally a relatively shallow lake (BC Hydro, 2002). In 1957, BC Hydro constructed a 30 m high, 189 m long earthen-filled dam which increased the water surface elevation from 312.5 m to 330.7 m, and surface area from 672 ha to 1,106 ha at full pool elevation (Perrin and Harris, 2006; Hirst, 1991a). The Elsie Lake reservoir is now ~7 km long and 1 km wide, floods ~400 ha of land, stores up to 84 million m³ of water, and has a normal drawdown of ~15 m (BC Hydro, 2002). The catchment area is 218 km² and the mean annual rate of inflow is 21 m³/s. Average annual flow of 10.7 m³/s is diverted year-round through a 7.8 km long tunnel and steel penstock to a powerhouse on Great Central Lake located south of the Elsie Lake reservoir (Perrin and Harris, 2006).

Tributaries

A total of 23 tributaries flow into Elsie Lake but of these, only the upper Ash River, Ramsay and Katlum Creeks, and Creek 2 have significant year-round flow (Burt and Robert, 2003) (Table 2). The Ash River, which is the natural outflow to Elsie Lake, flows south into the Stamp and Somass Rivers, and eventually into the Alberni Inlet. A minimum flow of 3.5 m³/s is released through a hollow cone valve to support fish habitat in the Ash River. The Ash River, Ramsay and Katlum Creeks and Creek 2 support resident fish while summer steelhead are known to access the Upper Ash River and possibly Ramsay Creek (Lewis and Ganshorn, 2005). The remaining 19 creeks in the watershed are small and often ephemeral (Burt and Robert, 2003).

TABLE 2. Names and summary information for major tributaries to Elsie Lake (Source: Burt and Robert, 2003; BC Hydro, 2002).

Tributary	Summary Information
Ash River	The Ash watershed has two sub-basins. The upper sub-basin is dominated by mountains up to 2000 m high which form the boundary between the Ash, Campbell and Comox watersheds; from these mountain sources, the Ash River flows into Oshinow Lake. Below Oshinow Lake, the Ash drops 80 m in 13 km to Elsie Lake.
Upper Ash River	Burt and Robert (2003) surveyed the lower 2.4 km of the Upper Ash River encompassing two reaches. The following stream summaries are taken directly from their report: The lowermost reach (Reach 1) is 1.3km long with a channel flowing through a steep walled canyon. Stream substrates are coarse and dominated by boulders, cobbles, and bedrock. The average field gradient was 1.6% but there are numerous bedrock cascades much steeper than this. In the lower portion of this reach there are a number of deep canyon runs and pools and adult trout (20 – 30 cm in length) were observed holding and feeding from within these habitats. In Reach 2 the valley walls open up, stream gradient diminishes (average 0.4%), and the channel becomes wider and more meandering comprised mainly of riffle/glide sequences. Substrate materials in this reach were found to be dominated by cobbles and gravels, and there are excellent spawning habitats toward the upper extent of our survey. A significant feature of the Upper Ash River is a 3.6 m rock falls located in Reach 1, 35 m above the mouth. This falls was felt to be a barrier to adfluvial trout during spawning migrations, however, larger trout may be able to ascend the falls in late summer when flows in the Upper Ash are substantially reduced (in July trout were observed attempting to jump the first step in the falls, although none were successful). This falls likely prevents Elsie Lake trout from accessing the abundance of high quality spawning habitat located in Reach 2 of the Upper Ash River.
Ramsay Creek	Habitat surveys covered 2.8 km of stream (the first two reaches above the mouth). Within the first reach (0.9 km) the river is confined within steep valley walls with a channel characterised by step cascades (mean gradient 3.5%). Substrates tend to be coarse (mainly boulders and cobbles, with spawning gravels restricted to a few isolated pockets along the stream margin. The reach offers excellent rearing habitat for trout parr (age 1+ and older). No complete fish passage barriers were found in this reach, however, a 1.1 m falls 120 m above the mouth and the numerous cascades may make ascent difficult. Observation of one adult trout in spawning colour half way up the reach attests that passage is possible for at least some fish. In Reach 2

Tributary	Summary Information
Katlum Creek	the valley walls open up, the channel widens, and the gradient diminishes to an average of 0.4%. Dominant substrates include cobbles, gravels, and fines. Spawning gravels were initially in pockets but became virtually unlimited beginning at 2.1 km from the mouth. Fresh redds were found in some of the pocket gravel locations and became more plentiful at the 2.1 km point. In the reach above Elsie Lake (Reach 1), Katlum Creek tends to have a relatively straight channel with the sections entrenched between bedrock walls or within a stable gully. The average channel width 9.7 m and the field gradient from field survey was 2%. A large log jam 157 m above the mouth has created an impassable barrier (a 3 m fall onto a bedrock shelf). The arrangement of the log jam has allowed some spawning gravels to accumulate below the log jam. A few small pockets of gravel were also found in pool tailouts between the log jam and stream mouth. The occurrence of redds and eggs found in these pockets suggested that every available spawning space had been utilized in spring 2002.
Creek 2	The habitat survey on Creek 2 encompassed the first 1.1km of stream above the mouth. The channel in this reach has an average width of about 15m and is confined within stable banks. Longitudinally, this reach has a step-cascade profile with an average gradient of about 5%. Substrates are dominated by cobbles and boulders with the exception of several sections where the stream flows over bedrock shelves. Upstream migration of adfluvial fish is possible for the first 813 m at which point a 5 m rock falls blocks further ascent. Spawning habitat is very limited below this barrier and occurs only in isolated pockets, primarily within the first 140 m above the mouth. Although not extensive, one of the key spawning areas for this creek is on the fan at the creek mouth (~30 m below the logging road bridge crossing). This area is inundated at full pool and thus its availability for spawning is dependent on reservoir level.
Creek 10	Creek 10 is substantially smaller others described here but appears to have sufficient flow to permit adults to ascend for at least part of its length. The survey extended upstream for 275 m, at which point a complete barrier was encountered (2 m vertical rock falls). However, at the survey flow (10 L/s) adult trout may only be able to ascend to a cascade at 129 m (11% gradient on the cascade). This stream runs across the forest floor with little vertical erosion (down-cutting) but with some lateral erosion of banks. The average gradient within the survey reach was 8% and the average channel width about 4 m. Spawning gravels occur in pockets with the best gravel in the 30 m section between Elsie Lake and the logging road.

Species Composition

Anadromous fish were historically absent from Elsie Lake because of a major falls located in the 25 km between the dam and the Stamp River (BC Hydro, 2002). Griffith (1993) surveyed these falls and provides a complete discussion related to fish access. Lanternman Falls, which is located 5.5 km above the Stamp confluence, was also assessed as a barrier under post-project flow to all migrating adults except summer steelhead (Horncastle, 1978). Some coho salmon may also ascend these falls in some flow conditions BC Hydro (2002).

According to Beamish and Northcote (1989), rainbow and cutthroat were present in Elsie Lake prior to its impoundment in 1959. Burns (1969) notes that gillnet samples from 1962 and 1969 consisted of rainbow, cutthroat, and hybrids of these species.

Dolly Varden were gillnetted in Dickson Lake many years ago (Anonymous, 1953; Carmichael and Philip, 1978) but were not captured in tributaries or lakes electrofished by Griffith in 1992 (BC Hydro, 2002). It is possible that this species is present only in isolated headwater lakes (BC Hydro, 2002).

Sculpins, stickleback and pumpkinseed have been sampled in Elsie Lake (BC Hydro, 2002) and there have also been incidental reports of kokanee (Triton, 1995; BC Hydro, 2002; Perrin and Harris, 2006). Pacific lamprey were present in Elsie Lake at the time of dam construction

(Beamish and Northcote, 1989). Electrofishing assessments conducted in 1986 and 1987 in lake inlets did not find this anadromous species, however, and it was concluded they failed to establish a landlocked freshwater population following dam construction (Beamish and Northcote, 1989).

Burns (1969) notes that he found hatchery steelhead in a gillnet sample collected in 1969. Surplus juvenile steelhead from the Robertson Creek hatchery were also released into Elsie Lake in nine separate years from 1982 to 1997 as part of a colonization program implemented by the province (Burt and Robert, 2003). Annual numbers of fish released ranged from 39,000 to 215,000 (Triton, 1995).

The only resident fish species present in tributaries to 0 are rainbow and cutthroat trout, and possibly some hybrids of the two species (Lewis and Ganshorn, 2005). Detailed discussions on the results of tributary sampling can be found in Burt and Robert (2003), and Lewis and Ganshorn (2005).

Summary of Work and Reports

Elsie Lake was surveyed by Provincial Fisheries staff in 1969 and 1980 (FISS) and has been assessed extensively for the FWCP by the Hupacasath First Nation and a number of other agencies and consultants. Fish assessments include work by Harding and Offin (1969), Horncastle (1978), Beamish and Northcote (1989), Burt and Robert (2003), The Ash River WUP Consultative Committee (2003), Burt and Lewis (2004), Perrin and Harris (2006), Robert and Lewis (2006), Lewis and Ganshorn (2005) and Lewis et al (2006). Some of these studies have included habitat inventories and fish presence surveys of various reaches of the Ash River, watershed snorkel surveys of the upper Ash River from Oshinaw to Elsie Lakes, bathymetric surveys and limnological and fish population sampling. In 2005, Perrin and Harris conducted an assessment of the trophic state of Elsie Lake to determine if the lake was a candidate for nutrient addition as a measure to restore fish populations.

2.0 Limits to Fish Production

Water Withdrawal

The Elsie Lake reservoir is relatively stable from April through June (Perrin and Harris, 2006) and is typically drawn down beginning in July. Elsie Lake has a relatively large active storage volume (over 80% of total volume) which is fully utilized for power generation (Hirst, 1991a). BC Hydro stores water in the reservoir for power generation during the drier summer and fall months and when the reservoir level drops below an elevation of 317.91 m, power generation ceases to conserve water for future fish flow releases (Lewis and Ganshorn, 2005).

There is a 1 – 2 week shutdown during August for annual maintenance (Burt and Robert, 2003) and the reservoir is normally fully drawn-down by September each year with drawdown ranging from 6 m –14 m below full pool level. Elsie Lake refills from October through November and usually does so rapidly, often within a month following the onset of heavy winter rainfall (Hirst, 1991a).

Following the completion of Elsie Dam, 401 ha of land were flooded resulting in the loss of 5 km of mainstem habitat in the Ash River upstream of Elsie Lake, or 30 ha of channel habitat and 30 ha of riparian habitat (BC Hydro, 2002). Other tributaries to Elsie Lake were also flooded

resulting in the loss of 5 km of tributary habitat including 14 ha of riparian habitat (BC Hydro, 2002). The flooding of Elsie Lake also resulted in the loss of 72 ha of wetland habitat.

For resident trout populations the 15 m draw-down regime at Elsie Lake probably offsets any net habitat gain that was created by the increased volume from impoundment. Moreover, if kokanee are, or were present in Elsie Lake, their spawning habitat will likely have been impacted by the large draw-down and rapid refilling of the lake.

Ash River flows are diverted year-round into Great Central Lake except during annual maintenance in August and these flows augment the live storage of Great Central Lake and the discharge of the Stamp River. Hirst (1991a) notes that this diversion has reduced flows to the downstream Ash River, increased flow into Great Central Lake, and affected wetted channel area, seasonal temperatures and productivity in these areas.

Logging

Other impacts on fish in the Ash River watershed are principally the historic and current effects of logging. Much of the timber above Elsie Lake has been harvested and according to BC Hydro (2002), much of the timber between Elsie and Dickson lakes has been harvested since 1972.

Stream and Lake Habitat

There is no stream habitat for trout spawning within the drawdown zone when the reservoir is at full pool (Ash River Water Use Plan Consultative Committee, 2003). Lewis and Ganshorn (2005) note that if fish were to spawn in the drawdown zone at lower reservoir levels, the eggs would be inundated if the reservoir level increased to full pool.

A study by Triton (1995) concluded that trout spawning habitat is in short supply in the lower 100 m - 200 m of Elsie Lake reservoir tributaries and this may limit recruitment to Elsie Lake. This study also found that five of 20 tributaries to Elsie Lake were not accessible to fish, six had no flow but the remaining streams had flow, appeared to be accessible, and had suitable substrate for resident trout spawning.

Lewis (2001) also conducted a study on Elsie Lake tributary habitat within the drawdown zone and found the highest quality and quantity of spawning habitat in the lowermost sections of the drawdown zone. He also quantified rearing habitat in the tributaries and determined that as the elevation of the reservoir increases, rearing habitat within the drawdown zone decreases. According to Burt and Robert (2003) the key limiting factors in the Elsie Lake watershed are:

1. A shortage of accessible spawning gravel which is a direct result of Elsie Lake reservoir inundating >90% of spawning gravels historically available to adfluvial fish. This may limit the recruitment of juvenile trout to Elsie Lake.
2. Limited amounts of stream habitat available for juvenile rearing depending on the level of spring runoff (i.e. greater runoff allows greater access to small tributaries). The implication of this is that much of each year's fry population is probably forced to migrate to the lake shortly after emergence due to competition for food and spacial resources.
3. The quality of littoral nursery habitats which is crucial to juvenile survival and subsequent adult recruitment. The annual drawdown has, for the most part, prevented

aquatic plants from colonizing littoral habitats and there is lack of emergent and submergent aquatic plants and riparian vegetation suggesting a shortage of cover and food supply for juvenile nursery habitats.

Barriers to Migration

A number of studies (Lewis and Ganshorn, 2005; Crippen Wright Engineering Ltd., 1956; Anonymous, 1959; Photographic Survey Corporation Ltd., 1956; and Anderson et al., 1959) do not give any indication of a barrier at the outlet of Elsie Lake prior to impoundment. Two surveys of the Ash River done in 1953 and 1954 identify Dickson Falls located in the Ash River 10 km above the confluence and 15 km downstream of Elsie Lake as the upstream migration limit of all salmonids (Anonymous, 1953; Anonymous, 1954; in Griffith, 1993). Selective blasting by the Fish and Wildlife Branch in 1975-76 allowed summer steelhead above Dickson Falls to the base of the Elsie Lake dam.

Fish Stocking

There has been a good deal of fish enhancement done in the Ash River watershed, with much focus on summer steelhead and coho stocking from Robertson Creek (Lewis and Ganshorn, 2005). Numbers ranging from 1,633 - 215,000 of summer steelhead (fry, parr, juveniles, smolts, and adults) were also stocked in the Elsie Lake reservoir on several occasions between 1982 and 1997. No assessment of the stocking was ever carried out.

Rainbow trout have comprised increasingly larger proportions of the samples since 1968, and in 1994 and 2002 this species accounted for >90% of the samples. We attribute this to the stocking of surplus steelhead into Elsie Lake by MOE in the late 1980's into the late 1990's. This practice has now been discontinued. The Agencies continue to discuss the potential impacts of releasing hatchery coho fry above Dickson Falls on steelhead, resident trout and char stocks.

Nutrients

Perrin and Harris (2006) conducted a detailed assessment of the trophic state of Elsie Lake and note that Elsie Lake reservoir is an ultra-oligotrophic, fast flushing system which may limit pelagic community development. These investigators found that concentrations of all forms of nitrogen and phosphorus were low, particularly in the spring and summer when biological demand for nutrients is high. Standing crop and fish production models showed the reservoir likely supports rates of fish production that are among the lowest of coastal ultra-oligotrophic lakes (Perrin and Harris, 2006).

The lack of planktivorous fish populations highlighted by Perrin and Harris (2006) may explain why mean sizes of cutthroat trout, which normally prey on planktivores including kokanee, are not large in size in Elsie Lake (mean size ~256 mm – 290 mm; Table 5). With little competition by species including kokanee, it may also explain the expansion and now dominance of rainbow trout in this large lake.

While Perrin and Harris (2006) state that although productivity in Elsie Lake reservoir is limited by the availability of nutrients, data gaps remain to determine the potential response by fish to nutrient addition. These researchers suggest that although an increase in biological production

through the pelagic food web to zooplankton is a likely outcome of nutrient addition, an increase in benthic production is also likely to occur from the same treatment.

3.0 Angling Statistics

Angler Effort

Angler effort has averaged ~1,300 angler days/year since 1986, however, there has been a downward trend in angler effort over most of the VILQ survey period (Figure 2). In 1989, angler effort reached 2,500 angler days dropping to <900 angler days in 1992 then rising in 2002 to ~1,200 angler days. Angler effort dropped again in 2006 and 2011 to ~700 angler days which is the lowest level recorded at this lake.

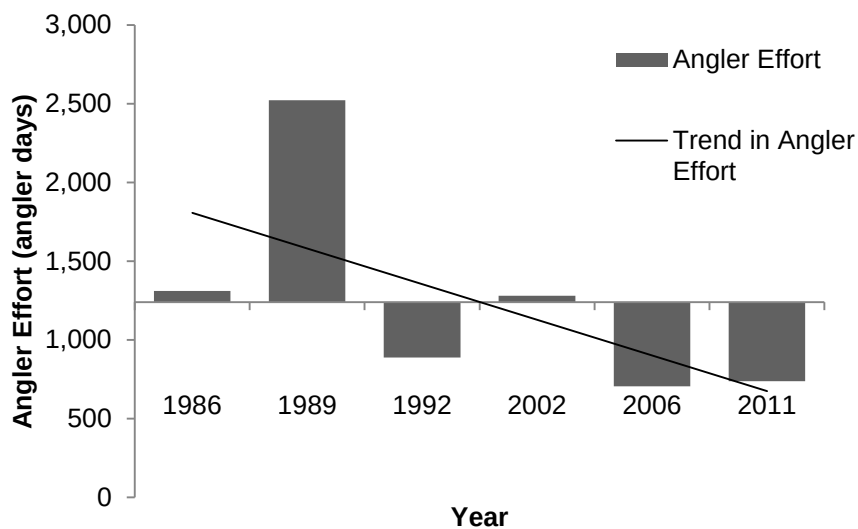


FIGURE 2. Angler effort (angler days) by year compared to average angler effort and trend in angler effort from 1986-2011 at Elsie Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Catch

On average, ~3,000 fish have been caught every year in Elsie Lake since 1986 and like angler effort, there has been a downward trend in catch over the 25 year survey period (Figure 3). There is considerable variability in the catch data from Elsie Lake, however. For example, from ~2,900 fish caught in 1986, total catch reached its highest level of ~5,000 fish in 1989. By 1992, the following survey year, catch declined to ~1,500 fish but in 2002 it rose to ~3,500 fish. In 2006, catch was ~1,300 fish and in 2011 catch was ~2,500 fish.

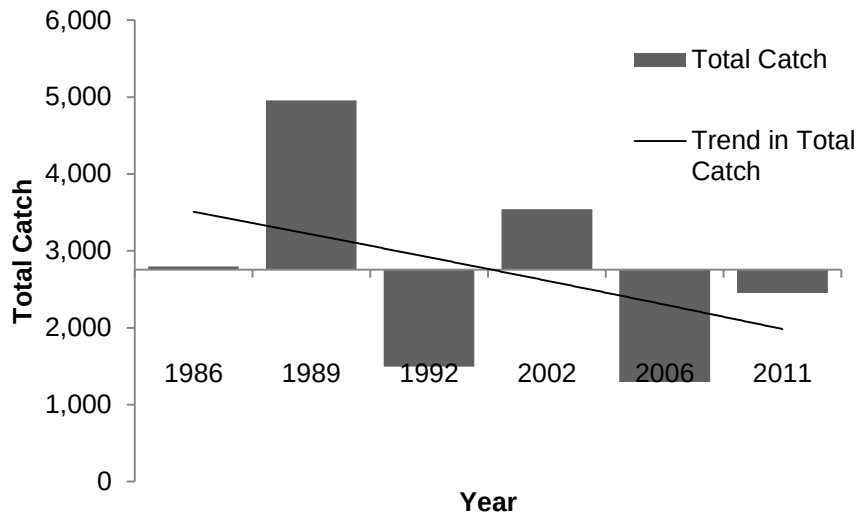


FIGURE 3. Total catch by year compared to average catch from 1986 - 2011 and trend in total catch at Elsie Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

We've shown the breakdown by species of fish caught in 2006 and 2011 in Table 3. Cutthroat comprised between 36% and 41% of the catch while rainbow comprised between ~57% and 64% of the angler catch. In 2011, anglers caught Dolly Varden for the first time and this species comprised <2% of the total catch that year.

TABLE 3. Catch of rainbow and cutthroat trout at Elsie Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	466	36.0	1,002	40.9
Rainbow	830	64.0	1,406	57.4
Dolly Varden	0	0.0	42	1.7
Total	1,296		2,450	

Angler Success

Angler success at Elsie Lake has averaged ~2.4 fish/day which is well-above the regional success objective of 1.6 fish/angler day. There also been an increasing trend in angler success over the survey period (Figure 4). Angler success ranged from ~2.4 fish/day in 1986, to 1.4 fish/day in 1992. The decrease in angler effort observed in 2002 was accompanied by an increase in angler success to almost 2.6 fish/day. Angler success declined to 1.8 fish/day in 2006, but rose to ~3 fish/day in 2011.

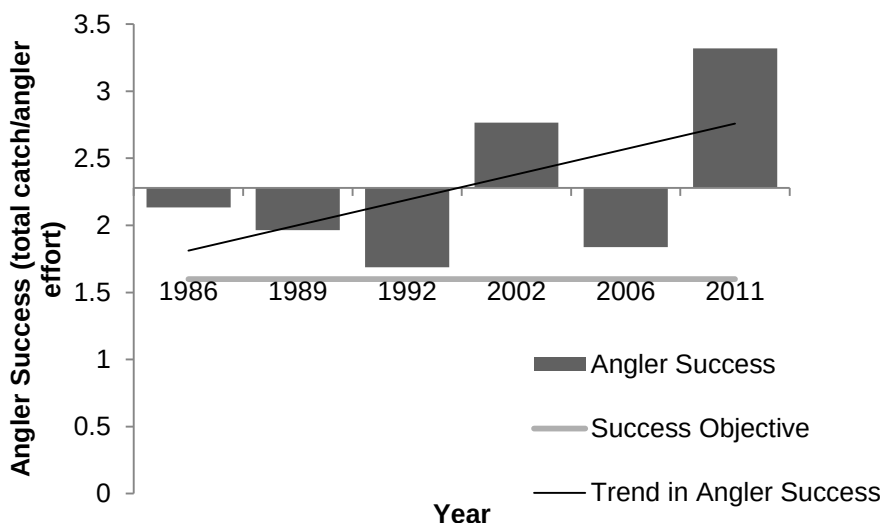


FIGURE 4. Angler success (total catch/total angler effort in angler days) compared to average angler success and the objective for angler success (1.6 fish/angler day) and trend in angler success at Elsie Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Angler Creel Surveys

A 1986 Vancouver Island angler creel census estimated a total of 2,795 fish caught annually in Elsie Lake with 1,500 (52%) kept by 420 anglers (Hirst, 1991a). Hirst (1991a) calculated the mean time expended per angler at Elsie Lake at 3.1 days/year, and estimated a success rate of 2.1 fish/day. Note Hirst's (1991a) estimation was close to the ~2.3 fish/day estimated by the VILQ that same year (Figure 4).

Harvest

Overall, harvest rates were ~50% in 2006 at Elsie Lake (Table 4). Anglers harvested ~51% of their cutthroat and 48% of their rainbow trout catches. In 2011, harvest rates fell to 21% with anglers harvesting only ~20% of their cutthroat catch and 23% of their rainbow catch.

TABLE 4. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Elsie Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	466	239	51.3	1,002	195	19.4
Rainbow	830	398	48.0	1,406	320	22.8
Dolly Varden	0	0	0.0	42	0	0.0
Total	1,296	637	49.2	2,450	515	21.0

4.0 Stock Status Indicators

Relative Abundance

We've shown the relative abundance of fish sampled in Elsie Lake between the 1953 and 2002 in Figure 5. Elsie Lake was sampled by gillnet in 1962 (N=108) and 1963 (N=18) and in both years the catch consisted of mostly cutthroat trout.

Despite the fact there is no information on the location, time and type of nets that have been set at Elsie Lake, it's clear there is an increasing proportion of rainbow trout and decreasing proportion of cutthroat trout in the samples (Lewis and Ganshorn, 2005) (Appendix 13). In 1969, samples consisted of 85% rainbow trout (including hatchery steelhead) and 15% cutthroat trout (Burns, 1969, Harding and Offin, 1969, Hirst, 1991b). The most recent survey in 2002 found >93% rainbow trout and rainbow/cutthroat hybrids (Burt and Robert, 2003; Perrin and Harris, 2006). A similar trend of increasingly large samples of trout is found in electrofishing data from tributaries to Elsie Lake (Appendix 13).

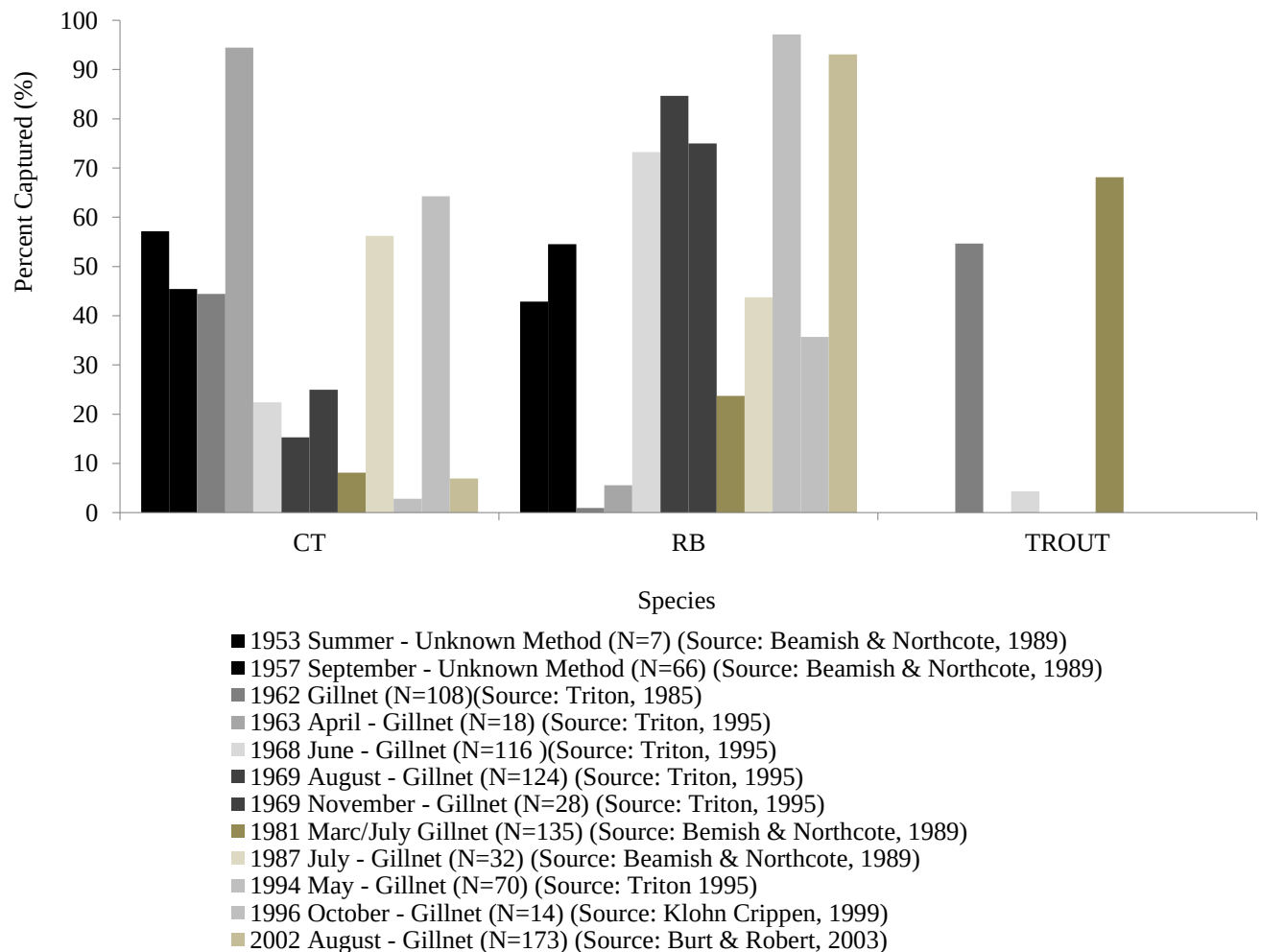


FIGURE 5. Percent cutthroat trout, rainbow trout and unidentified trout captured in Elsie Lake by gillnet and unknown sample method in 1953, 1957, 1959, 1960, 1962, 1963, 1968, 1969, 1981, 1987, 1994, 1996 and 2002 (Source: FLNRO files, Nanaimo; Pelcher, 1963; Beamish and Northcote 1989; Triton, 1995; Klohn- Crippen, 1999; Burt and Robert, 2003).

Snorkel Surveys

Ministry staff conducted snorkel surveys of the Ash River from 1995–2000 to enumerate steelhead. We've provided summaries of snorkel survey counts of all adult fish observed in Elsie Lake tributaries by Robert and Lewis (2006) in Appendix 13.

Length and Weight

We've provided a detailed a summary of length and weight data for Elsie Lake in Table 5. In the 1960's, cutthroat ranged from 190 mm - 392 mm and averaged 256.1 m. The average weight of the species that decade was 227.9 g. In the 1990's, cutthroat ranged from 215 mm - 402 mm, averaged 285.8 mm and had a mean weight of 240.8 g. Cutthroat trout in Elsie Lake currently range from 232 mm -400 mm and average 296.4 mm. The mean weight of this species in 2000 was 197.4 g.

TABLE 5. Minimum, maximum, mean and modal length and mean weight for cutthroat and rainbow trout captured by gillnets in Elsie Lake by decade 1960 – 2000 (Source: FISS; FLNRO files, Nanaimo).

Species	Decade	N	Length (mm)				Weight Mean (g) Mean
			Minimum	Maximum	Mean	Mode	
Cutthroat	1960	7	190.0	392.0	256.1	-----	227.9
	1990	11	215.0	402.0	285.8	-----	240.8
	2000	7	232.0	400.0	296.4	-----	197.4
Rainbow	1960	21	130.0	255.0	197.9	205	106.0
	1990	37	119.0	310.0	204.6	184	87.3
	2000	159	107.0	318.4	189.6	142	89.7

Rainbow trout sampled by gillnets in Elsie Lake in the 1960's ranged from 130 mm - 255 mm and averaged ~198 mm. The modal length of this species was 205 mm and the mean weight was 106 g. In the 1990's, rainbow ranged from 119 mm -310 mm and averaged 204.6 mm. The modal length for rainbow was 184 mm and the mean weight was 87.3g. This decade, rainbow trout range from 107 mm to 318.4 g and averaged 189.6g. The modal length of rainbow is now 142 mm and the mean weight is ~90g.

In addition to reviewing the trends in species composition, Lewis and Ganshorn (2005) examined the size of rainbow and cutthroat caught at Elsie Lake (Appendix 13). These investigators found that in 2002, the rainbow trout population consisted of a higher percentage of smaller individuals (<180 mm) than in 1994, and that the cutthroat population is composed of larger individuals than the rainbow trout population.

Age and Growth

Twenty-one cutthroat trout were sampled and aged over the past ~20 years and we've provided a length-at-age analysis in Figure 6A. One aged 1+ cutthroat was sampled and it was 215 mm, one age 2+ cutthroat was 257 mm, five aged 3+ cutthroat ranging from 225 mm – 323 mm and averaging ~272 mm, 11 aged 4+ cutthroat ranging from 232 mm – 349 mm also averaging ~272 mm, two aged 5+ cutthroat averaging 327 mm and one age 4+ cutthroat 400 mm have been sampled.

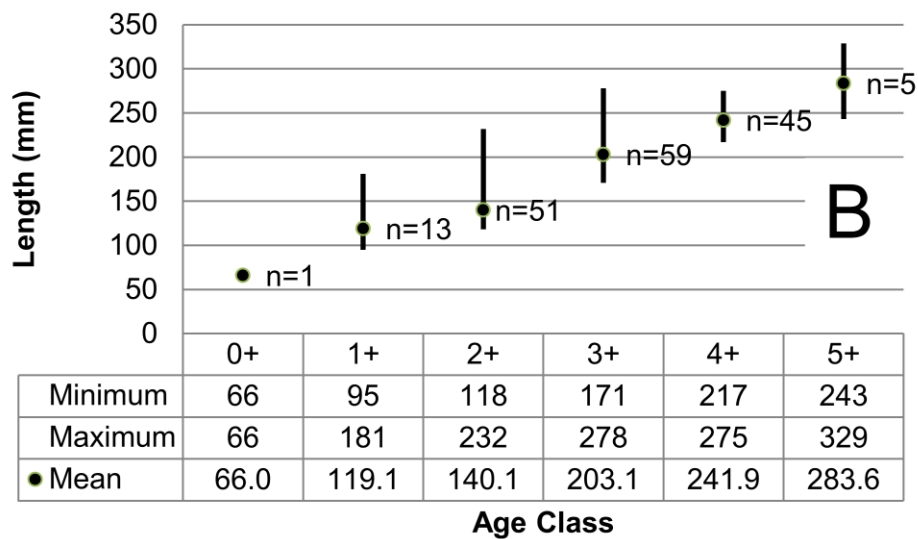
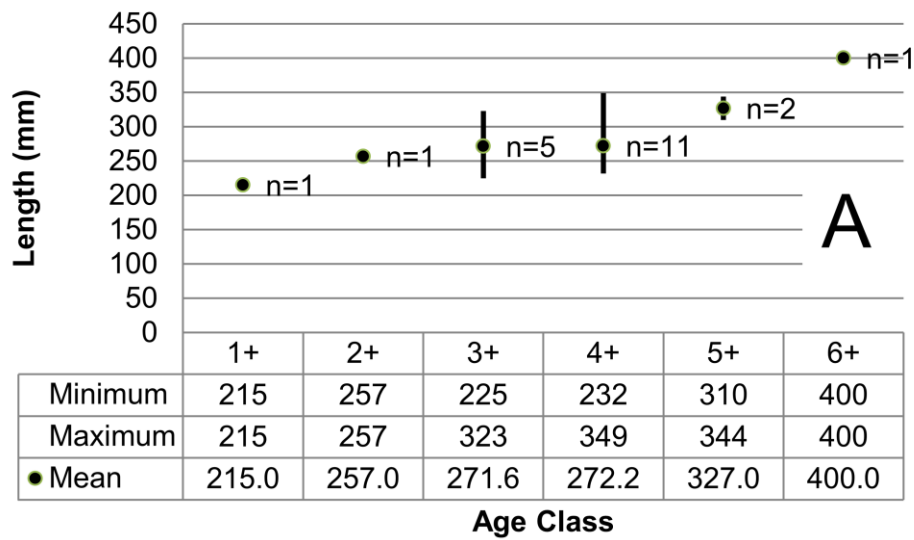


FIGURE 6. Length-at-age of (A) cutthroat trout (N=21) and (B) rainbow trout (N=174) sampled by gillnet in the 1990's and angling in the 2000's in Elsie Lake (Source: Burt and Robert, 2003; Klohn-Crippen, 1999 and Triton, 1995).

Investigators have also sampled and aged 174 rainbow trout over the past 20 years (Figure 6B). One age 0+ rainbow was sampled and it was 66 mm while 13 age 1+ rainbow ranging from 95 mm –181 mm and averaging 119 mm, 51 age 2+ rainbow ranging from 118 mm – 232 mm and averaging 140 mm, 59 age 3+ rainbow ranging from 171 mm – 78 mm and averaging 203 mm, 45 age 4+ rainbow ranging from 217 mm –275 mm and averaging ~242 mm and five age 5+ rainbow ranging from 243 mm –329 mm and averaging 238 mm have been sampled.

Mean Age

Lewis and Ganshorn (2005) examined the difference in age composition between rainbow and cutthroat trout and found that in 2002, Elsie Lake was dominated by age 4+ cutthroat trout (67% of the population), and the rainbow trout population was comprised of ages 2+ (28%) to 4+ (32%) fish (Appendix 13). The mean length of cutthroat trout sampled by angling and in gillnets is ~280 mm and the mean age is 3+ while the mean length of rainbow is ~190 mm and the mean age is 2+ (Table 6).

TABLE 6. Mean age of cutthroat and rainbow trout captured in Elsie Lake (Source: Burt and Robert, 2003; Klohn-Crippen, 1999 and Triton, 1995).

Species	N	Mean Length (mm)	Mean Age
Cutthroat	21	279.9	3+
Rainbow	174	189.9	2+

Catch Indicators

Total Catch

The number of cutthroat trout has been small relative to the number of rainbow trout captured in gillnets since the 1960's (Table 7). The number of rainbow trout have increased in the samples especially in 2000. No information on the number of gillnets, number of net sets, set locations or soak times has been provided so we cannot make catch/effort comparisons.

Table 7. Total catch of cutthroat and rainbow trout captured in gillnets Elsie Lake by decade 1960 - 2000 (Source: FISS; FLNRO files, Nanaimo; Burt, 2002).

Species	1960	1980	1990	2000
Cutthroat	11	29	11	7
Rainbow	43	46	73	161
Total	54	75	84	168

Data Gaps

Despite the large body of work on Elsie Lake, there is no habitat inventory data available for the Ash River or any of its main tributaries (Table 8). There has been relatively little work on fish distribution in Elsie Lake tributaries (i.e. Upper Ash) and there is no information on fish abundance in Elsie Lake to compare estimates of standing stocks in the tributary streams. It's also unknown whether spawning populations observed in 2005 snorkels counts reflect the capacity of Elsie Lake to produce adult fish.

TABLE 8. Summary of data gaps for Elsie Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	< 10 years	>10 years	No data
Gillnetting	X		
Angler Creel Survey		X	
VI Lakes Questionnaire	X		
Snorkel Surveys	X		
Electrofishing (streams)	X		
Juvenile age, weight, density	X		
Lake/Limnology*	X		
Stream Habitat Inventory		X	
Ash River & tributaries			X
Angler Preferences			X
Water Quality/Lake Productivity	X		
Lake Fertilization*	X		

*baseline assessment-see recommendations by Perrin and Harris (2006).

5.0 Fisheries Objectives and Management Strategies for Elsie Lake

Existing Regulations

Elsie Lake is covered by the general regional regulations of four trout but not more than 1 > 50cm (two hatchery steelhead >50cm allowed). Anglers must release all Dolly Varden.

In Dickson Lake, there are no trout >50cm allowed; and there is a bait ban and single barbless hook regulation. There is no fishing from Dickson Lake to signs 200 m below Lanternman Falls, December 1 – April 30 in the Ash River and the Ash is closed all year from Dickson Falls downstream 30 m and all year from Elsie Lake to Dickson Lake.

Maximum Catch and Effort at Current Regulations

The maximum angler effort at the current regulations is ~5,000 angler days and the maximum catch is ~6,900 fish (Figure 7). The optimum sustainable angler effort is 3,000 angler days and the optimum catch is ~5,800 fish. At the optimum, angler success would be ~1.9 fish/day. The current angler effort and total catch is well below the optimum sustainable angler effort, the yield is below that predicted by MEI and Ryder's simplified regression (Appendix 8), and at ~3 fish/day, the current success rate is well above our regional target of 1.6 fish/day.

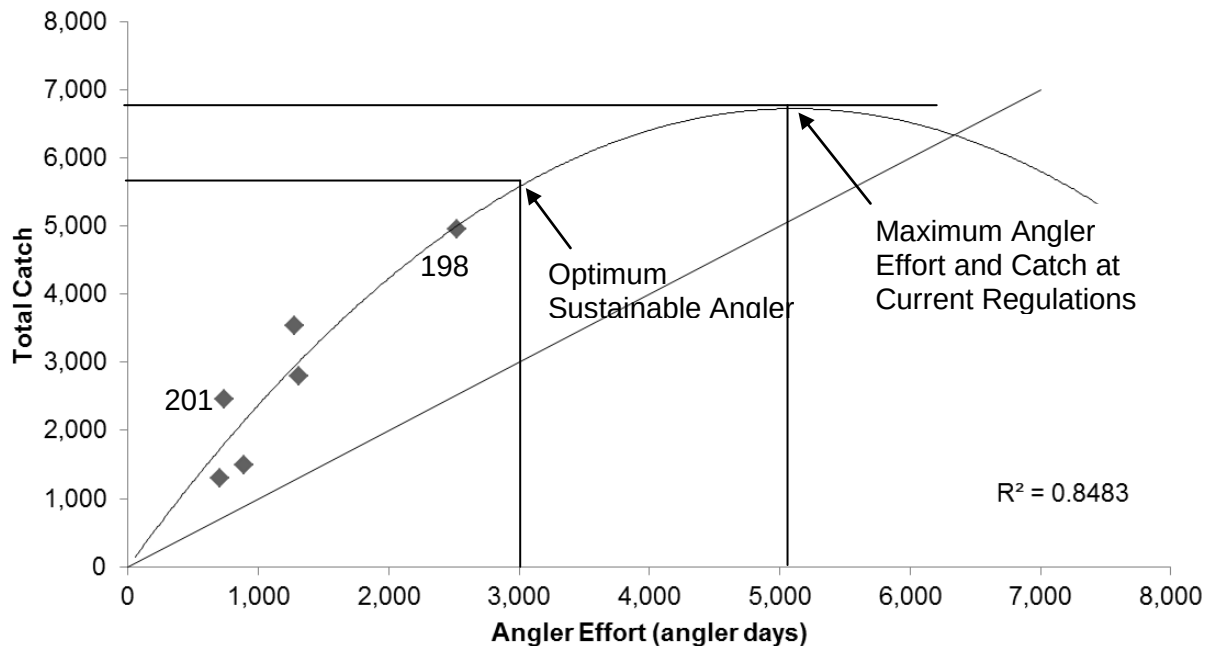


FIGURE 7. Angler effort (angler days) vs. total catch, maximum angler effort and catch and optimum sustainable angler effort and catch at the current regulations at Elsie Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

Angler effort at Elsie Lake is decreasing but angler success is increasing which suggests the fishery is healthy. This is supported by the work of Robert and Lewis (2006) who found that the streams currently accessible to Elsie Lake populations are at their theoretical capacity for juvenile production, meaning that escapement of adult fish from Elsie Lake is not limiting productive capacity. At ~20%, angler harvest is also not a concern at this lake.

While angler success is not a concern at present, the proportion of catch of each species should be monitored given the increasing abundance of rainbow trout in this lake. The lack of planktivorous fish in Elsie Lake, and the fact that cutthroat in this lake do not achieve a large size suggest the Elsie Lake stock may not be piscivorous. As such, there may be limited resources in the lake and the increase in rainbow trout may impact numbers of cutthroat.

Vancouver Island large lake cutthroat grow much larger than rainbow trout. However, in the case of Elsie Lake it appears that rainbow (stocked steelhead) have had a negative impact on the numbers of cutthroat. Steelhead have been stocked in numbers far above the carrying capacity of the lake and because of sheer numbers may have displaced cutthroat. It also appears Dolly Varden may only reside in tributaries in this watershed. The impacts to these stocks if coho were planted in tributaries would likely be dramatic and irreversible. We strongly discourage any stocking in the Elsie Lake watershed.

1. Current angler statistics suggest Elsie Lake can sustain more angler effort while maintaining catch rates. It is important to implement a gillnetting program to collect stock status data, particularly age data for cutthroat.
2. Given the absence of young cutthroat in the last gillnet sample, and the fact that cutthroat are getting older and larger, it's possible recruitment of young fish has

declined. We recommend tributary sampling to assess the juvenile component of the stock.

3. Rainbow trout stocks appear stable, and gillnetting data will provide catch indicator data to compare to past gillnet surveys. Future gillnetting surveys should also pay specific attention to catch indicators and mean size of rainbow trout in the event that numbers of this species continue to increase.
4. We do not recommend any regulations changes until the stock status for cutthroat can be determined.
5. We recommend monitoring angler catch using the VILQ to determine proportion of each species caught over time.
6. Schedule gillnetting every three years if regulations change.
7. Explore potential snorkel survey monitoring of the Upper Stamp River above Elsie Lake in 2015 to evaluate rainbow and/or cutthroat spawning.
8. Finally, we suggest that a number of fish assessments are necessary and we've detailed these in the Operational Management Plan (Table 9).

Operational Management Plan

We've summarized the operational management plan for Elsie Lake in Table 9. We recommend additional studies as outlined in Perrin and Harris (2006) given the increase in rainbow trout numbers and the fact that both rainbow and cutthroat may be relying on the same prey resources. In addition, a 2002 study by the Hupacasath First Nations suggested the two most crucial habitats impacted by Elsie Lake reservoir are lack of spawning habitat, and the poor quality of littoral nursery habitats. We recommend additional studies follow-up on this work.

TABLE 9. Operational Management Plan for Elsie Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Conduct gillnetting assessment to gather stock status data for cutthroat and rainbow trout. Repeat net locations and timing of past surveys and repeat or set standard times and location of gillnets for future surveys.	2018
	Conduct tributary electrofishing to assess juvenile component of stocks.	2018
	Implement additional studies recommended by Perrin and Harris (2006) and Robert and Lewis (2006).	2019+
Habitat Assessment and Restoration	Review and implement prescriptions provided in 2002 Hupacasath First Nations report regarding addition of spawning gravels; review and implement prescriptions by Burt and Robert (2003) to provide additional spawning habitat for all creeks combined excluding Ramsay Creek.	2020
VILQ	Evaluate changes in fisheries statistics every three years.	Ongoing

Chapter 7. Great Central Lake

Lake	Great Central
Planning Unit	West Coast
Watershed	Stamp/ Somass
Surface Area (ha)	5,085
Mean Depth (m)	124
Key Tributaries	Stamp River, McBride and Drinkwater Creek
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden, Steelhead
Limits to Production	Water Withdrawal, Nutrients
Regional Priority*:	5
<u>Angling Statistics 2011</u>	
Angling Effort	3,411 angler days
Total Catch	5,597 fish
Angler Success	1.6 fish/angler day
Current Harvest Rate	14%
Optimum Sustainable Effort	4,100 angler days
Optimum Sustainable Catch	6,100
Angler Success at Optimum	1.5 fish/angler day
Stock Status	Unknown; stock status data must be updated
Data Gaps	Gillnetting data is >3 decades old and more review of this lake's physical and biological factors are required to determine netting times and locations.
Management Objectives	Gillnet to establish stock status and monitor the fishery using the VILQ and the Ark derby. Also consider installing an angler creel survey box at the Ark Resort to monitor angler catch all year
Operational Plan Priorities	stock assessment.
Potential Partners	Cascade Forest Products, BC Hydro, Ark Resort, Port Alberni Fish and Game Association

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Great Central Lake Watershed

General Information

Great Central Lake is located ~15 km west of Port Alberni in the West Coast (WC) PU (Table 1). This large lake is ~45 km long, is situated 85 m above sea level, and discharges into the upper end of Alberni Inlet via the Stamp and Somass Rivers (Figure 1). Great Central Lake is the 2nd deepest lake on Vancouver Island with a maximum depth of 294 m and an average depth of 212 m (Shortreed et al, 2001). The lake has a surface area of 5,085 ha, a perimeter length of 82.3 km, a TDS of 20 ppm and a pH of 7.0.

TABLE 1. Location, size, depth and water quality parameters at Great Central Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
West Coast	00587ALBN	5,085	82.3	250	124	7.1	20	15.5	1969, 1975, 1978, 1986

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

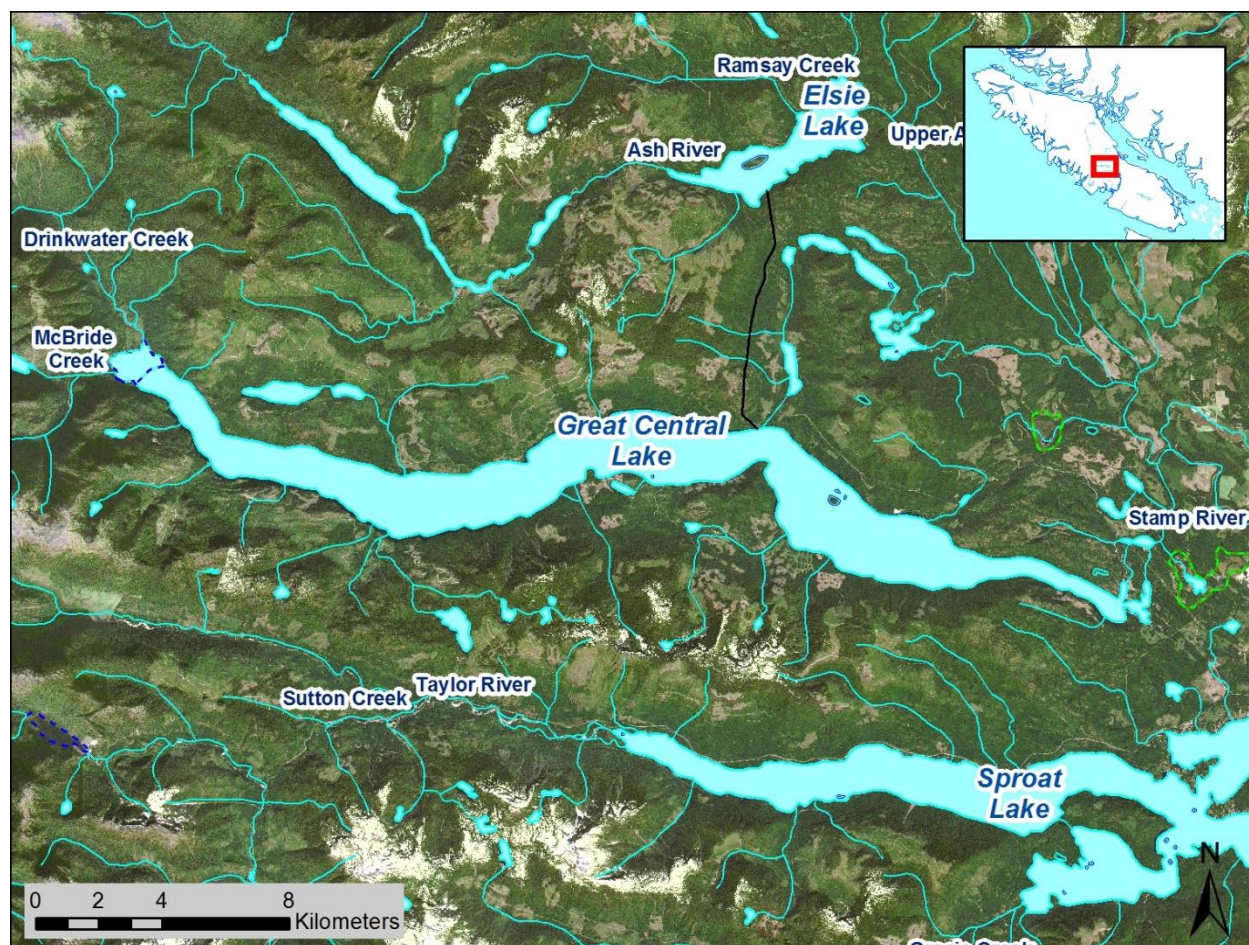


FIGURE 1. Map of Great Central Lake and tributaries; a bathymetric profile of this lake is provided in Appendix 14 (Source: iMap BC).

There is extensive logging in the Great Central Lake watershed, but shoreline development is limited to the outlet area. A dam located at the outlet of Great Central Lake controls water levels and provides summer water storage. There are no settlements in the drainage basin, however, Mainstream Canada Fish Hatchery, a private Atlantic salmon hatchery, is located adjacent to Great Central Lake at Boot Lagoon (Streamline Environmental Consulting, 2006).

Tributaries

The Stamp River is the main outlet of Great Central Lake (Table 2). A small portion of this river drains through Robertson Creek at the north end of Boot Lagoon. The Stamp River becomes the Somass River which drains to the Pacific Ocean at the head of Alberni Inlet in Port Alberni.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Great Central Lake (Source: FISS - Fisheries Inventory Stream Report; Horncastle, 1978; Barraclough and Robinson, 1972; Griffith, 1993; Lewis and Ganshorn, 2005).

Tributary	Length (km)	General Information
Stamp River	33.65	Main outlet of Great Central Lake, small portion of the river drains through Robertson Creek at the north end of Boot Lagoon.
Ash River	54.36	Ash River flows are diverted year round into Great Central Lake. These flows augment the live storage of Great Central Lake and the discharge of the Stamp River.
Drinkwater Creek	17.35	A main tributary to Great Central Lake located at west end contains two falls ~3 km upstream of the lake
Lanternman Creek	16.82	There is a 10 m barrier falls in the mainstem of Lanternman Creek, 3 km upstream from the mouth (Griffith 1993)
Wolf Creek	11.16	Wolf Creek splits into two forks ~2.4 km upstream from the mouth. There are vertical barrier falls in excess of 10 m in height in both forks (Griffith, 1993)
McBride Creek	8.73	A main tributary to Great Central Lake located at west end. McBride Creek splits into two main forks approx 1 km above the lake (Horncastle, 1978).
Ramsay Creek	15.1	
Gretchen Creek	10.2	
Margaret Creek	10.5	
Katlum Creek	7.3	
Hal Creek	6.7	
Deer Creek	6.4	
Bear Creek	5.2	
Dorothy Creek	4.5	
Forestry Camp Creek	4.5	
Beaver Creek	2.7	
Spaht Creek	2.5	
Love Creek	2.4	

The lower ~6.5 km of the Ash River, which is below two natural falls and directly above its junction with the Stamp River, is accessible to anadromous fish. Lanternman and Wolf Creeks are the two main tributaries in this area and provide spawning and rearing areas for coho salmon and steelhead and cutthroat trout.

Great Central Lake has two main tributaries at the west end of the lake: Drinkwater Creek and McBride Creek. Drinkwater Creek is ~17 km in length and has two falls located ~3 km upstream

of Great Central Lake. These falls are believed to be barriers to salmon, but may be passable to steelhead. McBride Creek splits into two main forks ~1 km above Great Central Lake (Horncastle, 1978).

Species Composition

Fish species in Great Central Lake include rainbow trout, cutthroat trout, Dolly Varden, kokanee, Chinook, coho and sockeye salmon, steelhead, lamprey, pumpkinseed, sculpin, and threespine stickleback (FISS). Rainbow trout were stocked into the lake by various hatcheries from 1923 to 1951 (FISS), and the DFO Robertson Creek hatchery, located 1.5 km downstream of Great Central Lake on the Stamp River, stocked steelhead into the lake in 1983, 1985, 1988, 1990, 1994, 1997 and 2001.

Great Central Lake sockeye comprise the major component of the Barkley Sound sockeye fishery and in the 1990's escapements to the lake averaged 196,287 (Hyatt and Leudke, 1999). Barraclough and Robinson (1972) noted that tributaries including Drinkwater, Lindsay and Fawn Creeks receive stream spawners, however, Great Central Lake is one of the few lakes in BC where most of the sockeye spawning occurs in areas along the lakeshore rather than in tributary streams. Lakeshore spawning commences the last week of September, reaches a series of peaks in three principal locations during October, and ends in November. About 50% of the spawning occurs along ~4.6 km of lakeshore between Lindsay and Forestry Creek, 30% along 1.1 km of shoreline west of Fawn Point, and 20% along 1.6 km to 4.8 km off North Creek (Barraclough and Robinson, 1972). The resulting progeny become lake residents for one or two years.

The Stamp River provides spawning and nursery areas for sockeye, spring, coho and chum salmon and steelhead and cutthroat trout. The river has been made accessible throughout its entire length by the construction of concrete fishways around Stamp Falls in 1951. All species with the exception of chum salmon utilize these facilities to reach the upper river and the lake, while chum salmon utilize the lower reaches of the Sproat River near its junction with the Stamp River. Chinook salmon spawn above and below the falls in the Sprout River and the juveniles disperse throughout this area and into the Somass below the Stamp-Sproat confluence. Rainbow and cutthroat trout, Dolly Varden, and kokanee are resident in the Sprout system. Coho and steelhead also spawn in tributaries to the Stamp River including Beaver, Deer, Jolly, Bear and Robertson Creeks

Resident fish species present in the Lower and Middle Ash River include rainbow trout, cutthroat trout, Dolly Varden, pumpkinseed, and stickleback. Cutthroat trout have been observed in the Lower Ash River, at the confluence with the Stamp River, in the Wolf and Lanternman Creek drainages, and between the outlet of Dickson Lake and Dickson Falls. An apparently allopatric population of cutthroat trout is found above the barrier falls located on Lanternman Creek. Griffith (1993) found that the cutthroat populations in Wolf and Lanternman Creeks were of low density however, he did not report cutthroat densities separate from that of rainbow trout. Lewis and Ganshorn (2005) sampled these creeks and found that most fish were rainbow trout, and there was evidence of rainbow-cutthroat hybridization in both drainages.

Past sampling has found high concentrations of Dolly Varden and rainbow trout in Drinkwater Creek, as well as small streams at the west end of the lake (Streamline, 2006). Dolly Varden are present in the Stamp River and are reported as having been observed at the mouth of the Ash River, between the Lower and Middle Ash River, and in Dickson and Ash Lakes (FLNRO files, Nanaimo). However, surveys conducted in 1992 did not find any fish in the Lower Ash

River and Griffith (1993) found no evidence of Dolly Varden when he electrofished and minnow-trapped Dickson Lake in 1992. The presence of Dolly Varden in the Middle Ash River is also now uncertain as although two fry were captured near Elsie Lake in 1991, no individuals were observed in sampling conducted in 1992 (Griffith, 1993 cited in Lewis and Ganshorn, 2005).

Summary of Work and Reports

Great Central Lake was assessed by Provincial Fisheries staff in 1978. Narver (1975) examined trout catches in the sport fishery of Great Central Lake in 1969 and 1970 to determine age and growth of trout before experimental lake fertilization. Detailed limnological sampling was carried out from 1977 until 1985 (Stockner and Shortreed, 1985), with less detailed sampling carried out in most years since. Annual acoustic and trawl surveys have been carried out on occasion since 1977 (Hyatt and Leudke, 1999).

Darryl Rigets and Associates (2005) conducted field assessments on portions of the Great Central Lake beach to assess spawning potential for sockeye salmon. These researchers also conducted field assessments of the tributaries to Great Central Lake that occur within or adjacent to proposed cut blocks. The objectives of these assessments were to classify streams for fish presence, and to locate any barriers to fish migration (Rigets and Associates, 2005).

Streamline Environmental Consulting (2006) completed an environmental impact assessment for a development site situated along the south shore of Great Central Lake near the outlet on Boot Lagoon and the right bank of the upper Stamp River.

2.0 Limits to Fish Production

Water Withdrawal

The level of Great Central Lake is regulated by the Stamp River Dam located in a constriction of the outlet channel from Great Central Lake. The original dam was raised and a fish ladder constructed in 1957. The dam is now maintained by Catalyst Paper which diverts water into a powerhouse on the north shore of Great Central Lake from an intake on the south side of the Elsie Lake reservoir. A dam on Doran Lake diverts water out of Great Central Lake and into Doran Creek, a small hydropower facility which discharges to the Taylor River in the Sproat Lake watershed (Streamline Environmental Consulting, 2006).

Catalyst Paper must provide water flows of 26.6 m³/s in or to the Somass River during the summer months (Streamline Environmental Consulting, 2006). A memorandum from the West Coast Vancouver Island Management Board in 2008 expressed concern that water level drops as a result of operation of this facility results in an estimated 3.5 vertical feet drop in Great Central Lake, the dewatering of fry nursery zones, and the killing of coho fry, stickleback, trout and char (FLNRO files, Nanaimo).

Stream Habitat

Burt and Horchik (1998) estimated the rearing population density and the rearing capacity for steelhead fry and yearlings in the Lower Ash River and the Wolf and Lanternman Creek drainages and found the available habitat in the Lower Ash River watershed to be below carrying capacity estimated for these systems. The Lower Ash River, Wolf Creek drainage, and Lanternman Creek drainages were estimated to contain 73% of the fry capacity, 74% fry

capacity, and 20% fry capacity respectively. Juvenile abundances in the Wolf Creek and Lanternman Creek drainages were estimated at 42% capacity and 6% capacity respectively. Considering the Lower Ash River watershed as a whole, these researchers estimated steelhead fry at ~65% of capacity, and yearlings at 21% capacity (Lewis and Ganshorn, 2005).

Nutrients

Great Central Lake is oligotrophic, with low nutrient concentrations and summer water temperatures often exceed 20°C for an extended period (Shortreed et al., 2001). This lake was the site of an annual fertilization experiment from 1970 to 1974 aimed at enhancing sockeye salmon (LeBrasseur and Kennedy, 1972) and there are numerous reports on the Great Central Lake Fertilization Program. Parsons et al. (1972), LeBrasseur and Kennedy (1972), and Barraclough and Robinson (1972) suggested that during the first year of fertilization, Great Central Lake algae, zooplankton, and fish all responded positively to fertilizer additions and LeBrasseur et al (1978) and Hyatt and Steer (1987) reported that fertilization applications substantially increased Great Central Lake sockeye numbers and the size of sockeye smolts.

LeBrasseur et al (1978) summarized data collected during the years of lake fertilization and made comparisons between the fertilized and unfertilized periods. These investigations found that fertilization was associated with higher mean summer epilimnetic primary production than during the unfertilized period. Shortreed et al (2001) presented summaries of the current knowledge of freshwater factors limiting sockeye production in several lakes in BC including Great Central Lake. He commented that from a fisheries production perspective, the fertilization of Great Central Lake should continue, but from an experimental and assessment perspective, it would be beneficial to have several years of unfertilized conditions for comparative purposes.

3.0 Angling Statistics

Angler Effort

The mean angler effort is ~3,000 angler days and there has been an increasing trend in angler effort at Great Central Lake over the past 25 years (Figure 2). Angler effort increased from <1,000 angler days in 1986 to almost 4,000 angler days in 1989, declined to 3,000 angler days in 1992, increased to ~4,000 days in 2002, then stayed within 500 angler days of the mean in 2006 and 2011.

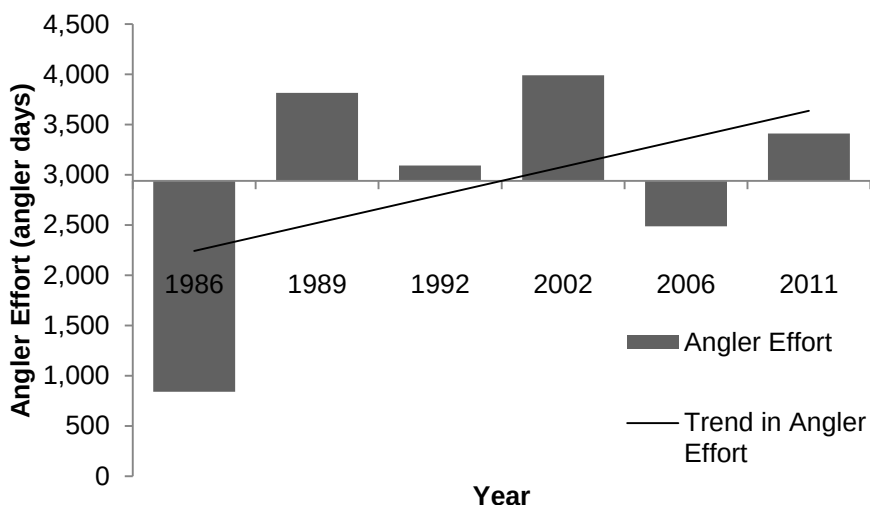


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Great Central Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Catch

Like angler effort, total catch has varied considerably since 1986 (Figure 3). In 1985, total catch was <1,000 fish but in 1989 catch rose to ~6,500 fish. In 1992, catch dropped to ~4,000 fish which was below the long term average of 4,800 fish. Since 2002, total catch has been above the long-term average but stable. In 2002, catch was ~5,500 fish, in 2006 total catch was ~5,700 fish and in 2011 catch was ~5,600 fish. Overall, there has been an increasing trend in total catch.

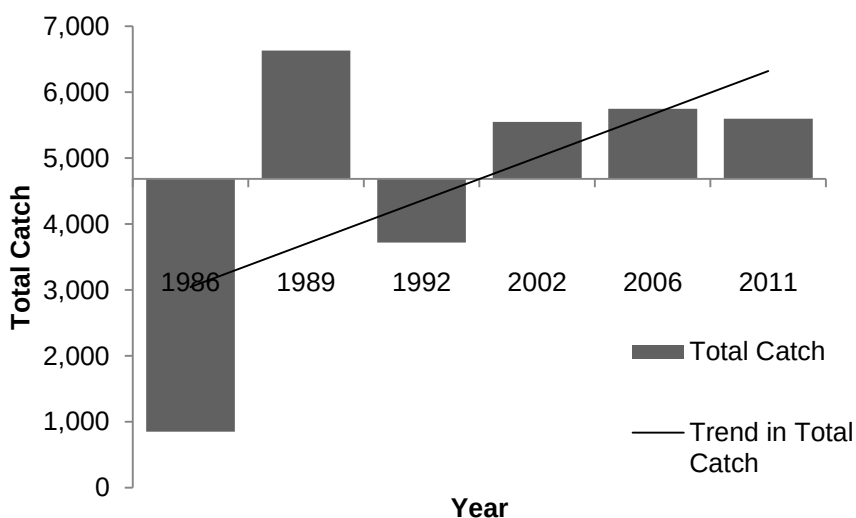


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in total catch at Great Central Lake 1986 – 2011 (Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Seventy-one percent of the total catch in 2006 was cutthroat trout (4,091 fish) and ~30% was rainbow trout (1,659 fish) (Table 3). In 2011, those proportions were reversed with ~32% of the catch comprised of cutthroat trout (1,504 fish) and 72% comprised of rainbow trout (4,051 fish). Dolly Varden comprised <1% of the catch that year. Total catch for each year was stable at ~5,500 fish.

TABLE 3. Catch of rainbow and cutthroat trout and Dolly Varden by anglers at Great Central Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	4,091	71.1	1,504	26.9
Rainbow	1,659	28.9	4,051	72.4
Dolly Varden	0	0.0	42	0.7
Total	5,750		5,597	

In the fall of 1969 and spring of 1970, Narver analyzed scale samples from 349 fish caught in the sport fishery on Great Central Lake in 1969 and 1970 (Figure 4). He found that in 1969, cutthroat trout comprised 87% and rainbow trout 13% of the angler catch while in 1970, cutthroat trout comprised 97%, rainbow trout comprised 2% and Dolly Varden comprised 1% of the angler catch (Narver, 1975). No kokanee were captured by anglers in either year.

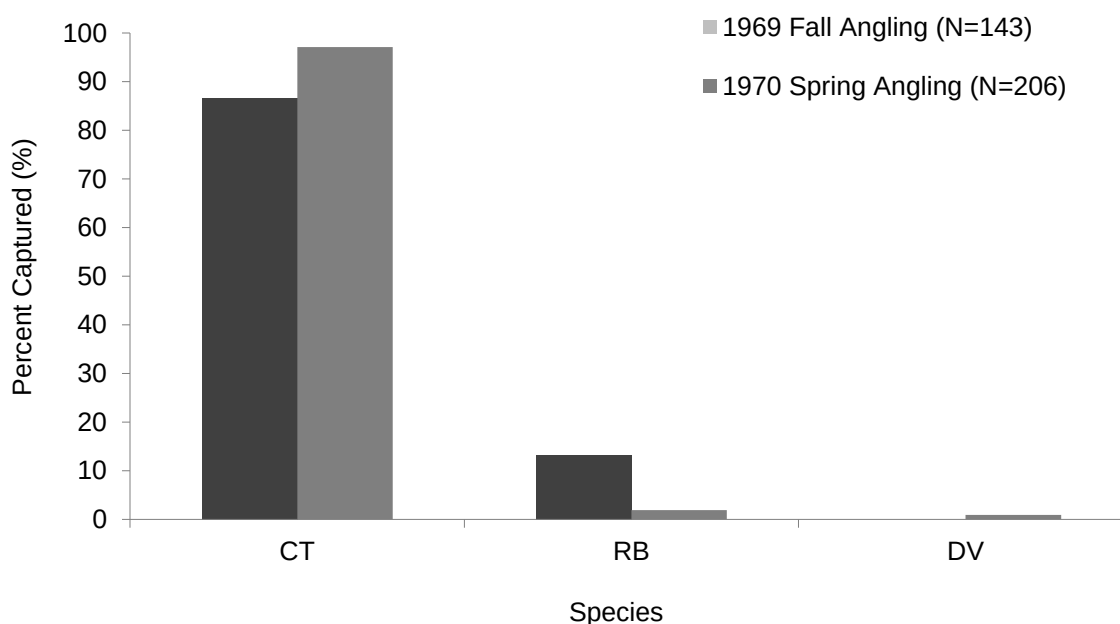


FIGURE 4. Numbers and percent of angler-caught fish from Great Central Lake 1969 and 1979 (Source: Narver, 1975).

Angler Success

Angler success has averaged ~1.5 fish/day since 1986 (Figure 5). Angler success was 1 fish/day in 1986 but rose to 1.6 fish/day in 1989. In 1992, angler success fell to ~1.2 fish/day but rose again to 1.3 fish/day in 2002, 2.3 fish/day in 2006 then dropped in 2011 to 1.6 fish/day.

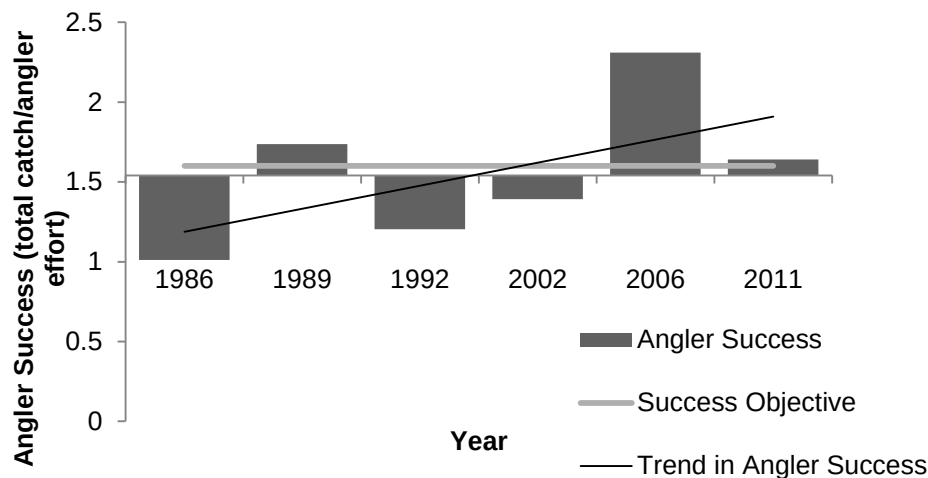


FIGURE 5. Angler success (total catch/total angler effort in angler days) compared to average angler success, the objective for angler success (1.6 fish/angler day) and trend in angler success at Great Central Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Angler Creel Surveys

In June 1976, an angler creel survey was conducted at Great Central Lake by the Fish and Wildlife Branch (Table 4). Anglers caught a total of 40 fish: 24 cutthroat trout; five rainbow trout; eight Dolly Varden; and three kokanee. Cutthroat trout ranged from 222 mm - 635 mm while rainbow ranged from 260 mm - 508 mm. Steelhead have access to this lake and we assume the larger rainbow were steelhead. Dolly Varden ranged from 285 mm - 495 mm and kokanee/sockeye ranged from 216 mm – 273 mm (FLNRO files, Nanaimo).

TABLE 4. Results of the June 1976 angler creel survey at Great Central Lake (N=40); fish noted as kokanee may have been sockeye juveniles (Source: FLNRO files, Nanaimo).

Species	Number	Maximum Length (mm)	Minimum Length (mm)	Mean Length (mm)
Cutthroat	24	635	222	360
Rainbow	5	508	260	380
Dolly Varden	8	495	285	411
Kokanee	3	273	216	237

Fishing Derbies

The Ark Resort, which is located at the east end of Great Central Lake, hosted three-day spring fishing derbies for many years and we've presented the results of events held between 1976 and 2010 in Table 4 and Appendix 14.

Anglers caught a total of 38 trout in May 1976, however, organizers did not record fish species or fish lengths. Weights of trout caught ranged from 454 g - 2,522 g (1 lb - 5.5 lb). It was suggested the larger trout size in the 1970's may have been the result of lake fertilization (Reid, G., 2011, pers.com.). Unfortunately, there is no way to determine if this is the case.

In April 1990, 85 anglers caught 51 trout while in April 1991 anglers caught 43 trout, ranging up to 2,494 g (5.5 lb). In April 1997, anglers caught 208 trout (123 cutthroat and 84 rainbow) with cutthroat ranging from 205 g - 2,650 g (0.5 lb - 5.8 lb), and rainbow ranging from 113 g - 1,566 g (0.2 lb - 3.5 lb).

In May 2009, anglers caught 129 trout with cutthroat ranging up to 2,131 g (4.7 lb) and rainbow ranging up to 3,613 g (7.9 lb). In May 2010 anglers caught 50 fish represented by 22 cutthroat ranging from 312 g - 2,466 g (0.7 - 5.4 lb), and 28 rainbow ranging from 184 g - 1,049 g (0.4 lb - 2.3 lb) (Ark Resort, Port Alberni; FLNRO files, Nanaimo).

TABLE 5. Results of fishing derbies at Ark Resort, Great Central Lake in 1976 (N=38); 1990 (N=51); 1991 (N=43); 1997 (N=208); 2009 (N=129) and 2010 (N=50); fish were identified by anglers and some fish may have been misidentified - see Appendix 14 for the raw data (Source: Ark Resort, Port Alberni; FLNRO files, Nanaimo).

Date	Species	Number	Maximum Weight (g)	Minimum Weight (g)	Mean Weight (g)
May 1976	Trout	38	2,522.2	453.5	860.6
April 1990	Trout	51	-	-	-
April 1991	Trout	43	2,493.9	141.5	923.1
April 1997	Cutthroat	123	2,649.6	205.2	710
	Rainbow	84	1,565.7	113.2	565
May 2009	Cutthroat	103	2,131.5	45.4	783.1
	Rainbow	26	3,613.5	136.1	690.6
May 2010	Cutthroat	22	2,467	311.9	795.1
	Rainbow	28	1,049.0	184.3	495.6

Harvest

We've presented the catch, harvest and percent harvest of cutthroat and rainbow trout in Table 6. Anglers harvested 22% of their cutthroat catch and ~36% of their rainbow catch in 2006. In 2011, anglers harvested 24% of their cutthroat but only 11% of their rainbow catch.

TABLE 6. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Great Central Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	4,091	898	22.0	1,504	362	24.1
Rainbow	1,659	591	35.6	4,051	446	11.0
Total	5,750	1,489	25.9	5,597	807	14.4

4.0 Stock Status Indicators

Relative Abundance

Great Central Lake was sampled by gillnet during the summer of 1978 (FLNRO files, Nanaimo) (Figure 6). Gillnets were set on June 16-19, 22-23 and July 17-20, and a total of 262 fish were captured. Dolly Varden comprised 62% of the sample, cutthroat trout comprised 20% of the sample, kokanee comprised 15% of the sample, and rainbow trout comprised 7% of the sample.

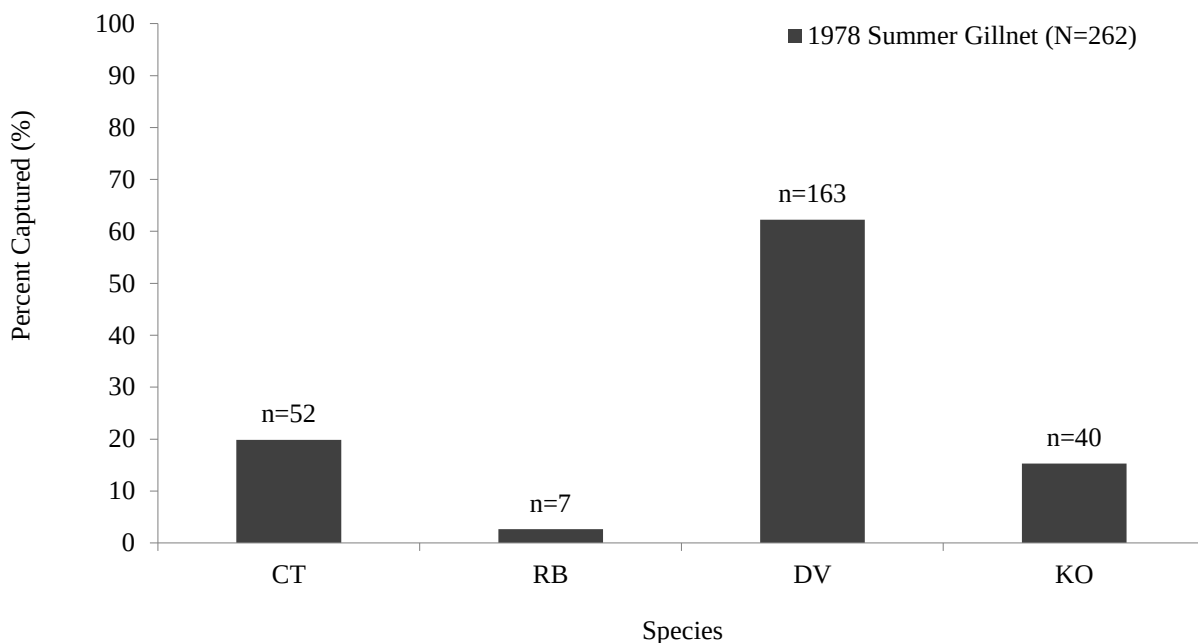


FIGURE 6. Number and percent cutthroat trout, rainbow trout, Dolly Varden and kokanee salmon captured in gillnets in June and July in Great Central Lake in 1978 (N=262). There is no information regarding how many nets, their type, locations or soak times provided in the files (Source: FLNRO files, Nanaimo).

Length and Weight

We've provided the minimum, maximum, mean and modal lengths of cutthroat sampled by angling and in gillnets, and rainbow trout and Dolly Varden sampled in gillnets in Great Central Lake in the 1970's in Table 7. Angler-caught cutthroat ranged from 235 mm – 610 mm and averaged ~393 mm while cutthroat caught in gillnets ranged from 118 mm – 570 mm and averaged ~236 mm. The modal length of angler-caught cutthroat was 432 mm, while the modal length of gillnet caught cutthroat was 188 mm.

TABLE 7. Minimum, maximum, mean length and modal length for cutthroat sampled by angling in 1979 (N=61) and in gillnets in 1978 (N=51) and rainbow trout (N=7) and Dolly Varden (N=163) captured in gillnets in 1978 in Great Central Lake; no information regarding number of gillnet sets, gillnet types, locations or soak times is provided in the files (Source: FLNRO files, Nanaimo; Narver, 1975).

Method	Length (mm)				
	N	Minimum	Maximum	Mean	Mode
<u>Cutthroat</u>					
Angling	61	235	610	392.9	432
Gillnet	52	118	570	235.8	188
<u>Rainbow</u>					
Gillnet	7	176	510	322.1	-----
<u>Dolly Varden</u>					
Gillnet	163	119	530	315.1	330

Seven rainbow trout ranging from 176 mm – 510 mm and averaging 322 mm, and 163 Dolly Varden ranging from 119 mm – 530 mm and averaging 315 mm were caught in gillnets in 1978 (Table 7). The modal size of the Dolly Varden was 330 mm.

Age and Growth

Narver (1975) provided a summary of the minimum, maximum and mean size-at-age for cutthroat trout captured by anglers in 1969 and 1970. In 1969, a total of 111 cutthroat were captured by anglers with the sample consisting mainly of age 3+, 4+ and 5+ fish with age 4+ fish being the most common (Table 8) (Narver, 1975). One age 1+ cutthroat was captured and it was ~200 mm while thirteen age 2+ cutthroat ranging from 210 mm –267 mm and averaging 237 mm were also caught. Age 3+ fish ranged from 216 mm - 375 mm and averaged 305 mm, age 4+ fish ranged from 317 mm - 571 mm and averaged 414 mm, and age 5+ fish ranged from 305 mm - 584 mm and averaged 474 mm. Six aged 6+ fish were also captured and these ranged from 406 mm - 457 mm and averaged 435 mm.

TABLE 8. Number, minimum, maximum and mean length for each age class of cutthroat trout captured by anglers from in October in 1969 (N=111) and May to July 1970 (N=129) in Great Central Lake. The data from 1969 suggests that angler exploitation of both cutthroat and rainbow trout (see Table 9) begins at ~200 mm and 2+ (Reprinted from: Narver, 1975).

October, 1969					May to July, 1970			
Age	n	Fork Length			n	Fork Length		
		Minimum	Maximum	Mean		Minimum	Maximum	Mean
1	1			197				
2	13	210	267	237				
3	38	216	375	305	24	197	349	274
4	31	317	571	414	52	235	522	341
5	22	305	584	474	39	254	546	423
6	6	406	457	435	12	286	598	451
7					2	470	508	489

In 1970, 127 cutthroat trout were captured by anglers with age 3+ fish being the youngest (Table 8). Age 3+ fish ranged from 197 mm - 349 mm and averaged 274 mm, age 4+ fish ranged from 235 mm - 522 mm and averaged 341 mm, and age 5+ fish ranged from 254 mm - 546 mm and averaged 423 mm. Twelve aged 6+ fish were caught and these ranged from 286 mm - 598 mm. The minimum length of these fish is suspect and we suspect that an annulus was missed during ageing. Two 7+ cutthroat averaging 489 mm were also caught.

Seventeen rainbow trout were captured by anglers in 1969 and these fish ranged from 2+ to 6+ years of age (Table 9). The single 2+ fish was 241 mm, while the two aged 3+ fish averaged 238 mm. There were three rainbow aged 3+ and these averaged 301 mm. The age 5+ fish averaged 432 mm and the age 6+ rainbow averaged 489 mm.

TABLE 9. Number, minimum, maximum and mean length for each age class of rainbow trout captured by anglers in October 1969 in Great Central Lake (N=23) (Reprinted from: Narver, 1975).

Age	n	Mean Length (mm)
2+	1	241
3+	2	238
4+	3	301
5+	7	432
6+	4	489

Catch Indicators

Total Catch

A total of 112 cutthroat, seven rainbow and 163 Dolly Varden were captured in gillnets in 1978 (Table 10). There is no information in the files about the number of gillnets, the number of net sets, the net locations or timing of this sample. This is unfortunate as this information could have provided insight into the catch/effort as well as to why the catch of Dolly Varden was so high relative to the catch of other species.

TABLE 10. Total catch of cutthroat and rainbow trout captured in gillnets Elsie Lake in 1970 (Source: FISS; FLNRO files, Nanaimo).

Species	1978
Cutthroat	112
Rainbow	7
Dolly Varden	163

Data Gaps

There are no snorkel surveys of tributaries to Great Central Lake and only one gillnetting assessment been completed and that was three decades ago (Table 11). Lake inventory, water quality and acoustic studies are also >10 years old. Although there are general stream inventory studies, there are no Level 2 WRP-style studies to identify restoration projects and priorities.

TABLE 11. Summary of data gaps for Great Central Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 yrs. old	>10 years	No data
Lake Inventory		X	
Fertilization Reports		X	
Beach Inventory - sockeye	X		
Water Quality/Lake Productivity		X	
Stream Inventory (general)	X		
Level 1&2 WRP Surveys			X
Fish Assessment (streams)	X		
Electrofishing Surveys (streams)	X		
Snorkel Surveys			X
VI Lakes Questionnaire	X		
Creel and Derby Surveys	X		
Angler Preferences			X
Gillnetting		X	
Acoustic Surveys		X	

5.0 Fisheries Objectives and Management Strategies for Great Central Lake

Existing Regulations

Great Central Lake is covered by the general regional regulations of four trout but not more than 1>50cm (two hatchery steelhead >50cm allowed). Anglers must release all Dolly Varden. Great Central Lake is also covered by a no retention of wild rainbow trout >60 cm regulation.

There is no fishing between 200 m above and 500 m below Stamp Falls, June 15 to November 15 and no fishing from the confluence with the Ash River upstream to the Great Central Lake Dam, including tributaries, January 1 – April 30. There is also a bait ban above the signs at Girl Guide Falls (~250 m upstream of the mouth of Beaver Creek) and tributaries and bait may only be used August 25 – May 30 below the signs at Girl Guide Falls. There is a 7.5 kWh (10 hp) engine power restriction on parts of the Stamp River.

There is no fishing from Dickson Lake to signs 200 m below Lanternman Falls, December 1 – April 30 on the Ash River. The Ash River is closed all year from Dickson Falls to the signs 30 downstream and is closed all year from Elsie Lake to Dickson Lake.

The remaining streams are covered by the general regulation of single barbless hook and bait ban all year and all streams are covered by the regional general regulations: two trout from streams (must be hatchery); mandatory release of all wild trout and wild steelhead.

Maximum Catch and Effort at Current Regulations

The maximum effort at the current regulations at Great Central Lake is ~7,000 angler days and the maximum total catch is ~7,300 fish (Figure 7). At the optimum sustainable angler effort (~4,000 angler days) the total catch would be ~6,000 fish and the success would be 1.5 fish/day. In 2011, the angling pressure and total catch was close to the optimum and the angler success was 1.6 fish/day which is our regional success objective. However, the total yield is still well below what is predicted using MEI and Ryder's simplified regression and even at the highest catch in 1989, yield was still half of the yield predicted using MEI (Appendix 8).

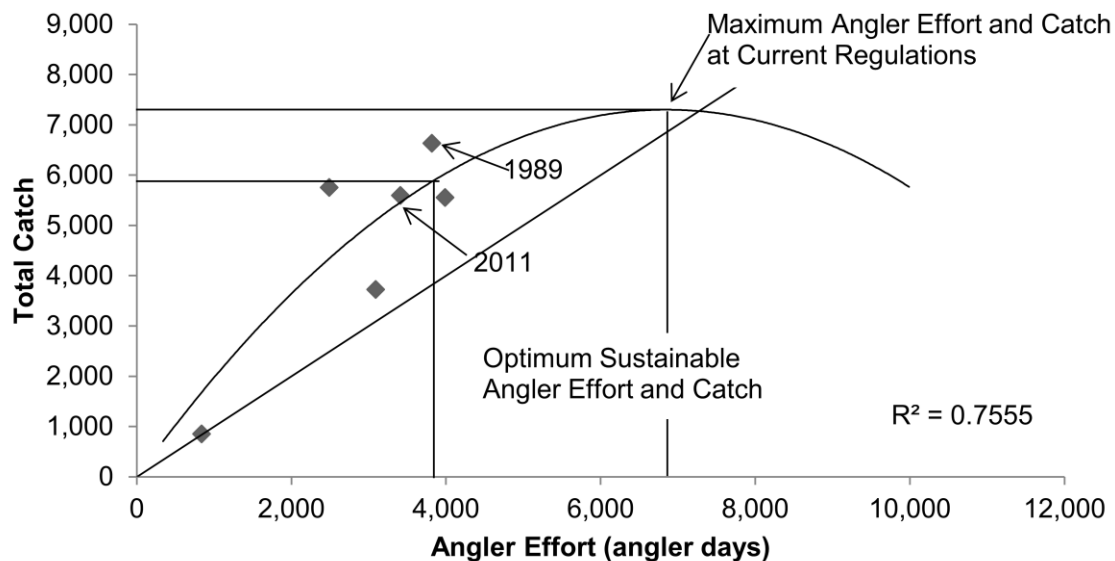


FIGURE 7. Angler effort (angler days) vs. total catch, maximum angler effort and catch and optimum sustainable angler effort and catch at the current regulations at Great Central Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

Angler catch has remained roughly constant over the past three VILQ survey periods and overall, angler success is increasing. Unfortunately, there is a great deal of variability in the angler effort data which is to be expected on this lightly-fished lake. Although it is not possible to project angler effort based on the VILQ, it's likely angler effort at Great Central Lake will either remain low, or decline as is the current trend throughout the region (Clarke, 2012).

It would be valuable to get a better idea of angler effort at Great Central Lake and we've suggested erecting angler creel boxes at the Ark Resort boat launch to enable that. In addition, the Ark derby is an ideal way of gathering information on angler-caught fish, and we've suggested attending this annual derby to ensure correct fish identification and gather data on angler-caught fish.

Given the proportion of Dolly Varden captured in gillnets in 1978, and the size of rainbow trout captured in derbies, fertilization may have been beneficial to this species which tends to prey on invertebrates. This is not clear, nor is whether fertilization affected cutthroat stocks at Great Central Lake. We suggest that existing data gathered by DFO during this program be reviewed to determine if fertilization was beneficial to these species and, if so, investigations be initiated with BC Hydro to re-establish fertilization (Table 11).

Finally, we recommend that future electrofishing studies establish the distribution of Dolly Varden as this seems to be in question in this watershed (Table 11).

1. Current angler effort, catch and success rate is close to optimum sustainable levels and no action other than monitoring with the VILQ is required.
2. Gillnetting data is >3 decades old and we recommend gillnetting in 2014 (Chapter 1 Table 16 and Figure 15) and comparing stock status indicators to determine if there is a decline in stock status. Some review of the lake's physical and biological factors is required to determine netting times and locations.
3. If conservation regulations are required, we suggest implementing a maximum size limit initially as per the recommendations provided in the Fisheries Objectives and Management Strategies in Chapter 1.
4. Schedule gillnetting every three years if conservation regulations are implemented.
5. Monitor the annual derby at the Ark Resort to collect data and ensure fish identification is correct and erect an angler creel survey box at the Ark Resort boat launch to collect additional angler effort and catch data.
6. The lake specific regulation for wild rainbow trout (i.e.) steelhead (no retention >60 cm) is inconsistent with the regional regulation which prohibits retention of steelhead >50 cm. We recommend removing the 60 cm regulation to bring this lake in line with the regional regulations.
7. Erect a sign at Great Central Lake at the Ark Resort Boat Launch to inform anglers of the regulations.

Operational Management Plan for Great Central Lake

We've outlined an operational management plan for Great Central Lake in Table 12. Stock conservation is the goal of plan and will be achieved through analysis of gillnet catches and continued monitoring of angler statistics through the VILQ and the Ark Derby. We've also recommended additional surveys including snorkel surveys, and lake productivity and habitat assessments, and restoration studies.

TABLE 12. Operational management plan organized according to management priorities for Great Central Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Set standard times and location of gillnets and conduct gillnetting assessment to gather stock status data for cutthroat and rainbow trout.	2015
	Monitor results of spring derby hosted by the Ark Resort; erect box creel at the Ark Resort boat launch to gather angler data.	2014
	Conduct snorkel survey of McBride and/or Drinkwater Creeks. A reconnaissance will have to be conducted to determine when to conduct these surveys to capture cutthroat and rainbow trout spawning.	2015
	Electrofishing to confirm Dolly Varden presence in the watershed.	2018
Regulations	Bring lake specific regulation for steelhead (>60cm) into alignment with regional regulation (no retention >50cm).	2014
Public Awareness	Erect a sign at Ark Resort boat launch to advise the public and anglers of regulations.	2014
Lake Productivity	Review existing data gathered by DFO during fertilization program to determine if this activity was beneficial to trout and Dolly Varden. If beneficial, request re-establishing the program including determining if funding is available through BC Hydro FWCP.	2020
Habitat Assessment and Restoration	Conduct Level 2 WRP studies to identify restoration projects and priorities.	2020
VILQ	Evaluate changes in fisheries statistics every three years.	Ongoing

Chapter 8. Henderson Lake

Lake	Henderson
Planning Unit	West Coast
Watershed	West Coast
Surface Area (ha)	1,545
Mean Depth (m)	97
Key Tributaries	Clemens Creek, Henderson River
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden
Limits to Production	Logging, Nutrients
Regional Priority*:	16
<u>Angling Statistics 2011</u>	
Angling Effort	14 angler days
Total Catch	0 fish
Angler Success	Unavailable
Current Harvest Rate	No data available
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	Unknown
Data Gaps	Gillnetting data is >10 years old and there is no recent VILQ data so fisheries status is also unknown.
Management Objectives	Monitor the fishery using the VILQ and update gillnetting data in 2018 or when angler effort >500 angler days (see operational model this chapter).
Operational Plan Priorities	Monitoring; possible fertilization in the future
Potential Partners	Uchucklesaht Band, DFO – Lake Enhancement Unit

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Henderson Lake Watershed

General Information

Henderson Lake is located at sea level ~25 km west of Port Alberni on the Alberni Inlet in the West Coast PU (Figure 1). This lake lies within the coastal-hemlock biogeoclimatic zone, has a surface area of 1,545 ha, a maximum depth of 250 m, and a mean depth of 97 m (Table 1).

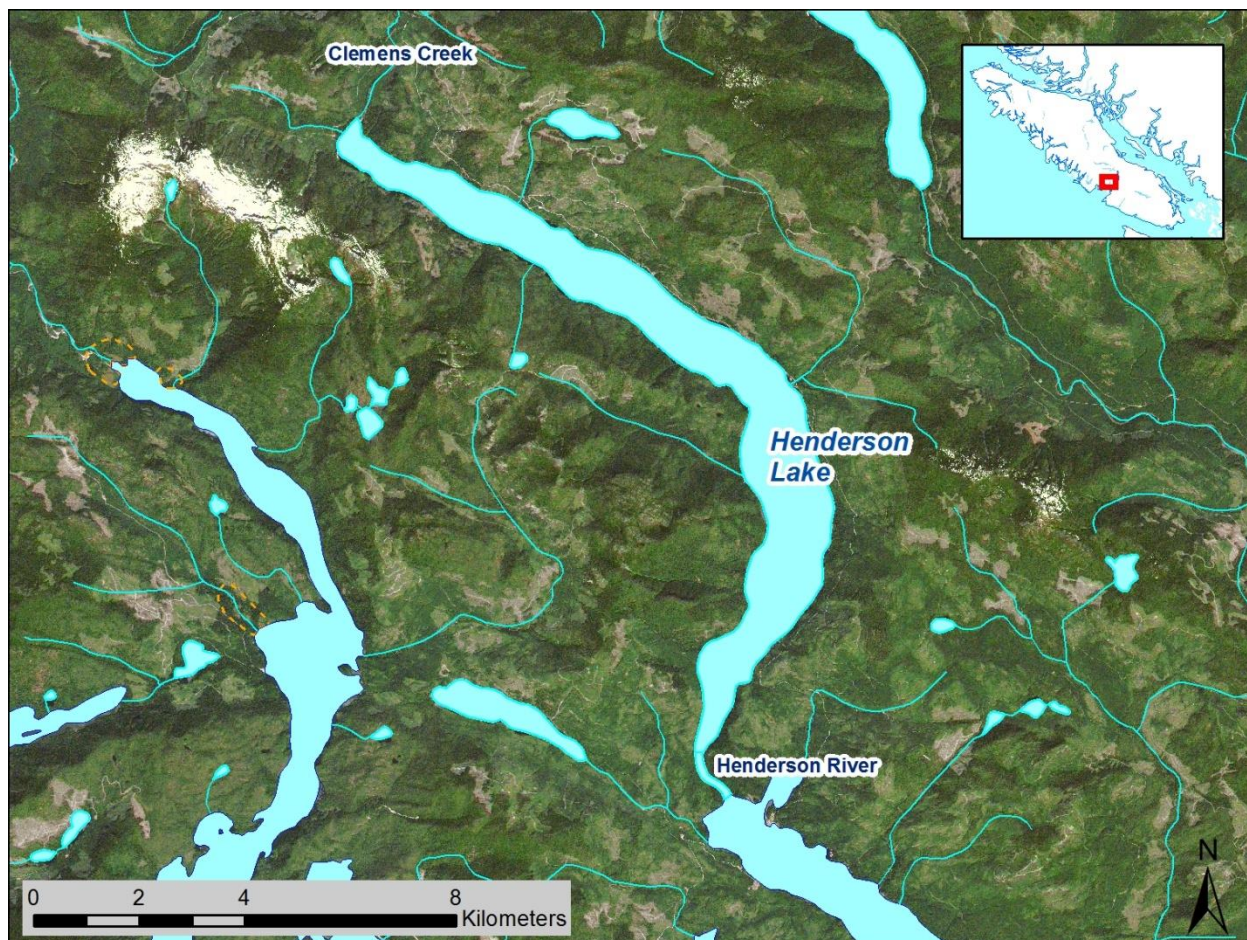


FIGURE 1. Map of Henderson Lake and tributaries; no bathymetric map is available (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Henderson Lake (FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)
West Coast	01446ALBN	1,545	37.4	250	97	6.9	63	-----	1972, 1975, 1986

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Logging is the major land use in the watershed and several habitat surveys suggest that Clemens Creek, which is the main spawning stream, has been impacted by logging activity. Henderson Lake was an historically important sockeye producer and there is a DFO Community sockeye hatchery operated by the Uchucklesaht Band at this lake.

Tributaries

The most important stream in the Henderson Lake watershed is Clemens Creek which is both the main inlet to the lake, and the only fish-producing tributary (Reid, G., 2013, pers. com.). Clemens Creek is a 2nd order stream with a drainage area of 17 km² (Table 2).

The outlet for Henderson Lake is the Henderson River which flows into Alberni Inlet. According to staff at DFO in Port Alberni, there is a limited recreational fishery for steelhead, Chinook, coho and sockeye salmon in the river. There is no information on trout or char fishing in Henderson River.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Henderson Lake (Source: FLNRO files, Nanaimo).

Tributary	Order	Length (km)	Other Information
Clemens Creek	2	16.8km	Inlet to Henderson Lake and is anadromous throughout its length. Cutthroat and rainbow trout, steelhead and Dolly Varden as well as sockeye, coho, Chinook, chum and pink salmon, sculpins and threespine stickleback are documented.
Henderson River	3	2km	Outlet to Henderson Lake; cutthroat and rainbow trout, steelhead and Dolly Varden, sockeye, coho, Chinook, chum and pink salmon are present. A limited sport fishery occurs for salmon and steelhead; no information on trout or char fishing.

Species Composition

Prior to 2009, sockeye returns ranged from 3,000 to 120,000, with an average escapement of 36,000 (Northwest Hydraulic Consultants, 2009). Henderson Lake is a former DFO Enrichment Program lake but lake productivity is low and this has been implicated in poor sockeye production since the termination of the fertilization program in 1999.

There is limited information on trout and char within the watershed and little or no data exists on cutthroat, rainbow trout or Dolly Varden populations in Henderson Lake. Both trout and char populations are believed to be limited (G. Reid, 2013, pers. com.). Chinook, chum, coho, pink, sockeye and kokanee salmon are found in the lake as are rainbow and steelhead. Sculpins and threespine stickleback are also documented.

Cutthroat, rainbow trout and steelhead are found in Clemens creek while Dolly Varden are found only in the headwaters. Salmon species that use the creek for spawning include sockeye, coho, Chinook, chum and pink. Sculpins and threespine stickleback are also found in this creek.

The Henderson River contains cutthroat and rainbow trout, steelhead and Dolly Varden, sockeye, coho Chinook, chum and pink salmon.

Summary of Work and Reports

Hyatt and Steer completed a report in 1987 documenting sockeye salmon management efforts in West Coast lakes including Henderson Lake, and Tschaplinski and Hyatt (1991) compared population assessment methods to estimate the abundance of sockeye returning to the lake. Henderson Lake is also one of the lakes included in the discussion by Shortreed et al (2001) who examined factors limiting juvenile sockeye production and nutrient enhancement potential in BC sockeye nursery lakes. In 2009, Northwest Hydraulic Consultants prepared a fertilization plan for Henderson Lake which provides technical details for applying granular fertilizer using floating fertilizer dispenser rafts.

Ostapowich Engineering Services completed a Coastal Watershed Assessment Project (CWAP) of the Henderson Lake watershed in 1999. Details from this report including the hydrologic condition of the watershed and impacts of forest development on the main streams can be found in the FLNRO files in Nanaimo. Notes from an inventory of Henderson Lake conducted in 1975 is available in Ecocat at: <https://a100.gov.bc.ca/pub/acat/public/search.doc>.

2.0 Limits to Fish Production

Logging

Clemens Creek, the major fish producing inlet to Henderson Lake, has undergone broad-scale logging and impacts are extensive (FLNRO files, Nanaimo).

Fish Stocking

The Uchucklesaht Band Hatchery on Henderson Lake was originally constructed as a sockeye/Chinook hatchery. It is unknown if stocking continues and, if so, which species the Band stocks.

Stream Habitat

Shortreed et al (2001) note that the high annual precipitation results in rapid flushing rates in Henderson Lake and that frequent intense rainfall in the fall and winter causes sudden freshets in Clemens Creek. As a result, these researchers suggest that spawning grounds are unstable and egg-to-fry survival may be low relative to streams with more stable flows. Although Shortreed et al (2001) were referring to sockeye salmon, the same situation would exist for the survival of eggs and fry of cutthroat trout in this creek.

Nutrients

Nutrients are a primary limit to fish production in Henderson Lake. Henderson Lake was fertilized each year from 1976 to 1999, and Hyatt and Steer (1987) reported that this program resulted in significant increases in sockeye spawning escapements in the lake. Regardless, the lake was not fertilized in 2000 due to a very low escapement of only 4,412 spawners in 1999 (Northwest Hydraulic Consultants, 2009). In 2007, liquid agricultural fertilizer was barged down Alberni Inlet and applied to Henderson Lake which proved to be a logistically challenging task, and a less onerous method for applying nutrients was needed. As of 2009, DFO was drafting a sockeye recovery and rebuilding strategy outlining a range of potential approaches to increase sockeye production in Henderson Lake (Northwest Hydraulic Consultants, 2009). In their

Henderson Lake fertilization plan, Northwest Hydraulic Consultants (2009) proposed the use of solid granular fertilizer to simplify the logistical aspects of the lake fertilization process. It's not known whether this, or any other fertilization plan has been implemented.

3.0 Angling Statistics

Angler Effort, Catch and Success and Harvest.

There is low angler participation at Henderson Lake with angling statistics only reported for 2002 (Table 3). That year, an estimated 21 angler days were expended at Henderson Lake with a reported catch of 126 fish and a success rate of six fish/day. There is no species information relative to the catch but it can be assumed they were cutthroat trout given a gillnetting survey in 1977 sampled only that species (Figure 2). There is no harvest data.

TABLE 3. Estimated angler effort (angler days), total catch, and angler success (catch/angler day) for Henderson Lake for the survey year 2002. Note: there were no responses from Henderson Lake from 1986 until 1992 or 2011. Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep).

Fisheries Statistic	2002
Effort (angler days)	21
Total Catch	125
Success (catch/day)	6.0

4.0 Stock Status Indicators

Relative Abundance

Henderson Lake was gillnetted in 1977. Twenty-two fish were captured of which seven (32%) were cutthroat trout and 13 (60%) were juvenile sockeye (Figure 2) (FLNRO files, Nanaimo).

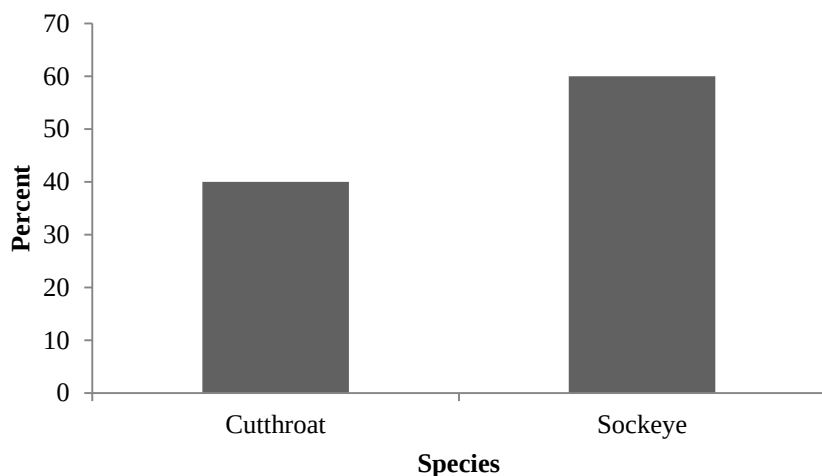


FIGURE 2. Percent cutthroat trout and juvenile sockeye salmon captured in gillnets in Henderson Lake in May, 1977 (N=22) (FLNRO files, Nanaimo).

Length and Weight

We've provided the results of the gillnetting survey conducted in 1977 in Henderson Lake in Table 4, and detailed fish sampling data can be found in Appendix 15. The seven cutthroat trout sampled in 1977 ranged from 199 mm – 450 mm and averaged ~248 mm. The modal length was 199 mm and there was no weight data recorded. Almost 60% of the seven cutthroat captured were between 201 mm – 250 mm (Figure 3). Note that the sampling was conducted in May so the results may not be representative of all size classes as some fish may have still been in the tributaries spawning.

TABLE 4. Minimum, maximum, mean length and mean weight for cutthroat trout captured in Henderson Lake in 1977 (Source: FISS; FLNRO files, Nanaimo).

Decade	N	Length (mm)			
		Minimum	Maximum	Mean	Mode
Cutthroat	7	199.0	450.0	248.3	199.0

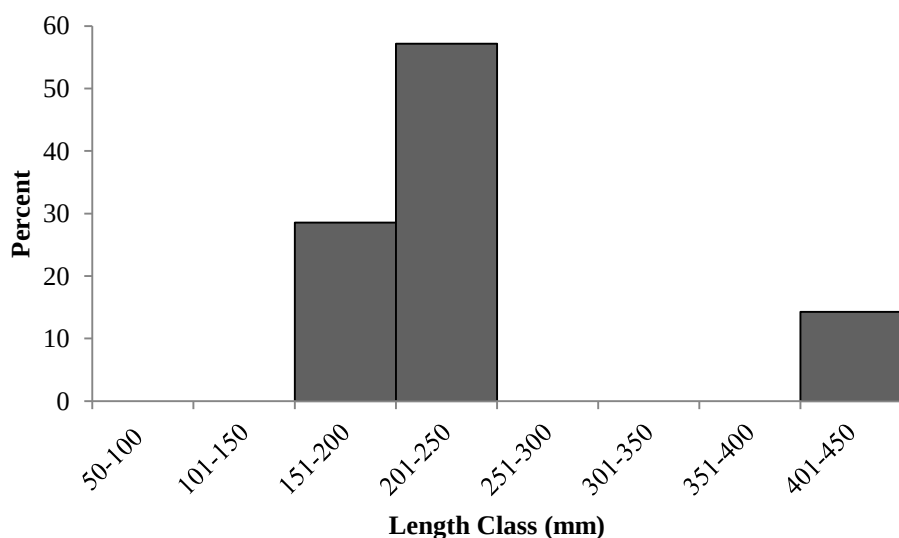


FIGURE 3. Percent length frequency of cutthroat trout captured in gillnets in Henderson Lake May, 1977 (N=7) (Source: FLNRO files, Nanaimo).

Catch Indicators

Total Catch

Only one gillnetting assessment which captured seven cutthroat has been conducted at Henderson Lake (Table 4). There was no information on how many nets were set, their locations or soak times.

Data Gaps

We've presented a summary of the existing data in Table 5. There is no bathymetric profile for the lake, gillnetting data is >10 years old and there are no snorkel or electrofishing surveys. Stream habitat assessments were completed >10 years ago, however, hydroacoustic and limnological surveys are <10 years old.

TABLE 5. Summary of data gaps for Henderson Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	< 10 years	>10 years	No data
Bathymetric Profile			X
Gillnetting		X	
Angler Creel Survey			X
Angler Preference Questionnaire			X
VI Lakes Questionnaire	X		
Snorkel Surveys			X
Acoustic Surveys	X		
Electrofishing (streams)			X
Limnology/Water Quality/Productivity	X		
Stream Habitat Inventory		X	
Fishery Data and Angler Preferences			X

5.0 Fisheries Objectives and Management Strategies for Henderson Lake

Existing Regulations

The Region 1 general quota of four trout/day and not more than one >50 cm (two hatchery steelhead >50 cm allowed) and two from streams (must be hatchery) applies to Henderson Lake. All wild trout and wild steelhead from streams and all Dolly Varden must be released.

Maximum Catch and Effort at Current Regulations and Maximum Allowable Harvest

Data from the VILQ is only available for 2002, consequently, we could not estimate maximum or optimal sustainable angler effort or catch. There is also no harvest data and no information on how often anglers catch their limit.

Fisheries Objectives and Management Strategies

Angler effort (21 angler days) and catch (125 fish) estimated by the VILQ suggests a virtually un-fished population at Henderson Lake. It's unlikely an angler has a chance of catching a trophy sized cutthroat trout since gillnets did not capture any cutthroat >500 mm and ~ 85% of the fish captured were <250 mm.

We've outlined an operational model for Henderson Lake in Figure 4. Henderson Lake is a low priority lake and in the absence of any changes in angler effort we recommend this lake be netted in 2018 then again every five years to monitor stocks (Table 16; Chapter 1). We do not recommend any changes in the regulations until angler days >500 at which time we recommend conducting a gillnetting assessment to document stock status. This will be critical in light of the observations of Shortreed et al (2001) who noted that egg-to-fry survival in Clemens Creek may be low because of high flushing rates in the watershed. If this is the case, recruitment of

cutthroat to the lake may be limited which could result in a rapid decline of stocks if angler effort and harvest increase.

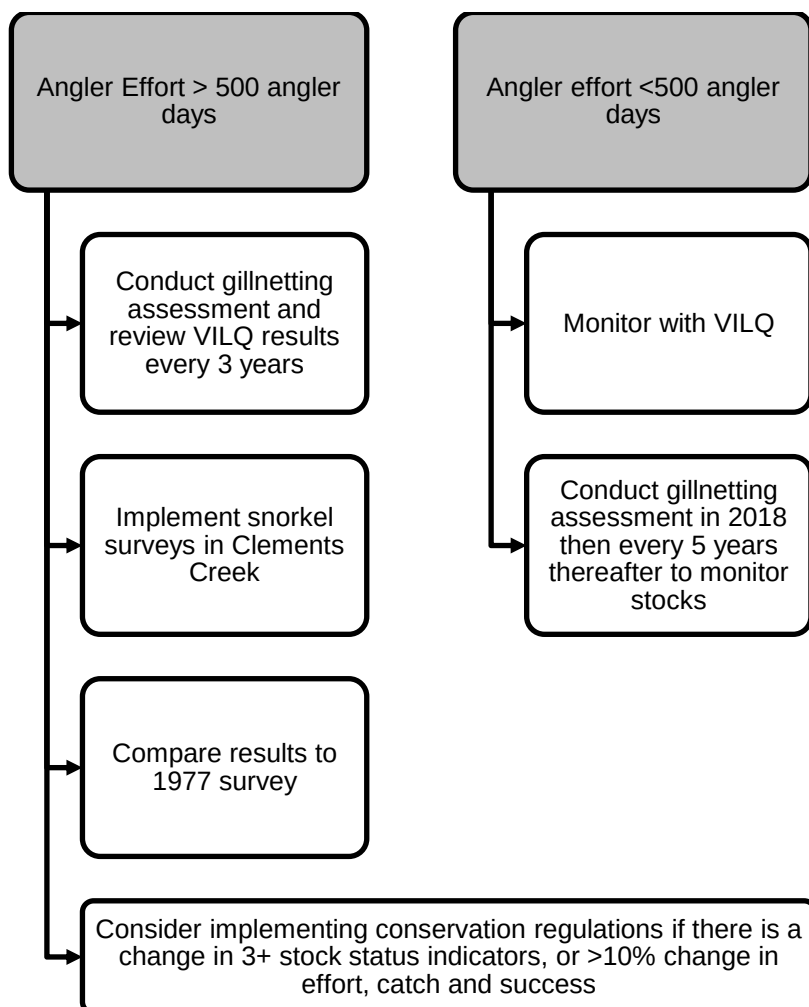


FIGURE 4. Operational model for Henderson Lake.

Operational Management Plan

We've provided an operational management plan for Henderson Lake which recommends snorkel surveys of Clemens Creek to determine the number of spawning adults (Table 6). We've also recommended contacting DFO to determine if they have netting data from their fertilization monitoring studies as its unknown what impact fertilization had on cutthroat which may forage on sockeye in the lake. We also recommend discussing with DFO the state of fertilization plans for Henderson Lake and, if fertilization is contemplated, implementing studies outlined by Shortreed et al (2001) that include obtaining several years of pre-treatment data on lake productivity, zooplankton community structure, and limnetic fish populations. Some limnological data can be collected during gillnetting and the Uchucklesaht Band may be available to collect water quality data if ongoing samples are required for future nutrient enhancement projects. Finally, we've suggested that habitat assessments and enhancement projects be conducted in the future.

TABLE 6. Operational Management Plan for Henderson Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Conduct gillnetting assessment to gather stock status data for cutthroat trout. Conduct gillnetting between July and August to ensure Dolly Varden and cutthroat are not spawning.	See Figure 4
	Conduct snorkel surveys of Clemens Creek to determine the number of spawning adults.	2018
Regulations	Develop regulations based on gillnet results and VILQ; implement conservation regulation if there is a change in three or more stock status indicators.	See Figure 4
Review Management Plan	Determine if any changes to proposed management plan are necessary given VILQ data.	2022
Lake Fertilization	Collect data on productivity, zooplankton community, and on limnetic fish as per Shortreed et al (2001) to determine if lake fertilization is warranted.	2018
Habitat Restoration	Conduct Level 1 and Level 2 WRP assessments for Clemmons Creek; implement restoration prescriptions for priority reaches and monitor structure effectiveness.	2020 +
VILQ	Evaluate changes in fisheries statistics every three years.	Ongoing

Chapter 9. Huaskin Lake

Lake	Huaskin
Planning Unit	Knight
Watershed	Embley River
Surface Area (ha)	2,120
Mean Depth (m)	64.9
Key Tributaries	Embley River, Huaskin Creek
Freshwater Fish Species	Cutthroat Trout, Dolly Varden, kokanee
Limits to Production	Logging
Regional Priority*:	15
<u>Angling Statistics 2002</u>	
Angling Effort	10 angler days
Total Catch	63 fish
Angler Success	6.3 fish/angler day
Current Harvest Rate	No data available
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	Unknown; gillnetting data was last collected in 1991; cutthroat ranged from 245 mm – 424 mm and averaged 335 mm. Dolly Varden were also captured and averaged 240 mm.
Data Gaps	Gillnetting and electrofishing surveys are limited and these and stream surveys are >10 years old; there are no snorkel surveys.
Management Objectives	Monitor fishery with VILQ and implement gillnetting if angler effort >500 angler days/year or in 2023 (Table 16; Chapter 1); consider a maximum size limit to protect large fish.
Operational Plan Priorities	Monitor with VILQ and gillnetting, electrofishing and snorkel surveys; some habitat assessments are also suggested.

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Huaskin Lake Watershed

General Information

Huaskin Lake is located ~35 km east of Port Hardy and lies within the Coastal-Douglas Fir biogeoclimatic zone in the Knight PU (Figure 1). The lake is just southwest of the Robinson Range on a convoluted and indented peninsula extending from the mainland (Coombes and Carswell, 1991). Huaskin Lake is situated at an elevation of 30 m, has a surface area of 2,100 ha, a perimeter length of 84.6 km, and a maximum depth of 65 m (Table 1).



FIGURE 1. Map of Huaskin Lake and tributaries; bathymetric map is provided in Appendix 16 (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Huaskin Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
Knight Inlet	00964SEYM	2,120	84.6	175	64.9				1991

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Tributaries

Coombes and Carswell (1991) found Huaskin Lake to be unproductive with the inlet streams offering insignificant spawning potential. There are 22 inlets and two outlets to Huaskin Lake of which Embley Creek, the main lake outlet, is the most important (Table 2). Construction of a fishway in 1978 at the tidewater mouth of Embley Creek enhanced anadromous fish access to the creek, and Coombes and Carswell (1991) suggested that available spawning habitat was probably more than adequate to maintain sportfish production.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Huaskin Lake (Source: Coombes and Carswell, 1991).

Tributary	Location	Other Information
Embley Creek	Main outlet of Huaskin Lake 4.8 km upstream from Embley Lagoon.	Main outlet to Huaskin Lake; no barriers to upstream movement although a large amount of debris was noted in the 1991 survey.
Huaskin Creek	Flows from the western end of the lake 150 m into a pond and 400 m west from the pond outlet into Acteon Sound.	At least two falls on the outlet (~4 and ~10m high) impassable to fish; although the lower reach is used by coho, chum and pink salmon. There is a waterfall further upstream.
Unnamed Creek 1– Inlet	Flows into the northeast end of the eastern arm of Huaskin Lake.	good pool: riffle habitat and riparian cover.
Unnamed Creek 2– Inlet	Flows into the eastern arm of the lake; not mapped	Small creek; instream habitat and cover noted and during the 1991 survey appeared suitable for spawning and rearing salmonids.
Unnamed Creek 3 – Inlet	Flows into the western shore of the middle arm of the lake.	Lake-headed; average wetted width of ~6 m and depth of 27cm; adult Dolly Varden and salmonids observed.
Unnamed Creek 4 – Inlet	Flows into eastern side of middle arm of lake	Low flow at time of survey but good habitat and many fry – most of which appeared to be Dolly Varden; likely offers the greatest amount of potential salmonid spawning habitat.
Unnamed Creek 5 – Inlet	Flows into western shore of middle arm of lake.	Some useable spawning habitat and lots of cover available.
Unnamed Creek 6 – Inlet	Flows into north side of small bay on east side of middle arm of lake.	Heavy fine substrate and no spawning habitat observed but rearing habitat noted; many fry noted which were believed to be kokanee.
Unnamed Creek 7 – Inlet	Flows into center of large bay on east side of middle arm of lake.	Appeared to be subject to flash floods; limited spawning habitat but some rearing areas noted; spawning may be on alluvial fan; many fry observed.
Unnamed Creek 8 – Inlet	Flows into eastern shore of a bay on south arm of lake	Mostly rearing habitat; limited spawning habitat.
Unnamed Creek 9 – Inlet	Flows into northern shore and is the largest inlet to the lake.	2 of 3 dams (6 m and 1.5 m) are impassable; ~80 m of the stream accessible to fish from the lake although the dams were in poor condition and could have failed by now.
Unnamed Creek 10 – Inlet	Flows into northeast side of lake.	Large amounts of rearing/pool habitat and cover but no significant spawning areas.
Unnamed Creek 11 – Inlet	Flows into southern end of northeast side of lake	Some rearing and spawning habitat and fry observed and these were believed to be Dolly Varden.
Unnamed	Flows into southwest	Much spawning and rearing habitat noted as well as

Tributary	Location	Other Information
Creek 12 – Inlet	end of lake.	cover.
Unnamed	Flows into north side of western arm of lake.	Not surveyed because of debris at mouth but fish habitat appeared likely.
Creek 13 – Inlet	Flows into western arm of lake.	No large amounts of spawning habitat noted but some rearing habitat.
Unnamed	Flows into south side of western arm of lake.	Two channels; rearing habitat but not much spawning habitat noted.
Creek 15 – Inlet	Flows into western arm of lake.	Stream has minor side-channel; much cover and rearing habitat; 15 cm fish noted; dark/stained water.
Unnamed	Flows into western arm of lake.	
Creek 16 – Inlet	of lake.	

Huaskin Creek, the 2nd outlet to Huaskin Lake, flows into Dury Inlet (Table 2). The lower reach is used by salmon but there are at least two falls immediately upstream of the outlet which are impassable to fish. Coombes and Carswell (1991) observed that most of the remaining inlet creeks are too steep and too small to support large spawning populations.

Species Composition

Cutthroat trout, Dolly Varden, and kokanee salmon, coast range sculpin, and threespine stickleback have been observed in Huaskin Lake (Coombes and Carswell, 1991). Both Huaskin and Embley Creeks contain cutthroat, rainbow, coho, Dolly Varden, sculpins and stickleback. There is a connection from Huaskin Lake to the ocean which provides access for anadromous fish including steelhead, Chinook, chum and coho.

Embley Creek has an even-year run of pink salmon of up to ~100,000 fish and coho numbers have ranged up to ~7,500 some of which spawn in feeder streams to the lake (Coombes and Carswell, 1991). Spawning chum numbers range from ~1,500 to ~3,500 and some chum as well as steelhead are believed to spawn in the lake.

Summary of Work and Reports

No surveys were done prior to 1991 when Coombes and Carswell completed their comprehensive fish, habitat and water chemistry survey of Huaskin Lake. In 1993, Law conducted a reconnaissance of the area and his observations are included in the Huaskin Lake file at the Ministry office in Nanaimo. Also in 1993, DFO completed an overview fish count of Huaskin Creek and these data can be found in Ecocat at: <https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=14908>. The Ministry of Forests completed some forestry-related surveys of the Huaskin Lake watershed such as terrain stability and stream classification assessments and these are also available in Ecocat at: <https://a100.gov.bc.ca/pub/acat/public/search.do>.

DFO Vancouver and the Pacific Biological Station (PBS) have reports and surveys relating to the Embley Creek fishway construction as well as a survey of the creek for spawning salmon. Some of this information is available from the SISS volume #12A-Alert Bay but most of the information available in those reports was based on personal knowledge of the fisheries officers and patrol staff and is not available in a report or survey format (Coombes and Carswell, 1991).

2.0 Limits to Fish Production

Logging

The Huaskin Lake watershed has been extensively logged and although logging that occurred from the 1920's and earlier, and in the 1940's is not visually apparent from the lake, logging done in the last decade is obvious to the south of the east-west arm of the lake and from Embley Creek.

A remnant 44 m long and 6.7 m high stone and timber splash dam at the outlet of Little Jennis Lake impounded the lake surface by ~4.3 ha. Historically, this lake was used as a log pond so logs could be temporarily stored and released at high water through a sluiceway into Huaskin Lake. The dam is no longer operational, is abandoned and is partially breached. As a result of the log storage, there are large amounts of floating debris in Huaskin Lake and the two outlet streams (Coombes and Carswell, 1991).

Stream Habitat

The reconnaissance survey conducted by Coombes and Carswell (1991) found few streams that appeared to offer significant spawning potential. The most important stream was Embley Creek which is the main outlet of Huaskin Lake. The construction of a fishway at the mouth of Embley Creek minimized one obstacle to spawning fish, but at the time Coombes and Carswell completed their survey there were still major log jams that could impede fish passage. The fishway was scheduled for major rebuilding when funds permitted but it's not known whether that work was completed.

The Huaskin system may be spawning habitat limited but the lake shoreline is comparatively long and may offer some spawning areas. This has not been investigated. Coombes and Carswell (1991) noted that given the low productivity of the lake the spawning areas may be adequate for recruitment. They suggested a survey be completed to measure the available areas and obtain an accurate figure of the potential spawning habitat.

Nutrients

Coombes and Carswell (1991) state that Huaskin Lake is hyper-oligotrophic except for nitrogen levels which they termed borderline. They suggested that if it were not for the presence of stickleback and the lack of sockeye, Huaskin Lake could be a target for lake fertilization to improve fish production. DFO proposed that Huaskin Lake be examined for potential fertilization, though no water quality data was ever collected (FLNRO files, Nanaimo).

3.0 Angling Statistics

Angler Effort, Catch and Success and Harvest

Angler effort in Huaskin Lake is minimal with ten angler days having been reported in both 1986 and 2002 (Table 3). Total catch at Huaskin Lake varied between the two years with five fish caught in 1986, and 63 fish caught in 2002. Angler success was estimated at 0.5 fish/day in 1986 and 6.3 fish/day in 2002. The average catch/day for the two years combined was 3.4 fish/day. There is no harvest data.

TABLE 3. Effort (angler days), total catch and success (catch/angler day) at Huaskin Lake 1986, 2002. Note: there were no responses from Huaskin Lake for 1989-1992 or 2011 (Source: Aitzhanova, et al. 2003, Andrews, 2007, Silvestri, 2013 in prep).

Fisheries Statistic	1986	2002	Average
Effort (angler days)	10	10	10
Total Catch	5	63	34
Success (catch/angler day)	0.5	6.3	3.4

4.0 Stock Status Indicators

Relative Abundance

A sample of 160 fish comprised of 36 cutthroat trout, 39 Dolly Varden and 85 kokanee salmon were collected in gillnets in August 1991 (Figure 2). More than 50% of the fish were kokanee with cutthroat and Dolly Varden comprising almost equal proportions of the remaining catch.

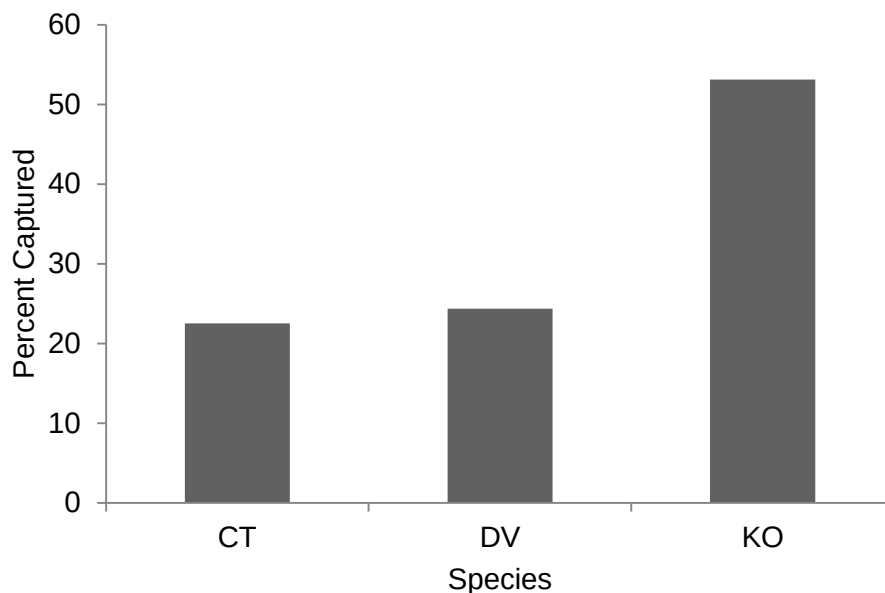


FIGURE 2. Percent cutthroat trout (n=36), Dolly Varden (n=39) and kokanee salmon (n=85) captured in gillnets in August 1992 in Huaskin Lake (N =160) (Source: Coombes and Carswell, 1991).

Coombes and Carswell (1991) observed that the health of the fish they captured was poor with a very high rate of *Salmincola* infections in the cutthroat trout, a moderate rate in the Dolly Varden, and a low rate in the kokanee. These investigators also found *Diphyllbothrium*, *Eubothrium* and *Cotylurus* infections in the captured cutthroat.

Length and Weight

We've provided a summary of the lengths and weights of the 36 cutthroat captured in 1991 in Table 4 and a length-weight relationship, length frequency distribution, and additional sex and maturity graphs in Appendix 16. Cutthroat trout ranging from 245 mm - 424 mm and averaging 334.9 mm were captured. The modal length was 277 mm, and the mean weight was 390.6 g.

TABLE 4. Minimum, maximum, mean length and mean weight for cutthroat and Dolly Varden captured in gillnets in August, 1992 in Huaskin Lake (N=75) (Source: Coombes and Carswell, 1991).

Species	n	Length (mm)				Weight (g)
		Minimum	Maximum	Mean	Mode	Mean
Cutthroat	36	245.0	424.0	335.4	277	390.6
Dolly Varden	39	169.0	318.0	240.1	237	165.0

Thirty-nine Dolly Varden were captured in 1991 and these ranged from 169 mm - 318 mm and averaged ~240 mm (Table 4, Appendix 16). The modal length was 237 mm, and the average weight was 165 mm.

Age and Growth

Though no ageing was done, Coombes and Carswell noted length-at-maturity of fish sampled (Table 5). Approximately 85% (30 fish) of cutthroat were immature and ranged from 245 mm - 405 mm and averaged 334.6 mm. The remaining 15% (5 fish) were mature and ranged from 277 mm - 424 mm and averaged 347.6 mm.

TABLE 5. Minimum, maximum, mean length and mean weight for cutthroat and Dolly Varden captured in gillnets in August, 1992 in Huaskin Lake (N=66) (Source: Coombes and Carswell, 1991).

Factor	Cutthroat		Dolly Varden	
	Immature	Mature	Immature	Mature
n	30	5	8	23
Minimum Length (mm)	245	277	169	185
Maximum Length (mm)	405	424	260	318
Mean Length (mm)	334.6	347.6	218.3	252.7

Twenty-six percent (8 fish) of the Dolly Varden captured were immature and ranged from 169 mm -260 mm and averaged 218.3 mm (Table 5). Seventy-four percent (23 fish) were mature and ranged from 185 mm -318 mm and averaged 252.7 mm.

Catch Indicators

Total Catch

The total gillnet catch in 1991 was 160 fish of which cutthroat comprised 22% (36 fish) and Dolly Varden comprised 25% (39 fish) and kokanee comprised 53% (85 fish) (Figure 2; Table 6). Netting was conducted in August, however, there are no other details regarding number of nets, number of sets, net locations or soak times.

TABLE 6. Total catch of cutthroat trout (n=36), Dolly Varden (n=39) and kokanee (n=85) captured in gillnets in August 1992 in Huaskin Lake ((N=160) (Source: Coombes and Carswell, 1991).

Species	N
Cutthroat	36
Dolly Varden	39
Kokanee	85
Total	160

Data Gaps

Data collected for the VILQ is now >10 years old (Table 7). Lake inventory, water quality and productivity and general stream inventories are >10 years old and no angler preference, surveys snorkel surveys or hydroacoustic surveys have been conducted. Limited site specific electrofishing surveys were conducted to establish fish presence prior to logging (Reid, G., 2011 pers. com.).

TABLE 7. Summary of data gaps for Huaskin Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 yrs. old	>10 years	No data
Lake Inventory		X	
Water Quality/Lake Productivity		X	
Stream Inventory (general)		X	
Spot electrofishing to establish fish presence		X	
Level 1 & 2 WRP Surveys			X
Electrofishing Surveys (streams)		X	
Snorkel Surveys			X
VI Lakes Questionnaire	X		
Angler Creel Surveys			X
Angler Preferences			X

5.0 Fisheries Objectives and Management Strategies for Huaskin Lake

Existing Regulations

The Region 1 general quota of four trout/day and not more than one >50 cm (two hatchery steelhead >50cm allowed) and two from streams (must be hatchery) applies to Huaskin Lake. All wild trout and wild steelhead from streams, and all Dolly Varden must be released.

The tributaries to Huaskin Lake including Embley Creek are covered by the regional regulations which require release of all wild trout and char.

Maximum Catch and Effort at Current Regulations and Maximum Allowable Harvest

Data from the VILQ is only available for 1986 and 2002 so we could not estimate maximum or optimal sustainable angler effort or catch. There is no information on how often anglers catch their limit at Huaskin Lake and no harvest data but we expect that actual yield is well below that predicted by the MEI (Appendix 8).

Fishery and Stock Status and Comparison to Regional Fisheries Objectives

Angler effort (ten angler days) and catch (average ~35 fish/year) suggest Huaskin Lake is virtually un-fished and it's probable that the current limit of four fish/day could be achieved given the lack of angler pressure and Coombes and Carswell's netting results. It's unlikely that an angler has a chance of catching a trophy sized cutthroat trout in Huaskin Lake since gillnets set in 1991 did not capture any cutthroat >500 mm, the mean size of cutthroat was ~335 mm (Table 4), and 70% were <350 mm (Appendix 16).

Although gillnet sampling indicates a stable population of cutthroat, Dolly Varden and kokanee (Coombs and Carswell, 1992), the quality of the fishery in Huaskin Lake is marginal at best because the fish are generally small (<40 cm) and heavily parasitized. In addition, catch rates are somewhat restricted because most Dolly Varden and all of the kokanee are unavailable to the sport angler.

We've outlined an operational model in Figure 3 which recommends monitoring with the VILQ until angler effort >500 angler days/year and success <5 fish/day. Huaskin Lake is a low priority lake and angler effort at this lake is not likely to increase primarily because this lake is remote and accessible only by air. While there are many small areas or point localities with good or reasonable access to the lake from the shore, most are not contiguous, and do not have extensive backshore access possibilities. Access to the shoreline from the lake is excellent in most areas, but there are many sections of the shoreline which are bordered by a broad tangle of logs and where the backshore is too steep and/or bushy to allow access (Coombs and Carswell, 1991). Although Law (1993) noted that fly-in fishing to the Embley Creek mouth was occurring, remaining outlets are very difficult and dangerous to access from the lake because of the logs which cover the surface of the water.

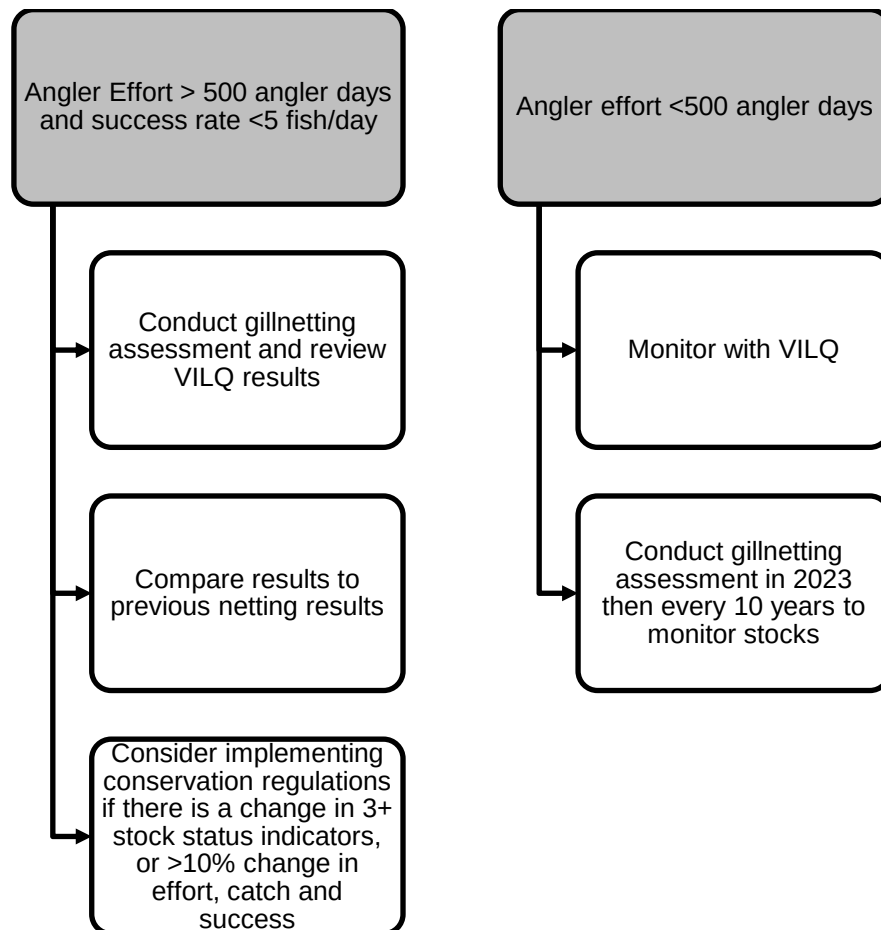


FIGURE 3. Five year management plan for Huaskin Lake. Huaskin Lake is a low priority large lake (see Chapter 1 for details) and does not require targeted management action until the number of anglers increases. This plan should be reviewed in 2015.

In the absence of any changes in angler effort, we recommend this lake be netted in 2023 then again every ten years to monitor stocks (Table 16; Chapter 1). In light of the government's objective to stimulate angling, it should be noted that relaxing the regulations at Huaskin Lake may help encourage angler effort. However, we recommend this strategy be implemented with caution due to the oligotrophic nature of Huaskin Lake, and because experience at other large lakes in the region demonstrates the sensitivity of wild cutthroat stocks, especially larger fish, to overharvest. Any future liberalization of regulations should be closely monitored using the VILQ to determine changes to angler effort increases in response to regulations changes, and a gillnetting survey to determine changes to stock status (Figure 3).

Operational Management Plan

We've provided an operational management plan for Huaskin Lake in Table 8 which recommends that stream and snorkel surveys accompany future gillnetting surveys to establish baseline data, and in advance of any regulations changes.

TABLE 8. Operational management plan organized according to management priorities for Huaskin Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Repeat Coombes and Carswell gillnet assessment and compare stock status statistics indicators. No stream surveys have been conducted and could be implemented with the gillnetting assessment.	See Figure 3
Regulations	Develop regulations based on gillnetting results and VILQ	See Figure 3
Review Management Plan	Determine if any changes to proposed management plan are necessary given VILQ and gillnetting data.	2023
Limnology	Water quality data is limited and there is a need to collect information on TDS; this work can be done when gillnetting.	Implement with next gillnetting survey
Habitat Assessment -	Consult with Ecosystems staff to review level of logging in the watershed if gillnetting surveys indicate declining fish populations.	During gillnetting assessment
VILQ	Evaluate changes in fisheries statistics every three years.	Ongoing

Chapter 10. Kennedy Lake

Lake	Kennedy
Planning Unit	West Coast
Watershed	Kennedy
Surface Area (ha)	6,475
Mean Depth (m)	38
Key Tributaries	Clayoquot and Kennedy Rivers, Sand River
Freshwater Fish Species	Cutthroat Trout, Dolly Varden
Limits to Production	Logging
Regional Priority*:	12
<u>Angling Statistics 2011</u>	
Angling Effort	1,211 angler days
Total Catch	3,063 fish
Angler Success	2.5 fish/angler day
Current Harvest Rate	1%
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	VILQ indicates a stable fish population and low angler effort
Data Gaps	No fish stock data.
Management Objectives	Monitor the fishery using the VILQ; gillnetting should proceed if angler effort >1,500 angler days and angler success <1.6 fish/angler day, or in 2023 and every ten years thereafter if there are no changes in the fisheries statistics.
Operational Plan Priorities	Monitoring with VILQ and gillnet according to schedule (Table 16; Chapter 1).
Potential Partners	DFO – Lake Enhancement Unit

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Kennedy Lake Watershed

General Information

With a surface area of 6,475 ha, Kennedy Lake is the largest freshwater lake on Vancouver Island (Figure 1). This lake sits at 12 m elevation, and is located ~13 km north of Ucluelet, and 70 km southwest of Port Alberni. Kennedy Lake lies within the Coastal-Hemlock biogeoclimatic zone in the West Coast PU, has a maximum depth of 145 m, and a mean depth of 38 m (Table 1). The lake has two discrete basins (Main and Clayoquot Arms) connected by a narrow (<300 m), shallow (<10 m) sill (Stockner and Shortreed, 1988).

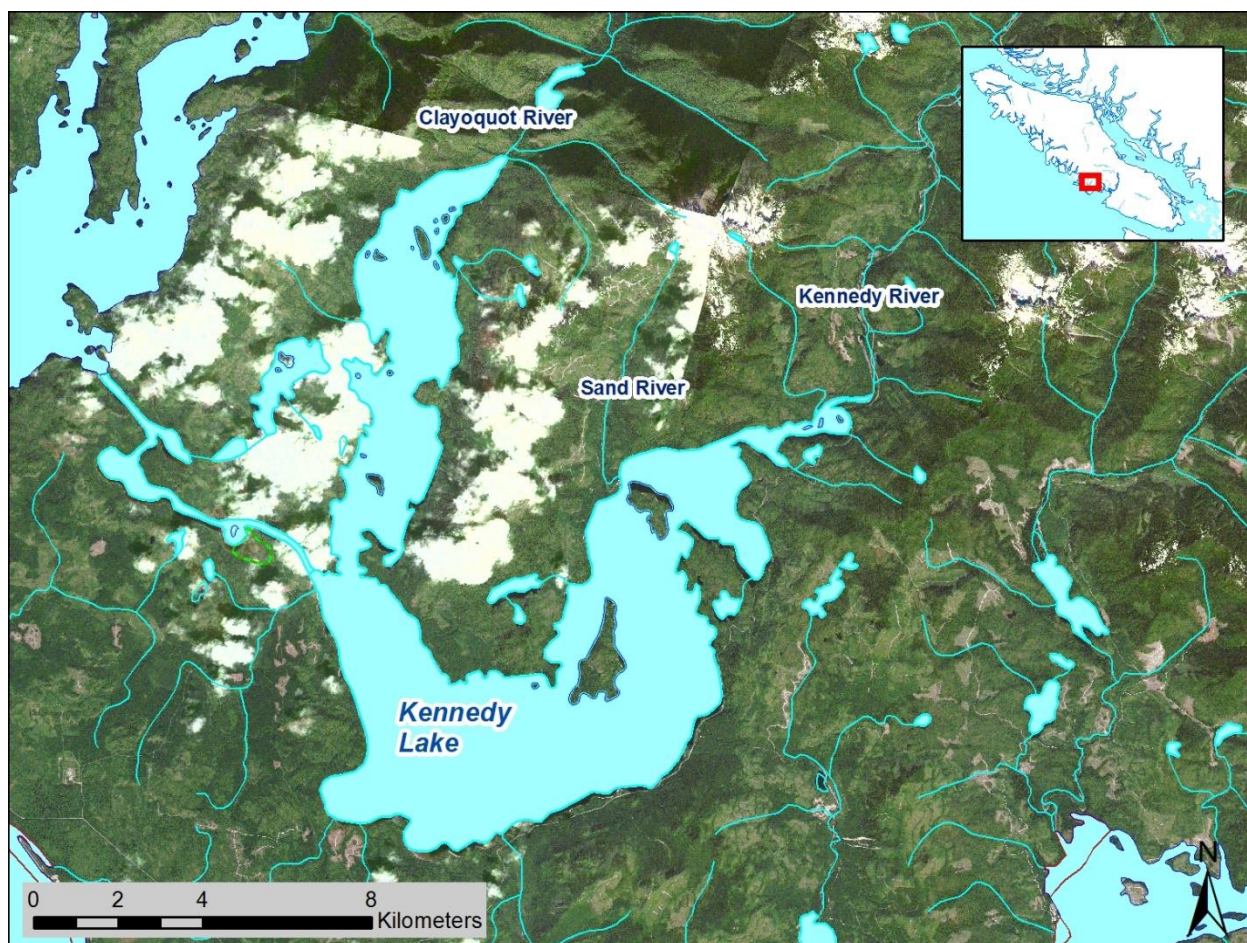


FIGURE 1. Map of Kennedy Lake and tributaries; a bathymetric profile is not available (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Kennedy Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)
West Coast	01168CLAY	6,475	111.9	145	38	7.2	21	7.5	1962 1975 1986

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Tributaries

The Kennedy, Clayoquot, and Sand Rivers are the main salmonid producing tributaries to Kennedy Lake (Table 2). A limited sport fishery for salmon and steelhead trout occurs in the Kennedy River which is the outlet for Kennedy Lake. No information exists on other trout and char fishing in this river. The lower Clayoquot River and several small spawning tributaries to the lake probably produce fish but these areas have not been surveyed.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Kennedy Lake (Source: BC FLNRO files, Nanaimo; Hazeldine and Burns, 1972; Catalogue of Fish and Stream Resources for Area 24).

Tributary	Order	Length and/or Drainage Area	Other Information
Clayoquot River	3	24 km; 60 mi ²	Lower reaches encompassed in the Clayoquot Arm Provincial Park; stream is ~ 24 km in length and ~20m wide; substrate is 5% boulder 80% cobble and 15% fines and sand; gradient increases to 5% at ~4km upstream; sockeye use the lower 1,500 m, and coho use the entire system gradient permitting; The Catalogue of Fish and Fish Habitat notes this as a coho stream of major importance.
Lower Kennedy River	3	~14 km	This stream flows from Kennedy Lake to the salt water of Tofino Inlet. The river is ~14 km long and 60 m wide; most of the substrate (65%) is classified as mud and 35% as boulder/cobble; gradient varies from 2.5% – 5% and there is a passable falls ~1 km from the mouth; only the bottom portion is used by Chinook salmon.
Upper Kennedy River		170 mi ²	This higher gradient stream (up to 10% in some areas) is ~24 m wide with substrate composed of: 5% bedrock; 65 boulder/cobble; 30% fines/sand. There is a impassible falls ~16 km from the mouth and a series of rapids and falls above this after which the stream flattens; sockeye and coho use this stream to the falls
Sand River	3	1.6 km	Boulder stream with sections of bedrock; stream flows through narrow steep-sided valley except in the lower ~500 m which crosses a flat; vertical falls located 1,500 m above river mouth; peak flows may be as high as 1,000 cfs. Hazeldine and Burns (1972) note the nature of the stream indicates it may be a steelhead stream and should be checked to confirm in late spring or summer.
Hatchery Beach	Located on Clayoquot arm of Kennedy Lake; major Kennedy Lake sockeye spawning area; ~80% of sockeye spawning escapement takes place here (Reid, G., 2012, pers. com).		

Species Composition

Ministry records list both sockeye and kokanee as present in Kennedy Lake (FISS). At one time, Kennedy Lake was a major producer of sockeye salmon, however, since the mid-1980's sockeye escapements to the lake have averaged only 11,000, which is a spawner density of <2 fish/ha (Shortreed et al 2001). These investigators point out that the visual means used to obtain these escapement estimates leave considerable uncertainty.

Coho and Chinook salmon, and cutthroat and rainbow trout are found in Kennedy Lake and some tributaries, while steelhead are found in the Kennedy River. Dolly Varden have only been found in the Clayoquot River, as fish sampling in the lake and tributaries is limited and cursory at best (Reid, G., 2010, pers. com). Little data exists on trout and Dolly Varden stock status in the watershed, and these populations are believed to be nutrient limited (Reid, G., 2010, pers. com.).

Sculpins, threespine stickleback, and peamouth chub are found in Kennedy Lake (Carl, Clemens and Lindsey in FLNRO files, Nanaimo). Crayfish are also present in the lake and a commercial harvest licence for the species was issued for Kennedy Lake in 1990. It's not known how viable that business was as it is no longer operational.

Summary of Work and Reports

Surveys of Kennedy Lake were conducted in 1962, 1975, 1986 (Table 1). Detailed limnological sampling was carried out from 1977 until 1985 by DFO and the lake's limnetic fish community was sampled in those years and for a number of years thereafter (Rutherford, et al. 1986; K. Hyatt, in Shortreed et al, 2001). Shortreed et al (2001) provides a description of the fertilization program at Kennedy Lake, and outlines some direction on possible constraints to sockeye production.

Hydroacoustic surveys to estimate the size of fish populations and minnow trapping to identify species which could compete with juvenile sockeye were conducted as part of a larger DFO lake fertilization study reported on by numerous authors (e.g. Shortreed et al, 2001; Stockner and Shortreed, 1979 and 1985; Stockner and Costella, 1980). A study by Cooper (1982) outlines interactions among *Neomysis mercedis* populations, zooplankton community structure, and lake fertilization at Kennedy Lake.

The Catalogue of Fish and Stream Resources for Area 24 (FLNRO files, Nanaimo) provides a cursory review of sockeye and coho escapements and general descriptions for the Clayoquot and Kennedy Rivers. Hazeldine and Burns (1972) give a brief description of the habitat, and Northwest Ecosystems (1986) documented their WRP restoration work directed at sockeye and coho enhancement on the Sand River. These reports can be found in the Ministry files in Nanaimo.

2.0 Limits to Fish Production

Logging

Logging is the major land use in the watershed and has impacted the major fish producing streams (Northwest Ecosystems, 1986; Hazeldine and Burns, 1972). An extensive section of the Sand River watershed has been logged including both sides of the flat area at the mouth, the west side of the river upstream to the headwaters, and a few openings on the east side of

the river. Logging roads parallel the stream for 5.6 km and into the headwaters (Hazeldine and Burns, 1972).

The lower Clayoquot River, Clayoquot Lake and the forested slopes northwest of the Clayoquot Arm are encompassed by the Clayoquot Arm Provincial Park which is a wilderness area and protects rare old-growth forests of Sitka spruce. Access to this park is by active logging roads only.

Nutrients

Kennedy Lake is highly oligotrophic, and as with most BC coastal lakes, the water residence time in this lake is short (1.1 year) (Shortreed et al, 2001). The Clayoquot Arm of Kennedy Lake was fertilized from 1978 until 1984, and the Main Arm was fertilized in 1979, 1980, 1985, and 1987–1989 (Shortreed et al, 2001). According to Shortreed et al., 2001), Kennedy Lake responded strongly to fertilizer additions and there were substantial increases in chlorophyll concentration, photosynthetic rates, and zooplankton biomass. In addition, sockeye smolt size increased 30% the first year Kennedy Lake was fertilized despite a 60% increase in fish density that also occurred that year (Hyatt and Stockner, 1985). Shortreed et al. 2001 suggest that restoration of Kennedy Lake sockeye requires fertilization as well as additional fry recruitment. The fertilization program at Kennedy Lake is currently on hold but there is interest in re-establishing the program in the future (Wightman, C., 2012, pers. com.).

3.0 Angling Statistics

Angler Effort

The average angler effort over the 25-year VILQ survey period is ~800 angler days/year (Figure 2). Angler effort was ~1,150 angler days in 1986; it dropped to 800 angler days in 1992 and to ~600 angler days in 2002 (Figure 2). In 2006, angler effort dropped again to 565 angler days but in 2011 angler effort rose to 1,200 angler days. The average angler effort over the past 25 years is ~800 angler days/year.

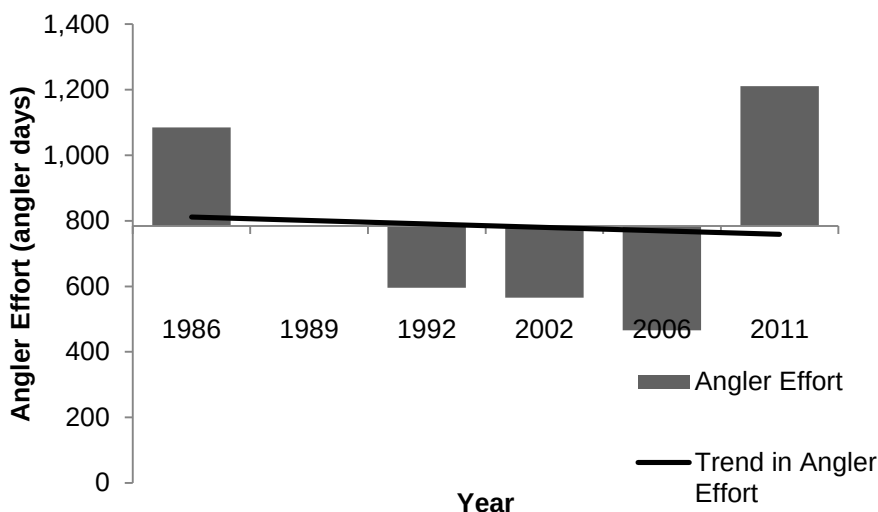


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Kennedy Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Catch

The average catch for Kennedy Lake is 1,700 fish though the catch has varied greatly over the survey period. Total catch at Kennedy Lake dropped through the 1990's and early 2000's but increased recently (Figure 3). Total catch was ~2,000 fish in 1986, 1,700 fish in 1989, <1,000 fish in 1992, ~1,600 in 2002 and <1,000 fish in 2006. In 2011, total catch rose to 3,000 fish.

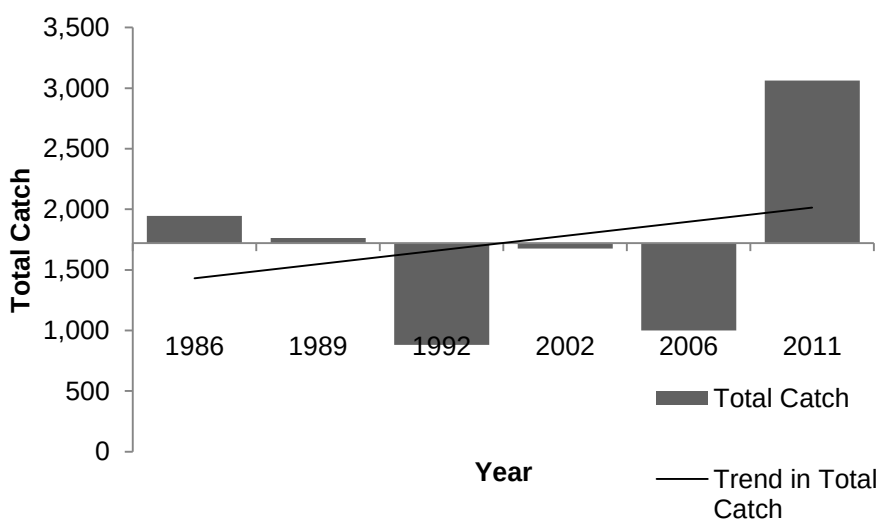


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Kennedy Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Approximately 97% of angler catch at Kennedy Lake is cutthroat trout (Table 3). In 2006, anglers caught 966 cutthroat (96.6 % of the total catch) and in 2011 they caught ~3,000

cutthroat (97% of the total catch). Less than 5% of angler catch is rainbow trout with only 34 rainbow caught in 2006, and 84 caught in 2011.

TABLE 3. Catch of rainbow and cutthroat trout at Kennedy Lake 2006 and 2011 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	966	96.6	2,979	97.3
Rainbow	34	3.4	84	2.7
Total	1,000		3,063	

Angler Success

Angler success in 1986 was ~1.7 fish/day and ~2.2 fish/day in 1989 (Figure 4). In 1992, angler success dropped to 1.4 fish/day; the lowest during the survey period. In 2002, angler success reached its highest level of ~3 fish/day but in 2006 success rate dropped to 2.1 fish/day. Angler success rose to 2.5 fish/day in 2011. The average angler success at Kennedy Lake is 2.1 fish/day which is higher than the regional success objective of 1.6 fish/day.

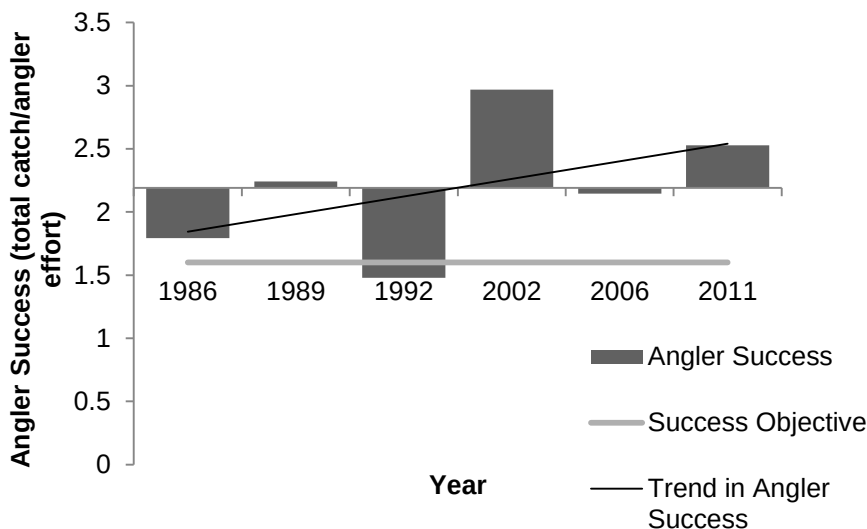


FIGURE 4. Angler success (total catch/total angler effort in angler days) compared to average angler success and the objective for angler success (1.6 fish/angler day) at Kennedy Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Harvest

Anglers did not report harvesting fish of either species in 2006, nor did they harvest any cutthroat in 2011 (Table 4). That year, however, anglers did harvest 50% of their rainbow trout catch (~42 fish).

TABLE 4. Catch, harvest and percent harvest of rainbow and cutthroat trout at Kennedy Lake 2006 and 2011 (Source: Andrews; 2007, Silvestri, 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	966	0	0.0	2,979	0	-----
Rainbow	34	0	0.0	84	42	50.0
Total	1,000	0	0.0	3,063	42	1.4

4.0 Stock Status Indicators

Relative Abundance

Kennedy Lake has never been gillnetted and there is no biological data for either species of trout. Although the lake was fertilized and DFO did hydroacoustic work, no fish data is available (Hyatt, K. 2012, pers. com.).

In the absence of any gillnetting data and based on the results of the VILQ in 2006 and 2011, its likely cutthroat trout comprise most of the fish biomass in the lake (~97% of angler catch) (Table 3). Rainbow trout likely make up only a small proportion of the fish population and despite the fact that Dolly Varden have been documented in the Clayoquot River, it's unlikely that this species enters the Kennedy Lake fishery as no Dolly Varden have been reported in the VILQ.

Data Gaps

We've summarized the data gaps for Kennedy Lake in Table 5. Although limnological data exists as a result of the lake enrichment program, there is no bathymetric profile for the lake, no gillnetting or electrofishing data. The only fish sampling data we found were summaries of results from stickleback trapping data included in Ministry files. Data gaps also exist regarding fish use and presence in most tributaries and although cursory habitat assessments of the tributaries have been completed, these are >10 years old and should be updated.

TABLE 5. Summary of data gaps for Kennedy Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Bathymetric Profile			X
Gillnetting			X
Angler Creel Survey			X
Angler Preference Questionnaire			X
VILQ	X		
Snorkel Surveys			X
Acoustic Surveys		X	
Electrofishing (streams)			X
Lake/Limnology Inventory		X	
Stream Habitat Inventory		X	
Water Quality/Lake Productivity		X	
Instant Angler Counts or Box Creels			X

5.0 Fisheries Objectives and Management Strategies for Kennedy Lake

Existing Regulations

Kennedy Lake is covered by the Region 1 general regulations of a daily quota of four fish/day but not more than one >50 cm (two hatchery steelhead >50 cm allowed) and two from streams (must be hatchery). There is no data on how often these goals are achieved. All wild trout and Dolly Varden must be released.

Maximum Catch and Effort, Harvest and Yield at Current Regulations

Despite the fact there is considerable variability in the angler effort and catch data, there is a close relationship between these fisheries statistics at Kennedy Lake ($R^2=0.76$). It appears as though Kennedy Lake is under-fished given there was not enough angler effort to calculate a polynomial (i.e. the points are all too low on the ascending limb of the curve) so we couldn't project the maximum or optimum sustainable angler effort or catch (Figure 5). In addition, because of such low angler catches, the yield is well below the predicted yield based on MEI (Appendix 8).

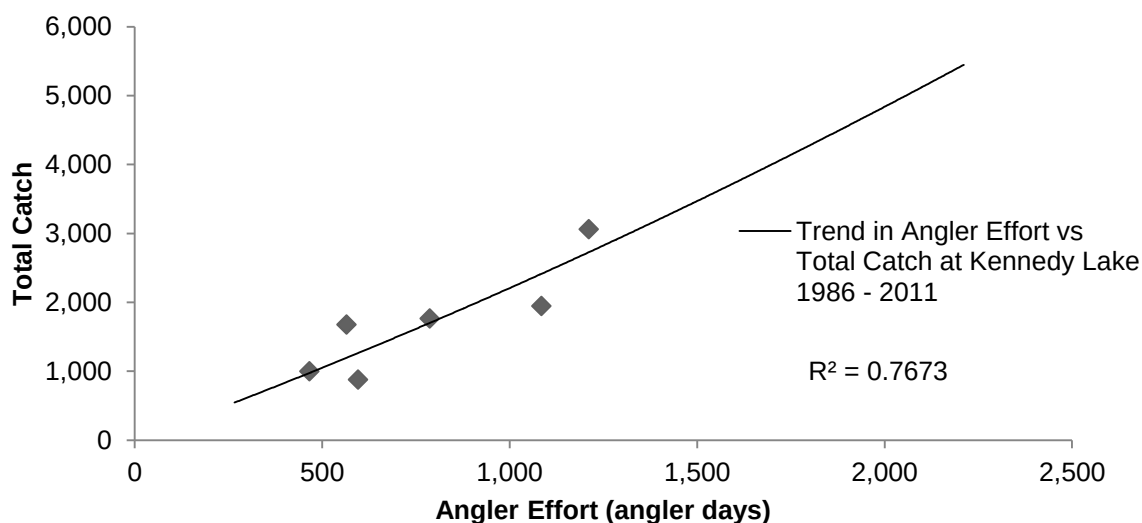


FIGURE 5. Angler effort (angler days) vs. total catch at the current regulations and trend in angler effort and total catch (second order polynomial) at Kennedy Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

The existing regulations likely protect stocks in the lake and cutthroat in the tributary streams given the low number of angler days at Kennedy Lake. Unfortunately, there is no data on how often the general quota of 4 fish/day is achieved, and there isn't enough data to evaluate the effectiveness of any of the current regulations at Kennedy Lake or tributary streams.

The relatively constant angler success rate of ~2 fish/day over the past two decades suggests a virtually un-fished population and the major data gap at this lake is the lack of stock status indicator data. It appears as though the population of fish in Kennedy Lake could absorb more angler effort and we've suggested gillnetting to establish baseline stock status indicators if angler effort >1,500 angler days/year and angler success <1.6 fish/day (Figure 6). In the absence of meeting those criteria, we suggest the Kennedy Lake fishery be monitored using the VILQ, and be gillnetted every ten years starting in 2023 as per the outline provided in Table 16 in Chapter 1.

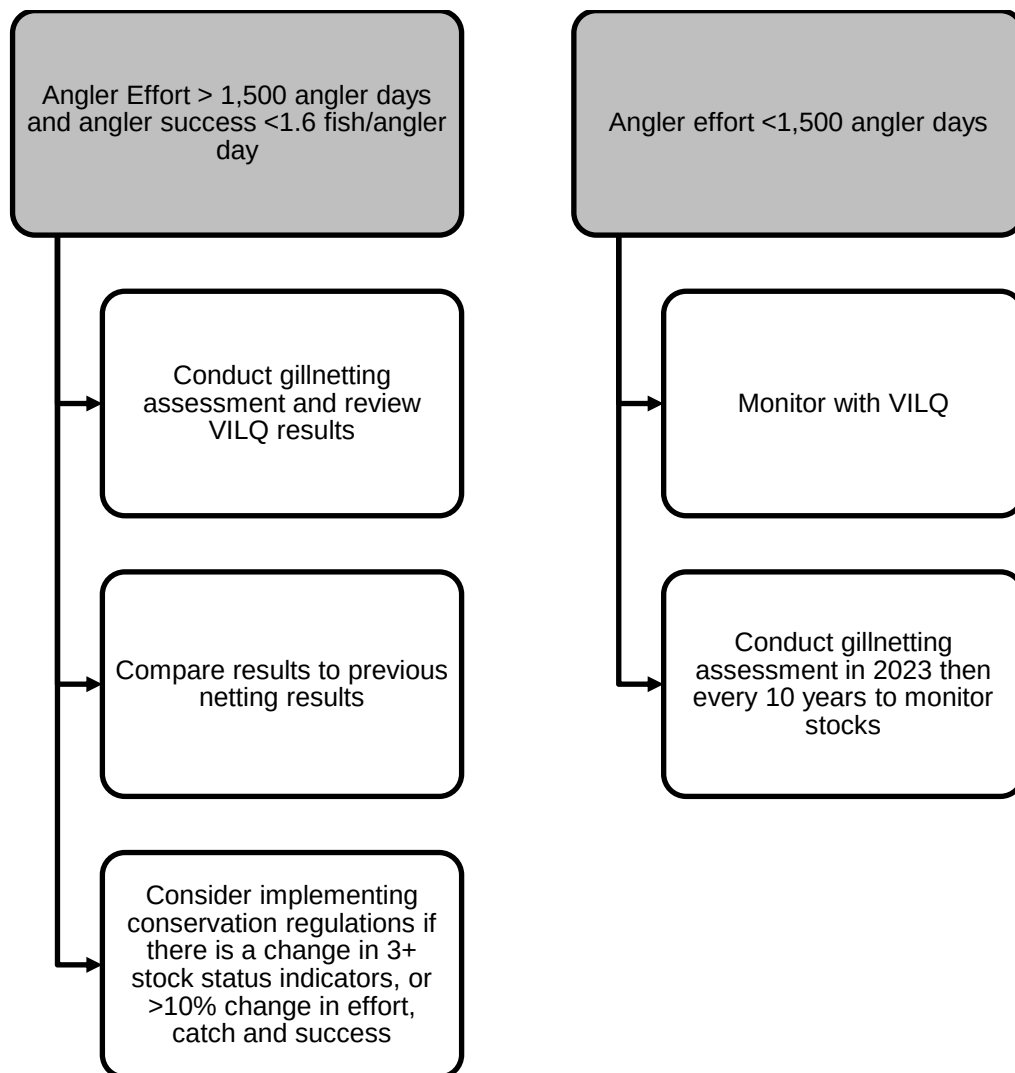


FIGURE 6. Operational management model for Kennedy Lake. Kennedy Lake is a low priority large lake (see Chapter 1 for details) and does not require targeted management until the VILQ indicates increases in angler effort. Gillnetting can proceed in 2023 with other lower priority lakes.

Conservation regulations should focus on conserving cutthroat stocks, and maintaining or increasing the size of this species if VILQ and gillnet monitoring suggest these regulations are necessary. Depending on the results of the gillnetting assessment, maximum and/or minimum size regulations may be appropriate as per our recommendations in Section 11 of Chapter 1.

Operational Management Plan for Kennedy Lake

We've provided an operational management plan for Kennedy Lake in Table 6. In the absence of any other action it's essential that monitoring continue through the VILQ to document changes in fisheries trends, and management objectives be re-evaluated following a review of fisheries statistics. We've also recommended a box angler creel to provide more information on catch and harvest, and instant angler counts conducted by air on long weekends and holidays to provide insight into the true level of angler effort at this lake (Table 6).

TABLE 6. Operational management plan for Kennedy Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Conduct gillnetting assessment to collect stock status data; review in light of data from VILQ.	As per Figure 7 or 2023 and every 10 years (Table 16; Chapter 1).
Fisheries Monitoring	Implement box creel to provide more information on catch and harvest Conduct instant angler counts by air on long weekends and holidays to provide information on angler effort.	As opportunities arise.
Regulations	Develop conservation regulations based VILQ results.	As per Figure 7 and recommendations in Section 11 Chapter 1. 2023
Review Management Plan	Determine if any changes to proposed management plan are necessary given VILQ data.	
Lake Fertilization	Fertilization could be considered but must be proceeded by a gillnet survey to establish stock status and monitoring criteria. Review previous fertilization results and discuss with DFO to determine if there is potential to reinstate this program. If so, monitor effectiveness and impact on fisheries.	As per DFO schedule
VILQ	Evaluate changes in fisheries statistics every three years.	Ongoing

Chapter 11. Lower Campbell Lake

Lake	Lower Campbell
Planning Unit	Campbell Oyster
Watershed	Campbell
Surface Area (ha)	2,694
Mean Depth (m)	17.1
Key Tributaries	Campbell River, Beavertail, Fry, Greenstone, Miller Creeks
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden
Limits to Production	Logging, Water Withdrawal
Regional Priority*:	6
<u>Angling Statistics 2011</u>	
Angling Effort	4,497 angler days
Total Catch	9,258 fish
Angler Success	2.1 fish/angler day
Current Harvest Rate	37%
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	Maximum, mean and modal size of cutthroat and maximum and mean size of rainbow declined since 1950's
Data Gaps	Gillnetting data will be ten years old in 2014; we recommend gillnetting and conducting snorkel surveys in 2014. Limnology data is >10 years old and there has never been an acoustic survey.
Management Objectives	Cutthroat and rainbow comprise ~equal proportions of the fishery and management actions must focus on both species. Review results of the next VILQ with gillnetting data to determine if more conservative regulations are required.
Operational Plan Priorities	Update stock status and review fisheries statistics. Other work includes initiating habitat restoration and enhancement including barrier removal, addressing low flow issues and lake fertilization projects identified in the past.
Potential Partners	BC Hydro, NVI Mines, Campbell River Fish and Game Association, Campbell River Band, Kwakwaka'wakw District Council

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Lower Campbell Lake Watershed

General Information

Lower Campbell Lake, known also as Campbell Lake, is located ~2 km west of Campbell River. This lake flows east into John Hart Lake, then into the Campbell River which discharges into Discovery Passage at the town of Campbell River (Figure 1). Lower Campbell Lake is situated 178 m above sea level, and lies within the Coastal Western Hemlock zone in the Campbell Oyster PU.

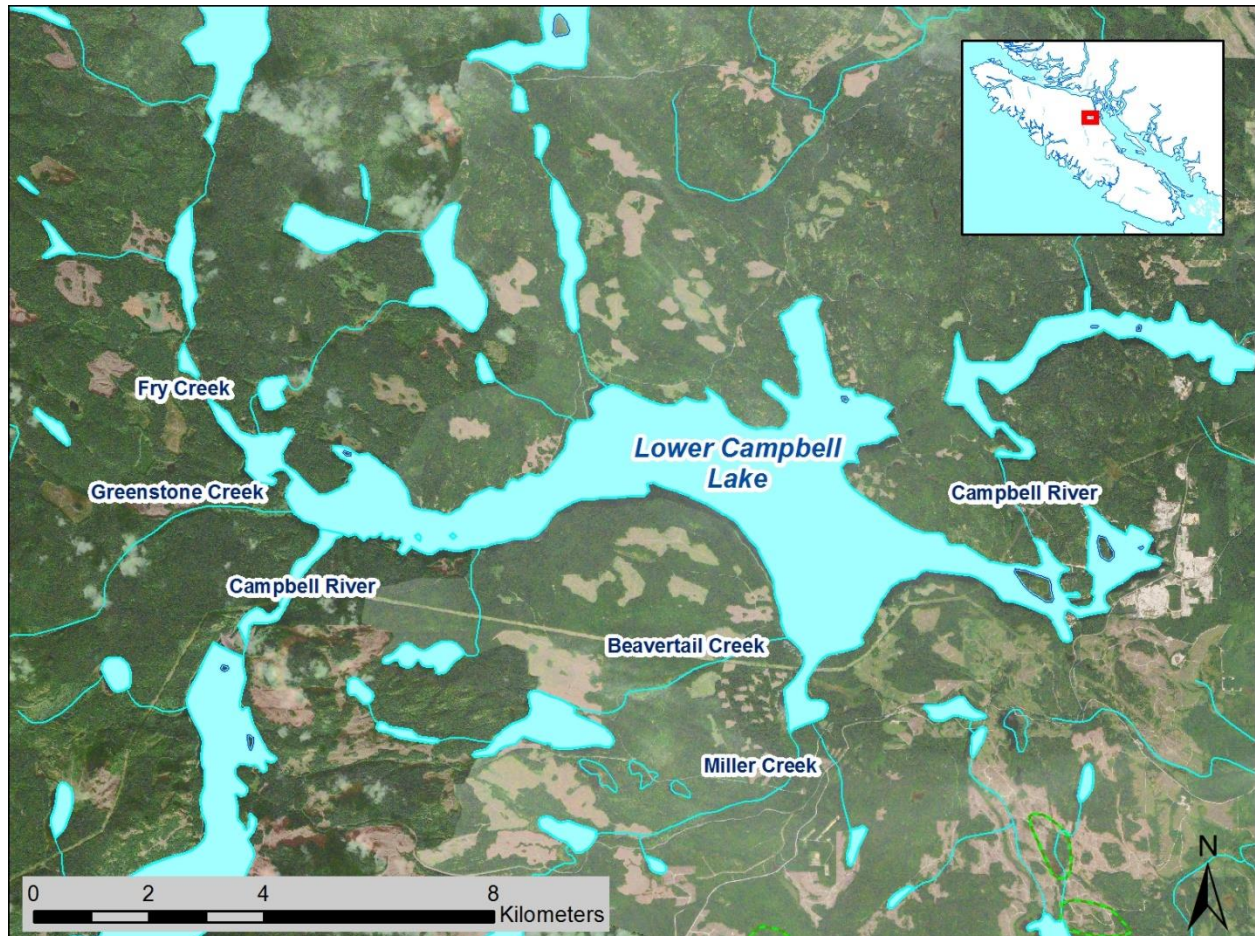


FIGURE 1. Map of Lower Campbell Lake and tributaries; a bathymetric profile is not available (Source: iMap BC).

Lower Campbell Lake is part of the Campbell River Hydro development which consists of three dams on the Campbell River mainstem – John Hart, Ladore and Strathcona – completed in 1953, 1958 and 1958, respectively (BC Hydro, 2002). The lowermost facility is John Hart Dam which impounds the John Hart Reservoir and diverts water to a powerhouse located downstream of Elk Falls on the Campbell River. The middle reservoir is Lower Campbell Lake, impounded by the Ladore Dam which receives flows from the Salmon and Quinsam River diversions. The Strathcona Dam impounds the Upper Campbell Reservoir and backs water into Buttle Lake.

Lower Campbell Lake was surveyed 12 years prior to impoundment and at that time the lake had a surface area of 1,075 ha, a mean depth of 17 m, and a maximum depth of 60 m (Carl, 1937). The lake temperature was warm (e.g. 10° C at 30 m), there were signs of moderate oxygen depletion at depth, and benthic fauna were sparse (Carl, 1937). Three years after reservoir formation, a well-defined thermal gradient was apparent and temperatures ranged from 18° C at the surface, to <4° C at 60 m (McMynn and Larkin, 1953). Dissolved oxygen was 83% of saturation at 55 m, secchi disk readings were 8 m, and TDS was ~40 mg/l (Table 1).

TABLE 1. Location, size, depth and water quality parameters at Lower Campbell Lake (Source: FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
Campbell Oyster	00058CAMB	2,694	89.2	75.6	17.1	7.4	40	7.6-8.0	1951, 1953, 1980

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters. See Table 2 for a more complete summary of reports on Lower Campbell Lake watershed.

The present Lower Campbell Lake reservoir has a surface area of ~2,694 ha, a maximum depth of 75.6 m, a mean depth of ~17 m, a TDS of 40 ppm (Table 1) and the mean water retention time is 32 days (BC Hydro, 2002).

Tributaries

We've presented a summary of major tributaries in the Lower Campbell Lake watershed in Table 2. The Campbell River is the 2nd largest river on Vancouver Island with respect to drainage area, and the 3rd largest in terms of MAD. This river, which has been a source of hydroelectric power since 1947, supports a variety of fish species including all five species of salmon, summer and winter runs of steelhead, cutthroat and rainbow trout, lamprey, Dolly Varden, sculpins and threespine stickleback.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Lower Campbell Lake (Source: Bell and Thompson, 1977; Hirst, 1991a; MJ Lough and Associates, 2000).

Tributary	Order	Other Information
Campbell River		This river is the 2 nd largest on Vancouver Island and has been studied extensively; numerous reports are available through MOE, Environment Canada, DFO, BC Hydro etc.
Beavertail Creek	2 nd	Excellent trout stream; lake headed with moderately sized drainage areas; abundant gravel for spawning and cobble and boulder cover for fry and log jams and pools cover for parr.
Fry Creek	2 nd	This creek is impacted by diversion flows from the Salmon River diversion - areas are eroded and there is a loss of substrate and cover in some reaches. This important spawning stream is subject to ongoing dewatering because of hydro operations. This situation frequently exposes redds.
Greenstone Creek	2 nd	Drains steep, mountainous slopes west of Lower Campbell Lake; flow regime appears to be further affected by extensive clear cut logging in the headwaters of the watershed.
Miller Creek	3 rd	Outlet flow for the BC Hydro Quinsam diversion from Wokas Lake; moderately sized drainage area; large with stable flow regimes year-round; abundant spawning habitat; stable habitat for juvenile rearing.
Unnamed inlet to L.		Relatively large stream size, channel morphology, abundant cover and stable

Tributary	Order	Other Information
Campbell Lake from Gosling Lake		flow regime suggests Reach 1 of this creek provides excellent fish spawning and rearing conditions throughout the year.
Unnamed inlets on south shore of L. Campbell Lake		A number of unnamed inlet streams on the south side of the lake in the Lukwa Lake, Miller creek and Beavertail Lake watersheds were found by MJ Lough and Associates (2000) to have higher quality fish habitat due to lower gradients (3% – 9%), stable channel morphology and relatively abundant spawning and rearing substrate in the first reach. Although these streams may be intermittent for short intervals during low flow, minimum flows for fish are likely present well into the summer (see MJ Lough and Associates, 2000 for detailed maps and descriptions).
Unnamed inlets on the north shore of L. Campbell Lake		A small number of inlet streams on the north side of the lake provide good fish habitat; stream gradients range from 5% – 8% with cobble and gravel as the dominant substrates; many of these streams have intermittent flows or dry for short periods in the summer thereby limiting fish use.

Beavertail Creek is one of the major trout-producing streams in the Lower Campbell Lake watershed and has stable flow regimes throughout the year, although lower flows in summer may limit fry production. Fry Creek, the outlet of Brewster Lake, is an important spawning stream for trout, char and kokanee salmon. Fry Creek runs from Whympier to Gray and eventually into Fry Lake then into Lower Campbell Lake. Greenstone Creek is utilized for spawning and rearing by Dolly Varden (Rimmer, *In*: MJ Lough and Associates, 2000) and Miller Creek, which is an outlet for the Quinsam River diversion, is an important trout producer in the watershed.

MJ Lough and Associates (2000) sampled streams along the south shore of Campbell Lake and found streams with gradients from 3% - 9%, stable channel morphology, and relatively abundant spawning and rearing substrates in some reaches. These researchers noted that although these streams may be intermittent for short intervals during the low flow period, minimum flows for fish were likely present well into the summer. Remaining inlets were short, 1st order systems with moderate gradients, prone to intermittent summer flows during most summers, relatively stable channel morphology, and moderate instream fish cover. Fish sampling results suggested these streams support limited spawning and fry rearing until declining flows force stream resident fish into the lake (MJ Lough and Associates, 2000).

MJ Lough and Associates (2000) also surveyed six inlet streams along the north shore of Campbell Lake but found no fish and noted these streams had low water and did not appear to constitute viable fish habitat. In addition, some streams had possible migration barriers at their mouth. The remaining three inlet streams on the north side were inaccessible to fish and were not sampled.

Species Composition

Before impoundment, Lower Campbell Lake was inhabited by rainbow and cutthroat trout and Dolly Varden; stickleback and sculpins were the only non-sport fish species recorded (Carl, 1937). Rainbow trout were abundant but seldom >250 mm in length, while cutthroat trout were larger but seldom caught. Both rainbow and cutthroat trout were recorded as abundant in the three-year old reservoir formed from Lower Campbell Lake (McMynn and Larkin 1953), and eight years after impoundment Dolly Varden were recorded as being numerous (Fisheries Branch, Nanaimo, data files). MOE stocking records indicate that rainbow trout were stocked into Lower Campbell Lake between 1924 and 1951 (FLNRO files, Nanaimo).

Resident stocks of rainbow trout, cutthroat trout, Dolly Varden, and kokanee salmon are still present in Lower Campbell Lake as are prickly sculpin and threespine stickleback. Lower Campbell Lake is not directly accessible to anadromous fish but coho salmon and steelhead were introduced to this watershed via the BC Hydro diversion from the Salmon River headwaters (MJ Lough and Associates, 2000). Steelhead fry and pre-smolts introduced into Lower Campbell Lake in 1992 were progeny of Quinsam River steelhead reared at Quinsam Hatchery (FLNRO files, Nanaimo).

Summary of Work and Reports

We've presented a summary of the surveys conducted at Lower Campbell Lake in Table 3. The earliest documented fish sampling was funded by BC Hydro in 1937 to assess the lake prior to construction of the Ladore Dam and inundation of the valley to the Ladore Reservoir (McMynn and Larkin, 1953). Data on water chemistry, plankton abundance and benthic organisms was collected.

TABLE 3. Summary of historical surveys at Campbell Lake and tributary streams (Source: Lough, 2000; FISS, Ecocat, Sinclair, 1965, FLNRO files, Nanaimo).

Year	Survey Type	Author/Reference	Report Location
1937	Lake survey	Carl, 1937 (BC Hydro)	Unavailable
1951	Lake survey	MOE	Unavailable
1953		McMynn and Larkin, 1953	Unavailable
1957 - 1962	Gillnet assessment	MOE	FISS
1980	Water chemistry, limnology	BC Hydro	Unavailable
1975-1980	Aircraft angler counts	MOE	FLNRO files, Nanaimo
1982	Impact of the NVI Resources Ltd. Mining Operations on Buttle Lake and the Campbell River Watershed	Clark and Morrison, 1982	FLNRO files, Nanaimo
1984	Effects of Dissolved Metals on the Aquatic Biota of the Lakes of the Campbell River Watershed	Nordin et al., 1984	FLNRO files, Nanaimo
1996, 1997, 1998	Tributary electrofishing	MJ Lough and Associates, 2000	MJ Lough Environmental Consultants, Nanaimo
2000, 2003	Snorkel surveys	MJ Lough and Associates, 2000; MJ Lough Environmental Consultants, 2003	MJ Lough Environmental Consultants, Nanaimo
2002 - 2004	Dolly Varden Stock Status and Habitat Preferences in the Lower Campbell Lake Watershed; Angler creel survey	Michalski, 2006	Ecocat

Ministry staff assessed Lower Campbell Lake in 1951, 1980 and 1996, and the Fish and Wildlife Branch conducted angler surveys by aircraft of Lower Campbell Lake and small lakes in the Sayward Forest on holiday weekends in May and September between 1975 and 1980 (Table 1,

Table 2). The effects of water level changes on the limnology of Lower Campbell and Buttle Lakes were investigated by Sinclair in 1965.

Lough (2002) carried out field studies on Dolly Varden in tributary streams of reservoirs in the Lower Campbell watershed between September 2001 and June 2002 in response to the Ministry's objective of managing blue-listed species. Field data including counts and distribution of Dolly Varden, and time and location of Dolly Varden spawning was collected primarily through snorkel surveys. Between 2002 and 2004 MOE staff conducted stream and gillnetting assessments and snorkel surveys to document the status and habitat preferences of Dolly Varden in the Lower Campbell Lake watershed (Table 2). Eakins Hydrological Consulting (2005) outlined a detailed plan for providing flow to critical habitats in Fry Creek because of concerns raised regarding impacts to spawning habitat as a result of hydro operations.

2.0 Limits to Fish Production

Water Withdrawal

Fish populations within the Lower Campbell Lake watershed have been impacted by the construction and operation of hydro facilities. These impacts include: permanent loss or seasonal reductions of spawning, rearing and overwintering habitat due to the dam footprint; reservoir flooding; flow diversions, and operating flows reducing downstream habitat capability including reduced sediment or wood recruitment; reduced biological productivity in shoal areas of former lakes affected by large reservoir drawdown regimes; frequent water level fluctuations; reduced tributary and mainstem access where flows are diminished by diversions or where historic access is blocked by dams; reduced annual flow volumes downstream of all diversions; and increased water volumes in new channels affecting wetted channel area, seasonal temperatures, and stream productivity (BC Hydro, 2002).

Stream Habitat

In their assessment of tributaries to Lower Campbell Lake, MJ Lough and Associates (2000) identified a number of impacts to stream habitat as a result of BC Hydro manipulation of reservoir levels and diversion inflows. Impacts included: inaccessible spawning habitat during drawdown periods; inundation of spawning habitat during high reservoir levels and exposed or inundated redds during untimely changes in reservoir levels. These researchers recommended the development of a water use plan to help minimize the negative impacts to fish and fish habitat caused by hydro operations. Fry Creek, which is one of the most important spawning tributaries in the watershed, is subject to flooding and dewatering because of hydro operations and diversion flows which have impacted incubating and rearing trout and char (Michalski, 2006).

In addition to outlining impacts to stream habitat as a result of hydro operations, MJ Lough and Associates (2000) identified a number of restoration and rehabilitation opportunities to address barriers caused by collapsed culverts and cascades caused by slumping derelict railroad grades in the watershed. Site locations are identified in a map provided in MJ Lough and Associates, 2000.

3.0 Angling Statistics

Angler Effort

Angler effort on Lower Campbell Lake has averaged ~4,500 angler days and, overall, angler effort has been increasing since 1986 (Figure 2). In 1986, angler effort was ~4,300 angler days but angler effort declined in 1989 to ~1,700 angler days, increased to 2,600 in 1992, and then increased to ~7,000 angler days in 2002 and 2006. In 2011, angler effort dropped to ~4,500 angler days.

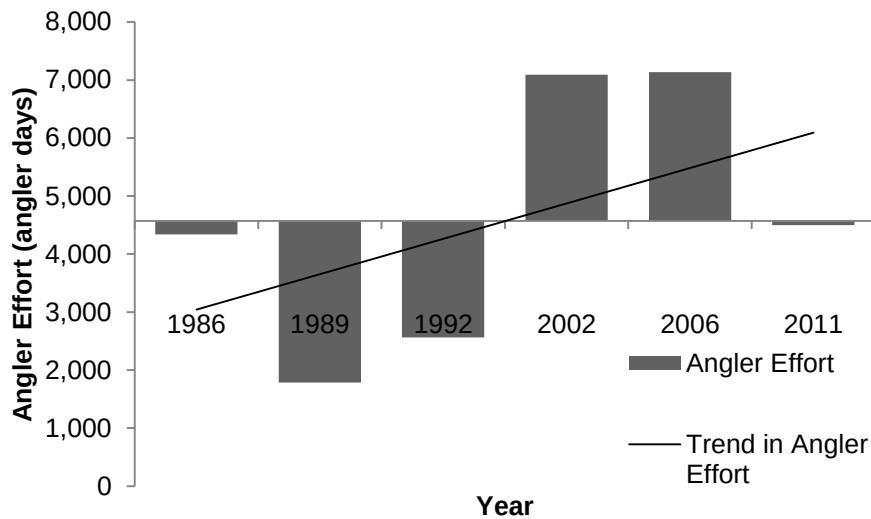


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Lower Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Instant Angler Counts and Angler Creel Surveys

Fisheries Branch staff conducted aerial counts and interviewed anglers fishing in the Lower Campbell Lake watershed on holiday weekends in May and September in the late 1970's and 1980. Angler use during that period varied between ~80 angler days for the two holiday weekends surveyed in 1976 and 1977, to ~300 angler days for the weekends surveyed in 1979 (Table 4).

TABLE 4. Summary of angler use (angler days), data collected during aerial angler counts and roving angler creels at Lower Campbell and associated flooded areas (Fry, John Hart, and McIvor Lakes and Strathcona dam) Victoria Day (May) long weekends 1977 – 1980 and 1986, during weekly angler creel surveys 2002 – 2004 and during a box angler creel survey in 2010 (Source: data files, Fisheries Branch Nanaimo).

Year	Period	Type of Survey	Angler Effort (estimated angler days)
1976*	May & September Long Weekends	Aerial counts & angler creel surveys	81
1977			81
1978			221
1979			308
1980			198
2002	All Year	Roving boat angler creel survey	735
2003			936
2004			1,316
2010**		Box angler creel survey	Unavailable

* Fry Lake Only

**Estimated by Fisheries Branch staff (Hirst, 1991a)

**Box angler creel survey; July - November 2010.

Regional Fisheries Staff and volunteers conducted roving boat angler surveys on Lower Campbell Lake between 2002 and 2004 to determine catch and effort statistics and assess the status of the Dolly Varden fishery. This study found that angler use at Lower Campbell Lake varied from 700 angler days in 2002, to 1,300 angler days in 2004 (Table 5) while a box angler creel survey conducted in 2010 found that most of the angling effort at this lake occurs from May until August (Figure 3; Appendix 17).

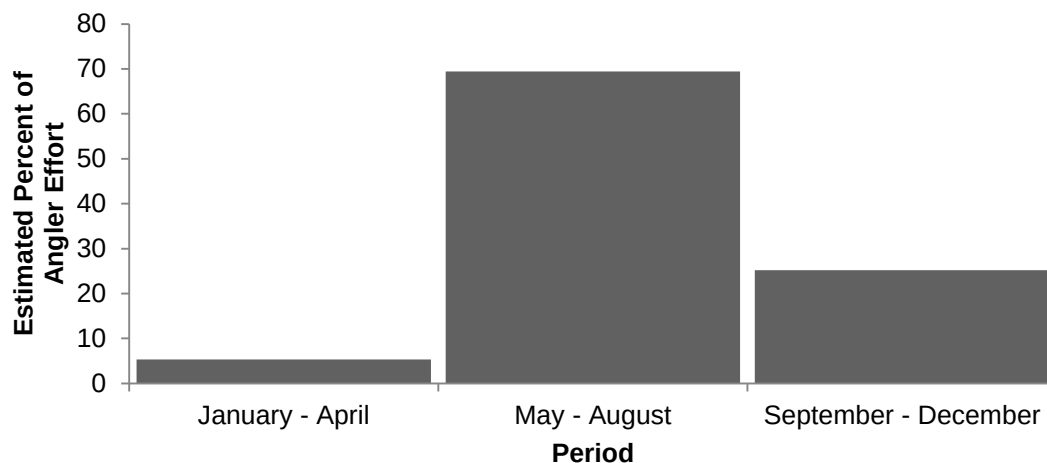


FIGURE 3. Percent of total angler effort by season at Lower Campbell Lake determined by box angler creel surveys conducted July, 2010 – June, 2011 (Source: FLNRO files, Nanaimo).

Catch

Angler catch has averaged ~10,000 fish/year over the 25 year survey period of the VILQ and the trend in catch is roughly stable despite fluctuations in 1992 and 2002 (Figure 4). Between 1986 and 1989 total catch was between ~9,000 and 10,000 fish. In 1992, total catch dropped to ~5,000 fish likely as a result of the corresponding decline in angler effort (Figure 2). By 2002,

total catch had risen to almost 15,000 fish but catch dropped in 2006 to 10,000 fish and to 9,000 fish in 2011.

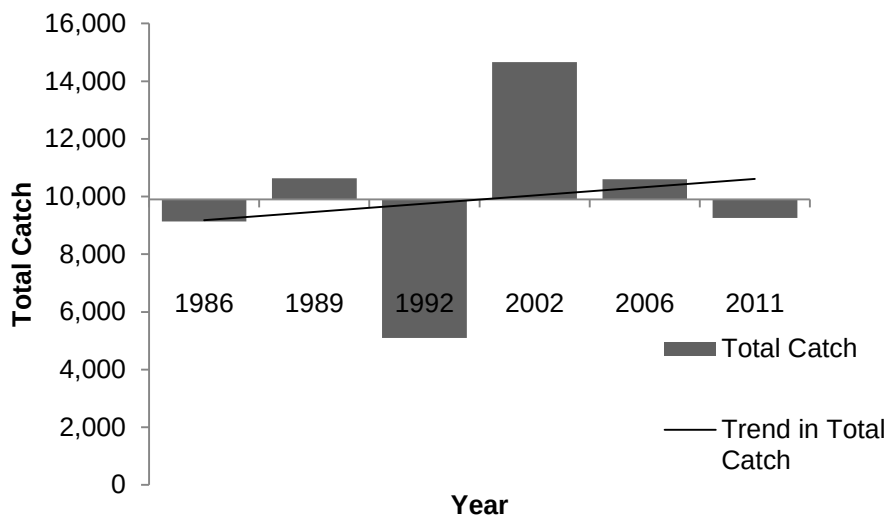


FIGURE 4. Total catch by year compared to average catch from 1986-2011 and trend in catch at Lower Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

According to the VILQ, just over 50% of the angler catch in 2006 was cutthroat trout (5,545 fish), ~40% was rainbow trout (4,443 fish) and <10% was Dolly Varden (614 fish) (Table 5). In 2001, 3,773 cutthroat trout comprised ~40% of the catch, 5,290 rainbow trout made up 57% of the catch, and 195 Dolly Varden comprised ~2% of the catch

TABLE 5. Catch of cutthroat and rainbow trout and Dolly Varden at Lower Campbell Lake 2006 and 2011. (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	5,545	52.3	3,773	40.8
Rainbow	4,443	41.9	5,291	57.1
Dolly Varden	614	5.8	195	2.1
Total	10,602		9,258	

A 1980 survey of 89 anglers on Lower Campbell Lake resulted in a catch estimate of 0.74 fish/angler hour. Total angling effort or catch composition were not estimated (Hirst, 1991b). A 1986 survey by the Fish and Wildlife Branch, Nanaimo estimated use of the lake by 315 anglers who caught 3,105 fish and kept 2,025 fish of unstated species. This resulted in an estimated angling success rate of 2.3 fish/day which is roughly equivalent to 0.76 fish/angler hour⁸ (FLNRO files, Nanaimo). Catch composition of the 1986 survey is not known.

Roving angler creel surveys conducted at Lower Campbell Lake from 2002 until 2004 by Fish and Wildlife staff had findings similar to the VILQ with respect to angler catch. These angler creel surveys found that cutthroat comprised ~47% of the angler catch (918 fish), rainbow

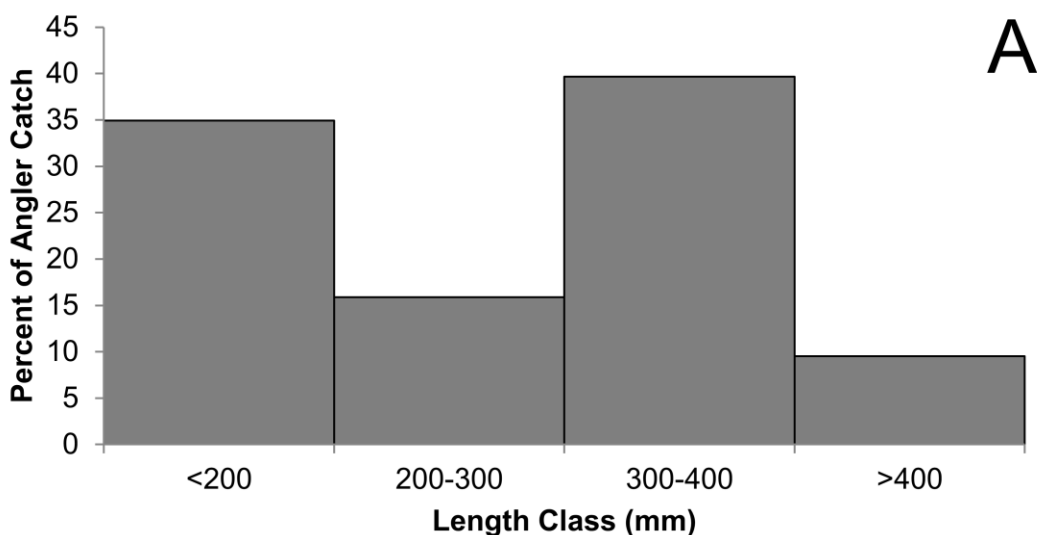
⁸ Calculation assumes 3 hours angling per day for the average angler (FLNRO files, Nanaimo).

comprised ~36% of the catch (709 fish), and Dolly Varden comprised the remaining 17% of the catch (336 fish) (Table 6).

TABLE 6. Catch of cutthroat and rainbow trout and Dolly Varden at Lower Campbell Lake determined from roving boat creels conducted in 2002 – 2004 (N=1,963) (Source: FLNRO files, Nanaimo).

Cutthroat		Rainbow		Dolly Varden	
Total Catch	Percent of Total	Total Catch	Percent of Total	Total Catch	Percent of Total
918	46.8	709	36.1	336	17.1

In addition to estimating the percent of angler catch, data from the roving angler creel surveys provided insight into the size of fish caught by anglers at Lower Campbell Lake. Almost 40% of the cutthroat trout caught by anglers were 300 mm – 400 mm and almost 10% were >400 mm (Figure 5A). Roughly 45% of the rainbow trout caught by anglers were 200 mm – 300 mm and ~35% were 300 mm – 400 mm (Figure 5B). More than 60% of the catch of Dolly Varden were 300 mm – 400 mm (Figure 5C).



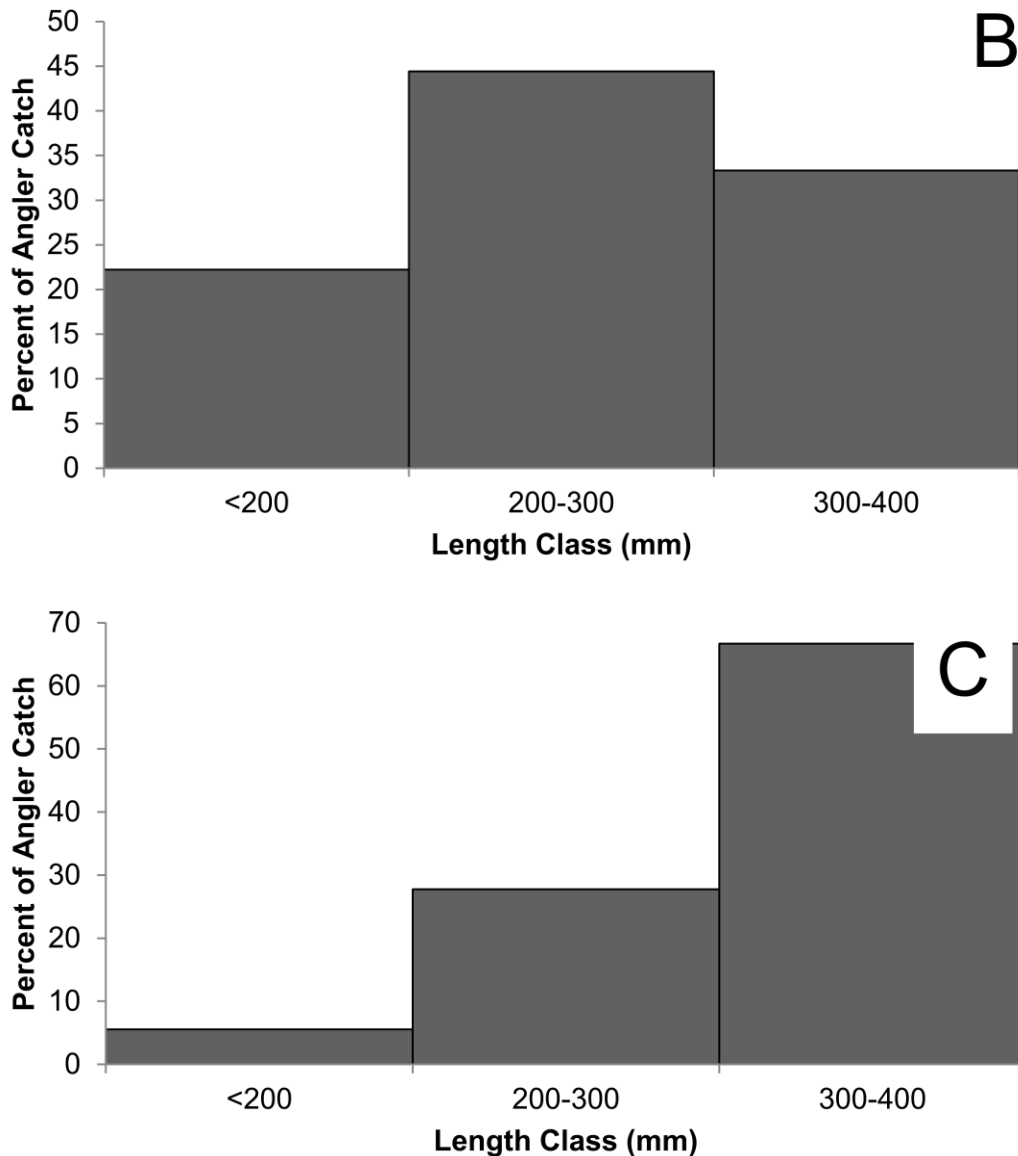


FIGURE 5. Percent of catch in each length class for (A) cutthroat trout (n=63), (B) rainbow trout (n=36) and (C) Dolly Varden (n=18) caught by anglers at Lower Campbell Lake 2002 – 2004 as determined in a roving angler creel survey (Source: FLNRO files, Nanaimo).

Angler Success

Angler success at Lower Campbell Lake has averaged ~2.1 fish/day since 1986 and overall there has been a downward trend in this statistic (Figure 6). Angler success reached a high of almost six fish/day in 1989, but declined to ~2 fish/angler day between 1992 and 2002. In 2006, angler success was ~1.5 fish/day which is the lowest level recorded at this lake since 1986. In 2011, angler success rose to ~2 fish/day.

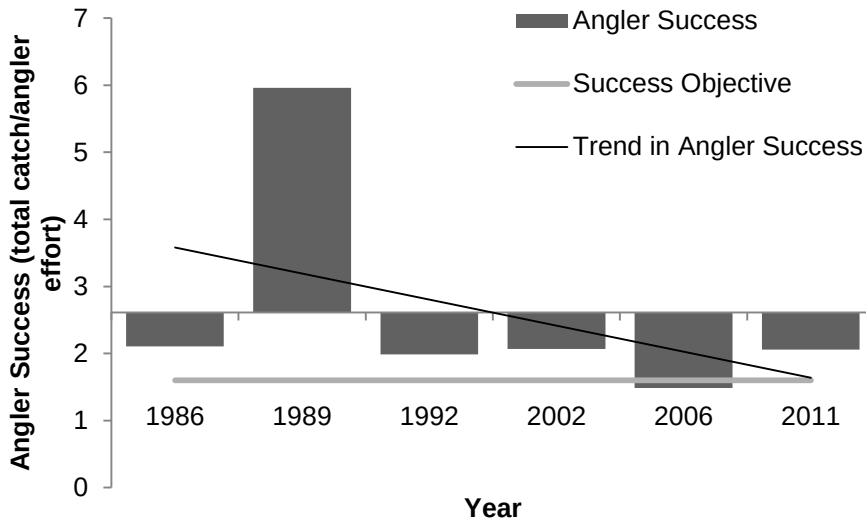


FIGURE 6. Angler success (total catch/total angler effort in angler days) and trend in angler effort compared to average angler success and the objective for angler success (1.6 fish/angler day) at Lower Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Angler success data calculated from angler creel surveys conducted in 1986 and 2002 – 2004 and a box creel in 2010 provide similar results for angler success (Table 7). In 1986, Hirst (1991a) estimated angler success at Lower Campbell Lake at 2.3 fish/day while roving angler creel surveys in the early 2000's estimated angler success at between ~1 fish/day and 2.8 fish/day. In 2010, a box survey of the lake suggested angler success was ~2 fish/day.

TABLE 7. Summary of angler success rate (fish/day) 2002 – 2004 determined from a angler creel survey conducted on Victoria Day (May) and Labour Day (September) long weekends in 1986 and during weekly roving angler creel surveys of Lower Campbell Lake 2002 – 2004 and from a box angler creel survey conducted at Lower Campbell Lake in 2010 (Source: Hirst, 1991a; data files Fisheries Branch, Nanaimo).

Year	Average Angler Success (fish/day)
1986	2.3
2002	1.18
2003	2.84
2004	1.63
2010	2.22

Angler Attitudes

Contrary to the relatively high angler success rate suggested by the VILQ and angler creel surveys, <40% of anglers said the angling was good or excellent, and almost 60% said it was poor when they were asked to rate fishing at Lower Campbell Lake in 2010 - 2011 (Appendix 17). Seventy percent of anglers also said they fish Lower Campbell Lake to catch fish to eat and anglers were divided (40% each) on whether they preferred to fish for cutthroat or rainbow trout.

Harvest

Harvest rates at Lower Campbell Lake appear to have been higher in the past than they are presently. For example, Hirst (1991a) estimated that in 1986, 315 anglers harvested 65% of their catch while the roving creel in the early 2000's estimated angler harvest at ~45% (Table 8). During that study anglers reported harvesting ~50% of the cutthroat trout they caught (465 fish) and 52% of their rainbow trout catch (371 fish). Anglers also reported harvesting 18% of their Dolly Varden (61 fish) despite the region-wide mandatory release regulation for this species.

TABLE 8. Catch, harvest and percent harvest of cutthroat and rainbow trout and Dolly Varden at Lower Campbell Lake determined during angler creel surveys of Lower Campbell Lake) 2002 – 2004 (Source: data files Fisheries Branch, Nanaimo).

	Cutthroat	Rainbow	Dolly Varden	Total
Total Catch	918	709	336	1963
Total Harvest	465	371	61	897
Percent Harvest	51	52	18	46

In 2006, data from the VILQ suggested that anglers harvested roughly 35% of the cutthroat trout they caught (1,920 fish) and ~ 32% of their rainbow trout catch (1,432 fish) (Table 9). In 2011, anglers harvested ~27% of their cutthroat (1,030 fish) ~44% of their rainbow trout catch (2,325 fish) and 14% of their Dolly Varden catch (28 fish). Overall, the harvest rate at Lower Campbell Lake was ~37% that year.

TABLE 9. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Lower Campbell Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	5,545	1,920	34.6	3,773	1,030	27.3
Rainbow	4,443	1,432	32.2	5,291	2,325	43.9
Dolly Varden	614	0	0.0	195	28	14.3
Total	10,602	3,352	31.6	9,258	3,383	36.5

4.0 Stock Status Indicators

Relative Abundance

Lower Campbell Lake has been gillnetted several times since 1961 and we've presented the results of these assessments in Figure 7. Rainbow trout dominated the catches in the 1950's, however, in 1960, both cutthroat and rainbow trout dominated the catch with <5% of the sample comprised by Dolly Varden. The following year, cutthroat comprised 50% of the catch, but rainbow declined to ~25% and the catch of Dolly Varden increased to ~25%. In 1962, the catch of cutthroat decreased to <30%, the catch of rainbow increased to ~50% and Dolly Varden accounted for the remaining ~20% of the catch.

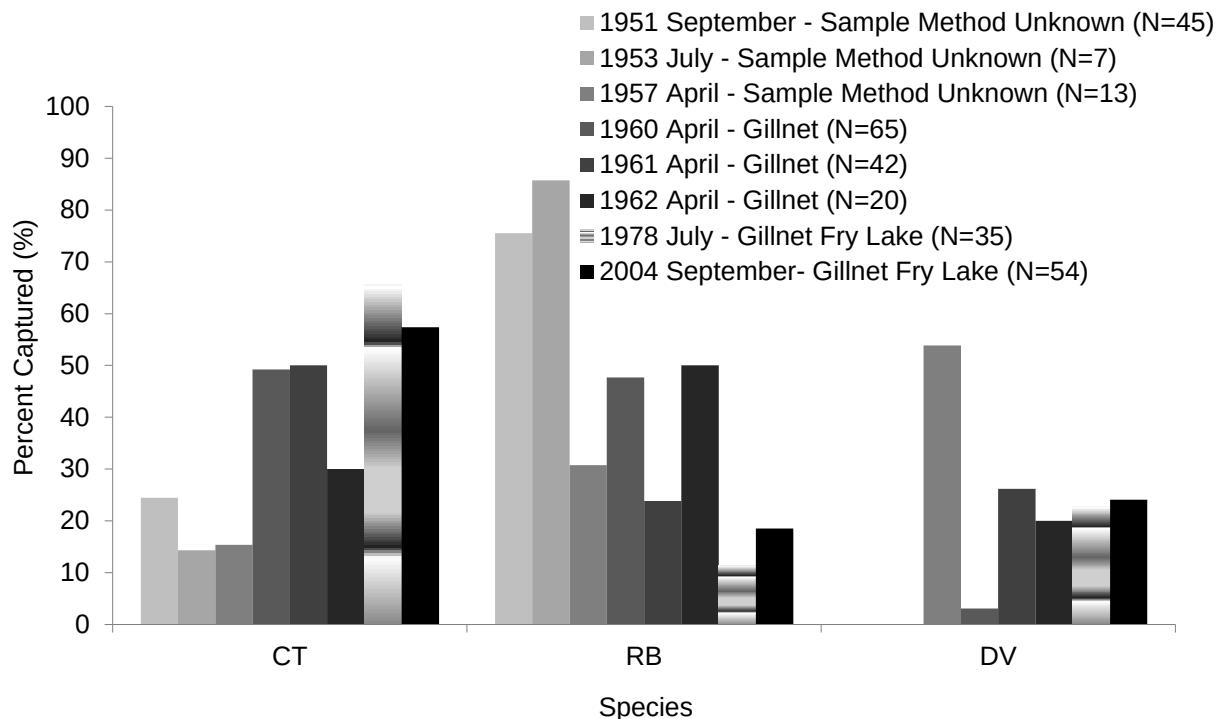


FIGURE 7. Percent cutthroat trout, rainbow trout and Dolly Varden captured in gillnets in Lower Campbell Lake 1951, 1953, 1957, 1960, 1961, 1962, 1978 and 2004. Sample method is noted as unknown for 1951, 1953, 1957; these surveys were conducted by the FLNRO files, Nanaimo and we assume that these were gillnet surveys. Due to flooding caused by BC Hydro modifications, Fry Lake is now part of Lower Campbell Lake and fish are able to move freely between the two areas. As a result, data collected from gillnets set at Fry Lake in 1978 and 2004 is presented with that collected at Lower Campbell Lake (Source: FLNRO files, Nanaimo).

In 1978 and 2004 Fry Lake, which is part of Lower Campbell Lake (see Figure 1) was gillnetted. In both years, cutthroat trout dominated the catch accounting for >60% of the catch in 1978, and ~60% in 2004 while rainbow and Dolly Varden each accounted for ~20% of the catch in each year (Figure 7). On the surface it appears as though rainbow trout, which were dominant in the early samples, declined in later samples. Unfortunately, we did not have standardized procedures for gill netting during early surveys so we're now unable to make statements regarding the apparent declines.

Snorkel Surveys

Fisheries Branch staff conducted snorkel surveys of Fry Creek and below the Strathcona dam in 2003 and 2004. The highest numbers of cutthroat were observed in Fry Creek (Figure 8). In their assessment of cutthroat trout spawning habitat in tributaries to Lower Campbell Lake in 2000, MJ Lough and Associates found 126 redds in the channel below the Strathcona dam making this area one of the largest spawning areas for cutthroat trout in the Ladore reservoir.

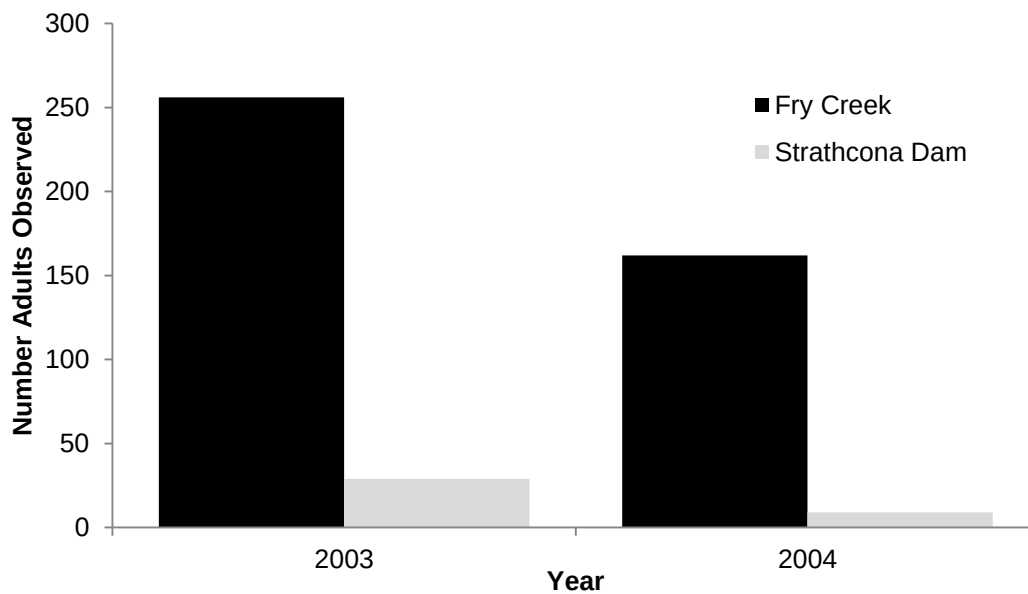


FIGURE 8. Number of cutthroat trout observed in Fry Creek and below the Strathcona Dam in March and April, 2003 (n=285) and 2004 (n=171) (Source: FLNRO files, Nanaimo).

Ministry staff also swam Greenstone Creek in 1998 and 1999 and, as with other tributaries, found the highest numbers of adult cutthroat present in March and April (Figure 9).

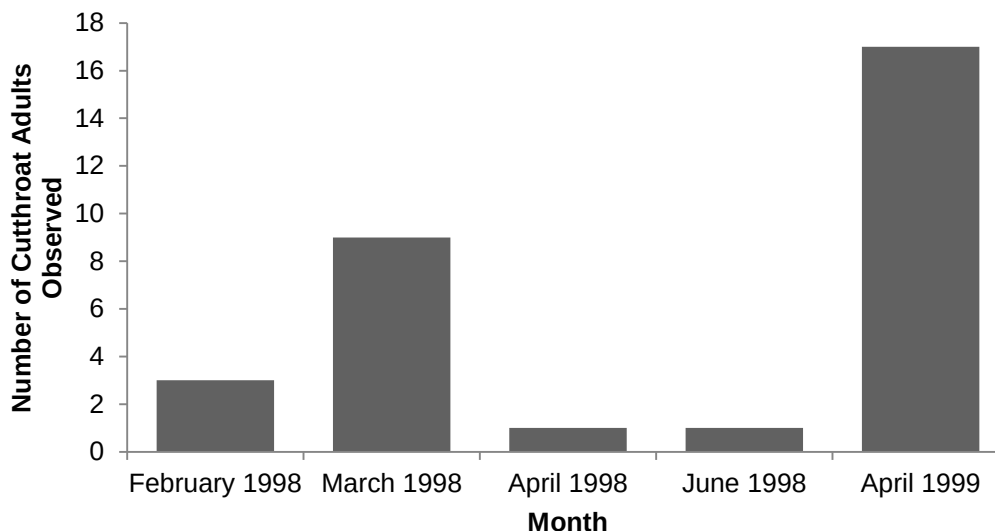


FIGURE 9. Number of adult cutthroat trout observed in Greenstone Creek February, 1998 – April, 1999 (N=31). Adult cutthroat trout are defined as fish >25 cm (Source: FLNRO files, Nanaimo).

MJ Lough and Associates (2000) found active rainbow trout spawning in early May in Greenstone Creek and un-eyed eggs were found in fresh redds. Fresh redds from a late-spawning component of the rainbow spawners were also found in late June. Rainbow trout spawning in Fry Creek in early spring with the majority of adults observed in May (Figure 10).

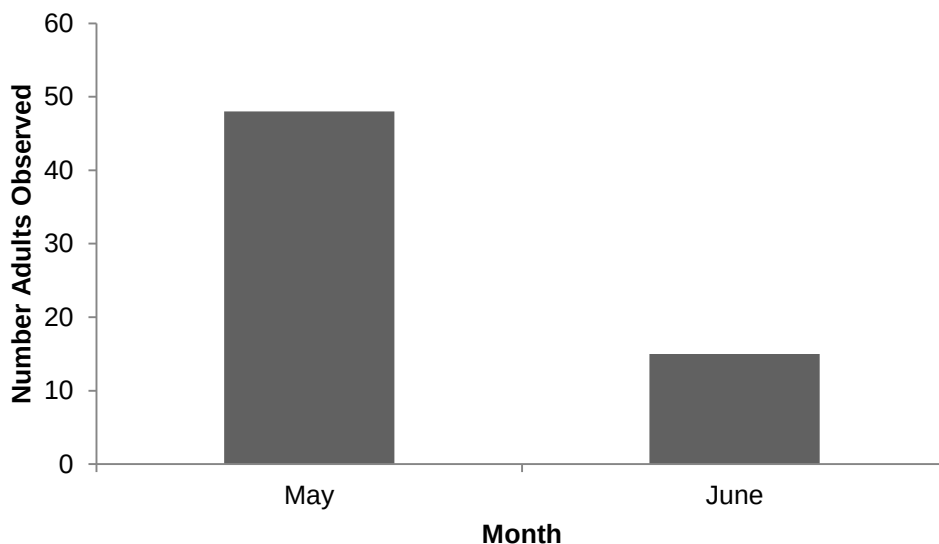


FIGURE 10. Number of adult rainbow trout (>200 mm) observed in Fry Creek May (n=48) and June (n=15), 2003 (N=63). Adult rainbow trout are defined as fish >200 mm (Source: FLNRO files, Nanaimo).

Lough et al (2003) conducted snorkel surveys of Greenstone, Fry and Miller Creeks and below the Strathcona Dam in 2001 as part of an investigation regarding life history characteristics of Dolly Varden. These investigators found that a few adult migrants already moved into the Strathcona Dam by mid-September and the numbers generally increased during late September and early-October as the adults moved from the reservoirs into the streams to spawn (Table 10; Appendix 17). The counts generally peaked around mid-October as most of the spawning population appeared to have arrived at their destination (Lough et al, 2003). Although most Dolly Varden observed in this study were 300 mm – 400 mm in length, some larger spawners in the Strathcona Dam area were estimated to range from 500 mm - 700 mm (Lough et al, 2003).

TABLE 10. Peak counts of Dolly Varden spawners and redds that were observed during snorkel surveys from September 13 to November 26, 2001 (Reprinted from: Lough et al, 2003).

Stream	Peak Number of Spawners	Redds	Date
Greenstone Creek	5	0	Nov 2/01
Fry Creek	0	0	Nov 2/01
Miller Creek	2	0	Nov 19/01
Strathcona Dam	105	108	Oct 15/15

Length and Weight

We've summarized the length and weight data for fish sampled by gillnetting in Campbell Lake in Table 11 and have provided length frequency distributions and length-weight relationships for each species in Appendix 17. The minimum length of cutthroat decreased from 230 mm in the 1950's, to 175 mm in the 2000's while the maximum size decreased from 571 mm in the 1950's, to 470 mm in the 2000 sample. Mean length decreased from ~329 mm to ~291 mm and the modal length shifted from 250 in the 1950's, to 210 mm in the 2000's. The mean weight of cutthroat trout was 522 g in the 1950's and 320 g in the 2000's. This suggests that there are fewer older fish which may be a result of anglers cropping off larger fish.

TABLE 11. Minimum, maximum, mean and modal length and mean weight of cutthroat and rainbow trout and Dolly Varden captured in Campbell Lake in gillnets by decade 1950 – 2000 (Source: FISS; FLNRO files, Nanaimo; Michalski et al, 2004).

Species	Decade	N	Fork Length (mm)				Weight (Mean) (g) Mean
			Minimum	Maximum	Mean	Mode	
Cutthroat	1950	13	230	571	328.8	250.0	522.2
	1970	23	175	375	256.9	180.0	199.9
	2000	31	175	470	290.6	210.0	320.3
Rainbow	1950	44	171	430	271.1	235.0	211.2
	1970	4	145	240	192.5	-----	95.3
	2000	10	185	300	221.5	230.0	122.0
Dolly Varden	1950	7	234	279	265.4	273.0	164.8
	1970	8	170	320	246.3	320.0	211.8
	2000	13	175	340	236.2	180.0	167.6

The minimum length of rainbow trout increased from 171.4 mm in the 1950's, to 185 mm in the 2000's while the maximum length decreased from 430 mm in the 1950's, to 300 mm in the 2000's (Table 9). The mean length of this species decreased from 271 mm in the 1950's, to 221 mm in the 2000's. The modal length shifted from 235 mm in the 1950's, to 230 mm in 2000 and the mean weight decreased from 211 g in the 1950's, to 122 g in the 2000's. Of interest is that 40% (the median) of the rainbow trout sampled in the 1950's were in the 276 mm – 300 mm size class, but <10% of the 2004 sample was in this size range with 90% of the sample <250 mm (Appendix 17).

The minimum size of Dolly Varden decreased from 234 mm in the 1950's, to 175 mm in the 2000's, the maximum size increased from 279 mm in the 1950's to 340 mm in the 2000's and the mean size decreased from 264 mm in the 1950's to 236 mm in the 2000's. Although almost 65% of the sample collected in 1957 was >250 mm compared to ~30% in 2004 (Appendix 17), the small sample sizes in each year makes it difficult to draw conclusions regarding stock status indicators for this species.

Age and Growth

We've provided length-at-age analyses for the cutthroat trout and rainbow trout aged from the 1950's samples and for Dolly Varden from the 2004 sample in Figure 11. Sample sizes are small and, therefore, subject to variation so we're unable to draw any conclusions regarding changes in this parameter. In summary, three age 1+ cutthroat ranging from 225 mm – 250 mm and averaging 238 mm, two aged 2+ cutthroat averaging 282.5 mm, four aged 3+ cutthroat ranging from 262–350 mm and averaging 308 mm, and one age 5+ cutthroat 457 mm were sampled (Figure 11A). Interestingly, many more age 1+ and age 2+ cutthroat were found in Lower Campbell Lake tributaries during electrofishing surveys conducted in the late 1990's (MJ Lough and Associates, 2000) which calls into question some of the ageing data for younger fish in the lake (Appendix 17).

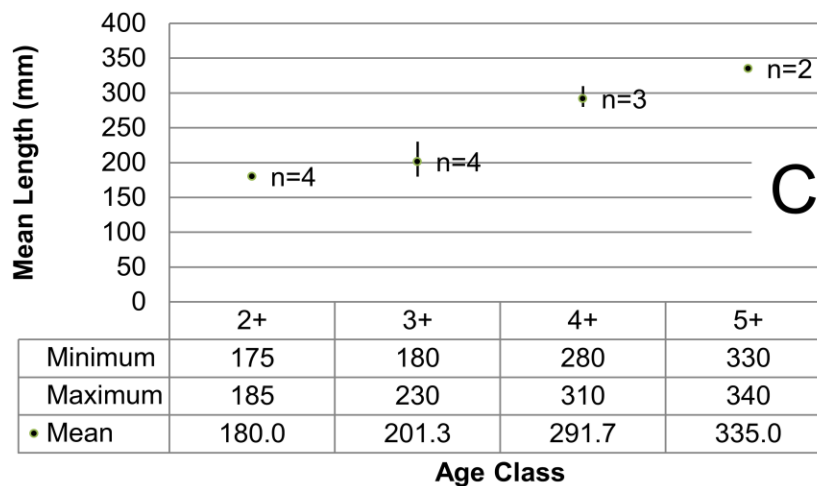
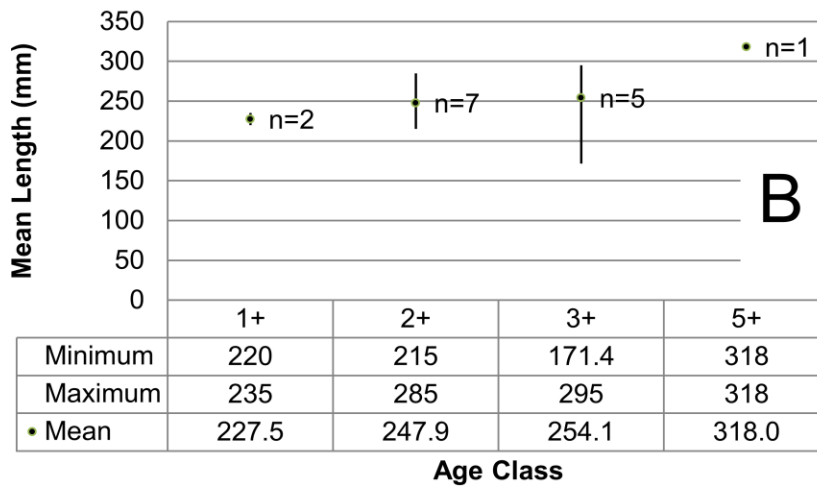
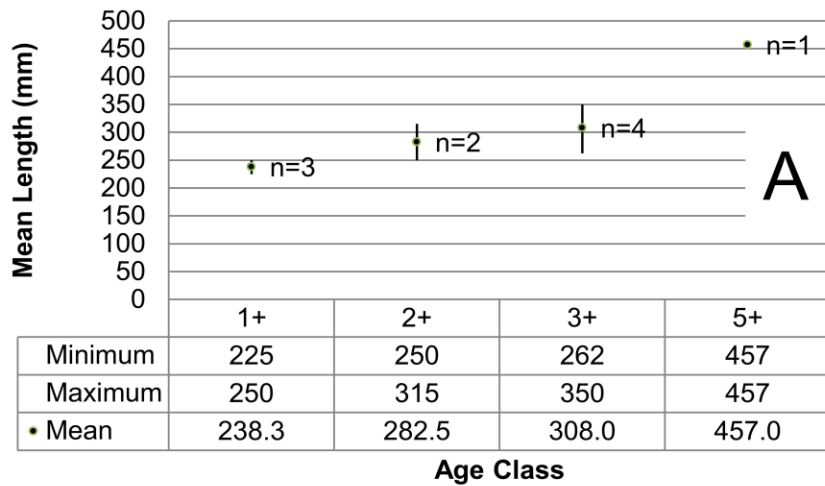


FIGURE 11. Length-at-age of (A) cutthroat trout sampled in gillnets in 1951 and 1957 (N=10); (B) Rainbow trout sampled in 1951 and 1957 (N=15) and (C) Dolly Varden sampled in 2000 (N=13) in Lower Campbell Lake (Source: FLNRO files, Nanaimo; Michalski, 2004).

Fifteen rainbow trout were aged from the samples collected in 1951 and 1957 (Figure 8B). Two aged 1+ fish ranging from 220 mm – 235 mm and averaging ~228 mm, seven aged 2+ fish ranging from 215 mm –285 mm and averaging ~248 mm, five aged 3+ rainbow ranging from 171 mm – 295 mm and averaging 254 mm and one age 5+ rainbow 218 mm were sampled.

Thirteen Dolly Varden were aged from the 2004 sample collected in Fry Lake (Figure 8C). Four Dolly Varden aged 2+ ranging from 175 mm –185 mm and averaging 180 mm, four Dolly Varden aged 3+ ranging from 180 mm –230 mm and averaging ~200 mm, three fish ranging from 280 mm – 310 mm and averaging ~290 mm and two aged 5+ Dolly Varden averaging 335 mm were sampled.

Growth and Maturity

We chose to evaluate growth and maturity of cutthroat and rainbow trout in Lower Campbell Lake because of the small samples sizes for age data. We grouped samples taken in the 1950's and 2000's and found that in Lower Campbell Lake, mature cutthroat trout average ~300 mm while mature rainbow trout average ~278 mm (Table 12). Our length-weight analyses also show that cutthroat trout reach ~450 mm on average, while rainbow trout reach ~300 mm (Table 11; Appendix 17). The sample sizes are small so this parameter should be re-evaluated in future assessments.

TABLE 12. Mean length of mature cutthroat trout (n=5) and mature rainbow trout (n=21) sampled in Lower Campbell Lake in the 1950's and 2004 (Source: FISS; FLNRO files, Nanaimo).

Species	n	Mean Length (mm)
Cutthroat	5	307.0
Rainbow	21	277.8

Catch Indicators

Total Catch

Sinking nets were used in gillnet samples taken in 1978 and 2004 and soak times were provided which enabled us to compare total catch and catch/hour of fish sampled in Lower Campbell Lake between the two years (Table 13). In 1978, a total of 35 fish or 1.5 fish/hour were caught. Nets caught one cutthroat/hour and <0.5 rainbow trout and Dolly Varden each per hour. In 2004, the total catch was 40 fish for a catch of 2.4 fish/hour. The catch of cutthroat trout increased to 1.8 fish/hour but catches of rainbow and Dolly Varden stayed <1 fish hour.

TABLE 13. Total and catch per net of cutthroat and rainbow trout and Dolly Varden captured in Lower Campbell Lake in 2004. Note: sinking nets were set in both years; the net in 1978 was set for 24 hours and the net in 2004 was set for 17 hours (Source: FLNRO files, Nanaimo; Michalski et al, 2004).

Species	1978		2004	
	Total Catch	Catch/Hour	Total Catch	Catch/Hour
Cutthroat	23	1.0	30	1.8
Rainbow	4	0.2	10	0.6
Dolly Varden	8	0.3	13	0.8
Total	35	1.5	40	2.4

Data Gaps

We've presented the age and availability of data from Lower Campbell Lake in Table 14. There's no bathymetric profile for the lake, limnology and water quality data is >10 years old and there are no hydroacoustic studies of this lake. Gillnetting, electrofishing assessments and instant angler counts, angler creel surveys and angler preference surveys are ~10 years old.

TABLE 14. Summary of data gaps for Lower Campbell Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Bathymetric Profile			X
Gillnetting	X		
Angler Creel Surveys	X		
Instant Angler Counts	X		
VILQ	X		
Snorkel Surveys	X		
Acoustic Surveys			X
Electrofishing (streams)	X		
Lake/Limnology Inventory		X	
Stream Habitat Inventory	X		
Water Quality/Lake Productivity		X	

5.0 Fisheries Objectives and Management Strategies for Lower Campbell Lake

Existing Regulations

Lower Campbell Lake is covered by the general regional regulations of four trout but not more than 1>50 cm and two from streams (must be hatchery). All wild trout from streams and all Dolly Varden must be released.

The Campbell River is closed all year between Elk Falls and the John Hart Dam Power Station and all year from the Strathcona Dam downstream 100 m. There is no fishing in any tributaries December 1–May 31.

Greenstone and Miller Creeks and their tributaries are closed all year and all remaining tributaries are covered by the regional regulations of single barbless hook and bait ban all year.

Maximum Catch and Effort, Harvest and Yield at Current Regulations

We were unable to estimate maximum and optimum angler effort and catch as there was considerable variability in the relationship between angler effort and catch ($R^2 < 0.5$) (Appendix 17). At present, the harvest rate is 37% at Campbell Lake and the yield is roughly 30% of what we predict based on MEI. In 2002, actual yield approached one-half of the predicted yield based on MEI (Appendix 8). The actual yield at Lower Campbell Lake is one of the highest of all large lakes in the region and the yield during the highest levels of angler catch and harvest at this lake has come closer to the predicted yield than any other lake with the exception of Upper Campbell Lake.

Fisheries Objectives and Management Strategies and Operational Management Plan for Lower Campbell Lake

Although there has been a downward trend in angler success, success rate has averaged 2.6 fish/day since 1986 and a decrease in angler effort in 2011 was accompanied by an increase in angler success. These factors together suggest a stable fish population at Lower Campbell Lake. Unfortunately, small sample sizes for cutthroat and rainbow trout caught in gillnets make comparisons of stock status indicators between decades unreliable so we have no way to verify stock status of either species. Despite the high angler success rate relative to other large lakes, most anglers believe the angling at Lower Campbell Lake is poor.

The trend for angler success is declining while angler effort is increasing so we recommend continuing to monitor the Lower Campbell Lake fishery closely. In developing new regulations, the first objective is to conserve wild stocks and the second is to allow the angler the opportunity to catch and kill a fish. Regulation changes may be required if there are decreases in angler success and increases in angler effort, decreases in catch, or if harvest rates, which according the VILQ are the highest of any large lake, continue to climb.

Lower Campbell Lake is a high priority lake and we recommend the following management actions:

1. Conduct gillnetting in 2014 and repeat every three years to determine and monitor stock status (Table 16; Chapter 1).
2. Monitor fisheries statistics using the VILQ. Continue using this tool if there are no concerns with the results of this survey and the gillnetting.
3. Develop more conservative regulations if angler success decreases to < 2.0 fish/day which is the long-term average for Lower Campbell Lake, and angler effort increases to $> 6,000$ angler days/year, or catch drops by 10%.
4. Cutthroat and rainbow trout comprise ~equal proportions of the Lower Campbell Lake fishery, therefore, management efforts including regulations must consider both species.
5. Maximum size regulations should be based on our suggestions outlined in Section 11 of Chapter 1 but refined based on the length-weight relationship developed for both species which identifies when fish growth stops in this lake (Appendix 17).
6. Erect angler creel survey boxes to collect additional information on angler catch and harvest.

Operational Management Plan for Lower Campbell Lake

In addition to gillnetting Lower Campbell Lake in 2014, we've recommended developing a partnership with the BC Hydro to implement public awareness programs focused on regulations and fish identification to assist anglers at Lower Campbell Lake (Table 15). We also recommend commissioning a kokanee assessment to determine the availability of prey for predacious cutthroat trout, and conducting snorkel surveys every two years at Fry Creek and below Strathcona Dam to document numbers of spawning cutthroat and rainbow and the availability of quality spawning habitat in these areas. This is important given that spawning habitat has been impacted by hydro operations and a lack of spawning habitat may limit fish production in the Lower Campbell Lake watershed. Finally, we've recommended habitat assessment and enhancement based on the recommendations of past studies including Northwest Hydraulics (2002); Lough (2000); Lough (2003); and Michalski (2006).

TABLE 15. Operational Management Plan for Lower Campbell Lake.

Activity	Objective	Tentative Schedule
Stock Status	Conduct gillnetting assessment to gather stock status data and compare to previous surveys.	2014 and every 3 years (Table 16; Chapter 1). 2015
Regulations	Repeat snorkel surveys to collect data on numbers and mean size of spawning cutthroat and rainbow trout Develop regulations based on gillnet and VILQ results; implement as in-season change if there is a conservation concern, consult with Campbell River Fish and Game Association (CRF&GA) if regulations changes are contemplated.	
Public Awareness	Investigate the potential with CRF&GA and BC Hydro to implement public awareness programs including signage at boat ramps and in campsites, information should include fisheries, stock, habitat information.	2016
Fisheries Monitoring	Review VILQ data as the survey is conducted to identify concerns; erect angler creel survey boxes to monitor angler catch and harvest and effects of any regulation change.	2017 and ongoing
Habitat Restoration	Review recommendations by Northwest Hydraulics for instream restoration on Fry Creek: stream flow restoration of Fry Creek; Level 1&2 inventories are complete on Fry and Miller Creeks - both these streams are diversion streams into Lower Campbell Lake. Restoration of Fry creek will benefit fish populations in four lakes including Brewster, Gray, Whymper and Lower Campbell lakes; augment low flows in Fry Creek.	2017+
Habitat Enhancement – Low Flow	Develop proposal for BC Hydro Bridge Coastal for removing barriers identified in MJ Lough and Associates, 2000 and Lough 2003. Request Flow Monitoring Agreement with BC Hydro to address redd and rearing habitat dewatering issues identified in Michalski (2006); review report by Eakins Hydrological Consulting (2005), consult with BC Hydro to determine if some or all of the recommendations in this report can be implemented to stabilize and provide flow for Fry Creek.	2017+
Habitat Enhancement – Fertilization	Small lake fertilization was identified in past plans as a means of increasing the fishery at Lower Campbell Lakes (Michalski, 2006). This should be re-evaluated and determined if BC Hydro can provide funds to implement.	2017+
VILQ	Ongoing	Every 3 years

Chapter 12. Nimpkish Lake

Lake	Nimpkish
Planning Unit	Nimpkish
Watershed	Nimpkish
Surface Area (ha)	3,653
Mean Depth (m)	122
Key Tributaries	Nimpkish, Woss, Octwanch and Kilpala Rivers
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden, Steelhead
Limits to Production	Logging
Regional Priority*:	13
<u>Angling Statistics 2011</u>	
Angling Effort	0 angler days
Total Catch	0 fish
Angler Success	No data available
Current Harvest Rate	No data available
Optimum Sustainable Effort	200 angler days
Optimum Sustainable Catch	400
Angler Success at Optimum	200
Stock Status	Unknown; no stock status data and no information on how often the regional quota of four fish/day is achieved.
Data Gaps	Gillnetting, snorkel surveys, juvenile assessments
Management Objectives	The lack of data is a major constraint to monitoring and managing the Nimpkish Lake fishery and cutthroat stock may be susceptible to over harvest. The priority is conservation of the wild stock cutthroat. We recommend developing protective regulations based on gillnet assessments. Regulations should aim to conserve wild stocks and provide opportunities at Nimpkish including: improving angler success; increased spawning escapements and increasing the size of angler-caught fish.
Operational Plan Priorities	Monitoring with VILQ; gillnetting, snorkel surveys, juvenile assessments
Potential Partners	Port Alice Fish and Game Association; Namgis First Nation

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Nimpkish Lake Watershed

General Information

Nimpkish Lake is located on northern Vancouver Island and drains via the Nimpkish River into the northern end of Johnstone Strait (Shortreed et al. 2001). The watershed is the largest on Vancouver Island and the lake itself is located at 20 m elevation, roughly 6 km from saltwater (Figure 1). The Nimpkish Lake Provincial Park, which comprises the southernmost slopes of the Karmutzen mountain range and all of Tlakwa Creek drainage, is located at the south end of Nimpkish Lake, ~32 km south of Port McNeill.

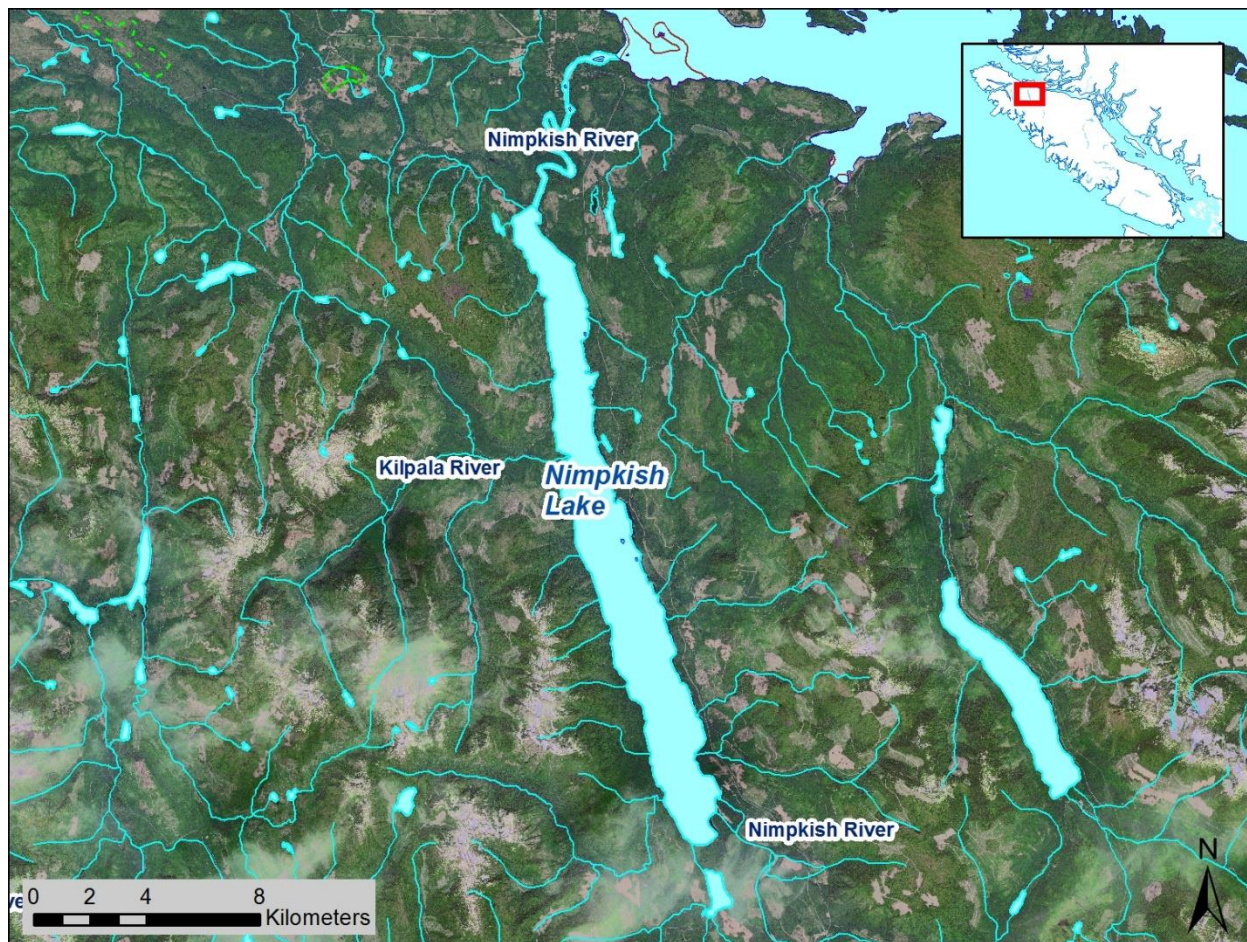


FIGURE 1. Map of Nimpkish Lake and tributaries; a bathymetric profile is not available (Source: iMap BC).

Nimpkish Lake is the fourth largest lake on Vancouver Island and has a surface area of 3,653 ha and a perimeter length of 54.3 km (Table 1). This lake has a maximum depth of 320 m and a mean depth of 122 m and is a monomictic⁹ lake which receives high annual precipitation resulting in a water residence time of only 1.4 years (Shortreed et al. 2001). Nimpkish Lake is ultra-oligotrophic and with a TDS of 17 which is the lowest recorded TDS of all the Island's large

⁹ Lakes and reservoirs which are relatively deep, do not freeze over during winter, and undergo a single stratification and mixing cycle during the year (usually in the fall).

lakes. The lake has a secchi reading of 9.5 m, a pH of 7, and an average epilimnetic temperature of 13.2° C (Shortreed et al. 2001).

TABLE 1. Location, size, depth and water quality parameters at Nimpkish Lake (Source: Shortreed et al. 2001; FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)
Nimpkish	00188NIMP	3,653	54.3	320	122	7.1	17	9.5	1975, 1986

Tributaries

Tributaries to Nimpkish Lake include the Nimpkish and Kilpala Rivers and Tlakwa (aka Willow) and Noomas Creeks (Table 2). The main Nimpkish River is the outlet for Nimpkish Lake and the river upstream of Nimpkish Lake is the most important with respect to fish habitat and use. Tlakwa or Willow Creek is entirely protected within the Nimpkish Lake Provincial Park. Many tributaries contain anadromous fish, however, there is limited habitat data available on these systems (Table 2).

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Nimpkish Lake (Source: W.M. Resource Consulting, 1996; Carr and Oliver, 1974, FLNRO files, Nanaimo).

Tributary	Order	Length and/or Drainage Area	Other Information
Nimpkish River	3	91.2 km ²	Outlet to Nimpkish Lake; four lakes (Nimpkish, Woss, Vernon, Schoen) within the Nimpkish River system; most important sockeye producer in the system.
Kilpala River	3	17.9 km.	This river contains Chinook and coho salmon, steelhead and anadromous Dolly Varden as well as coast range sculpins.
Tlakwa (aka Willow Creek)	2	15 km.	All of the Tlakwa Creek drainage is protected within the Nimpkish Lake Provincial Park; gradient <1%; substrate with some bedrock; 40% cobble; 30% gravel; 30% sand; one obstruction - a waterfall and cascades ~15m long; discharge 100 – 150 cfs.
Atluck Creek			This river contains Chinook, coho and sockeye salmon and unidentified species of trout. The creek is a tributary to Atluck Lake which contains cutthroat and stocked rainbow trout, kokanee and coho salmon.
Kinman Creek	2	8.8 km.	Coho and sockeye salmon are found in this creek as are rainbow trout.
Storey Creek	2	7.7 km.	
Noomas Creek	2	8.5 km.	The Noomas creek watershed is ~2,087 ha in size and there are no major sub-basins in the watershed. Fisheries values are relatively low and anadromous fish can travel to an impassable rock canyon at ~500 m upstream from the mouth.
Maquilla River		~35 km	The Maquilla River is partially logged, partially natural and has one major tributary named William Creek (Carr and Oliver, 1974). Approximately 4 km is accessible to anadromous fish; gradient 4%-5%; headwater substrate 50% gravel/50% sand/silt; downstream substrate changes to 40% cobble; 30% gravel; 30% sand; discharge is ~280 cfs; log jams occur throughout; coho have been noted.

Species Composition

The Nimpkish watershed is complex with at least three stocks of sockeye found in Nimpkish, Woss and Vernon Lakes. All stocks utilize Nimpkish Lake at some point in their life history (Reid, G, 2011, pers. com.) and it is believed the majority of sockeye progeny from the Nimpkish system rear in Nimpkish and Woss Lakes (Shortreed et al. 1990).

Nimpkish Lake was at one time an important contributor to the provincial sockeye fishery and from 1987 until 1997 escapements ranged from 20,000 – 237,000 (Shortreed et al. 2001). Stocks have suffered declines, and escapements in recent years have decreased to a few thousand spawners (P. Rankin, in Shortreed et al. 2001).

Cutthroat and steelhead trout, and Dolly Varden are found in Nimpkish Lake but only cutthroat trout are caught in the lake sport fishery. Salmon species that utilize the lake include sockeye, coho, Chinook, chum, pink and possibly kokanee. Prickly and slimy sculpins and threespine sticklebacks are also found in Nimpkish Lake.

The Nimpkish River contains cutthroat, steelhead and Dolly Varden as well as sockeye, coho, Chinook, chum and pink salmon. MOE stocked steelhead into this river for a number of years (Reid, G., 2011, pers. com.) and a limited sport fishery occurs in the river for both steelhead trout and salmon. No information exists on fishing for other trout species or char.

Summary of Work and Reports

A lake inventory including water quality analyses and a bathymetric profile of Nimpkish Lake was conducted by MOE in 1975 and data summaries are included in the Ministry files in Nanaimo. Limnological sampling was carried out in 1978, 1979, and from 1982 until 1986 (Shortreed et al. 1990), and Nimpkish Lake was part of a series of annual hydroacoustic and minnow trapping surveys in the late 1970's and 1990's by DFO (Hyatt, in Shortreed, et al. 1990). General information on these studies is noted in Stockner and Shortreed, 1979 and 1985; Stockner and Costella, 1980 and Shortreed et al, 2001. Other work on lakes in the watershed includes an assessment of performance of stocked rainbow trout in Atluck Lake conducted by Silvestri and Fosker (2003).

Carr and Oliver (1974) surveyed nine unnamed tributaries to Nimpkish Lake and their summaries are provided in the FLNRO files in Nanaimo. Summaries of annual snorkel surveys completed by the Ministry and the BC Conservation Foundation, and an annual report of salmon streams and spawning populations for the Nimpkish River conducted by DFO have been completed. Canadian BioSonics Ltd. conducted a fixed aspect acoustic study for sockeye salmon in the Nimpkish River in 1987; Ptolemy assessed angler catch of steelhead in the Nimpkish River in 1988; and the BC Conservation Foundation reported on the Nimpkish River watershed stream fertilization program from 2002 until 2008. A Coastal Watershed Assessment Project (CWAP) was conducted in the Noomas watershed by WM Resource Consulting in 1996. All reports can be found in Ecocat at: <http://www.env.gov.bc.ca/fish/>.

2.0 Limits to Fish Production

Logging

Much of the Nimpkish Lake watershed is in Tree Farm Licence and most of the watershed including the tributaries, has been logged. The limited numbers of habitat surveys suggest the major fish producing streams in the watershed have been impacted by logging (Reid, G., 2011, pers. com.).

Mining

In the 1950's the Nimpkish Iron Mine was developed and Wolf magnetite deposits on upper Storey Creek were examined but no detailed exploration took place due to lack of access (Laird, 1990). In the 1960's and 1970's, some geochemistry and geophysical assessments were done on the ridge between Storey and Kinman Creeks but results were inconclusive.

Several mineral deposits in the Nimpkish Lake area have produced ore, notably the Kilauea magnetite deposit on the Nimpkish River. Also, a small tonnage of high-grade zinc-lead-copper ore zone has been drilled at Storey Creek (Laird, 1990).

Fish Stocking

The Namgis First Nation has operated a hatchery near the mouth of the lower Nimpkish River since 1978 (Department of Fisheries and Oceans, 2011). Chum are incubated and reared in troughs and raceways, and sockeye are incubated until emergence then transferred to the lake. Coho and Chinook salmon are also incubated at this hatchery then reared in partnership with the Woss Community hatchery.

Stream Habitat

Habitat assessments in the watershed are limited, however, Carr and Oliver (1974) surveyed nine unnamed tributaries to Nimpkish Lake and found that some streams have low gradients, good cover and appropriate substrate, and provide good habitat for fish.

Nutrients

Nimpkish Lake is ultra-oligotrophic and plankton biomass is very low even for an oligotrophic coastal lake (Shortreed et al, 2001). This is the deepest lake on Vancouver Island with the lowest MEI (0.04) of any large lake in the region and this severe nutrient limitation is the major constraint to fish production.

Nimpkish Lake was fertilized from 1982 until 1987 and in 1989 and according to Shortreed et al. (2001), the lake's plankton communities responded substantially to the fertilizer additions. These authors also noted that given the lake's strong P-limitation and highly oligotrophic status, it's probable that fertilizer additions would also result in increased growth and/or survival of juvenile sockeye, and that Nimpkish Lake is a highly favourable candidate for future fertilization.

3.0 Angling Statistics

Angler Effort

The VILQ shows low angler participation at Nimpkish Lake with, on average, ~200 angler days expended annually (Figure 2). Angler effort was estimated at 275 angler days/year in 1986 but fell to ~190 angler days/year in 1989 and 1992. The highest angler effort (450 angler days) was estimated in 2002 but in 2006, angler effort dropped to 170 angler days and in 2011 no angler effort was reported at Nimpkish Lake – a situation which is very similar to that at Alice Lake (Chapter 2).

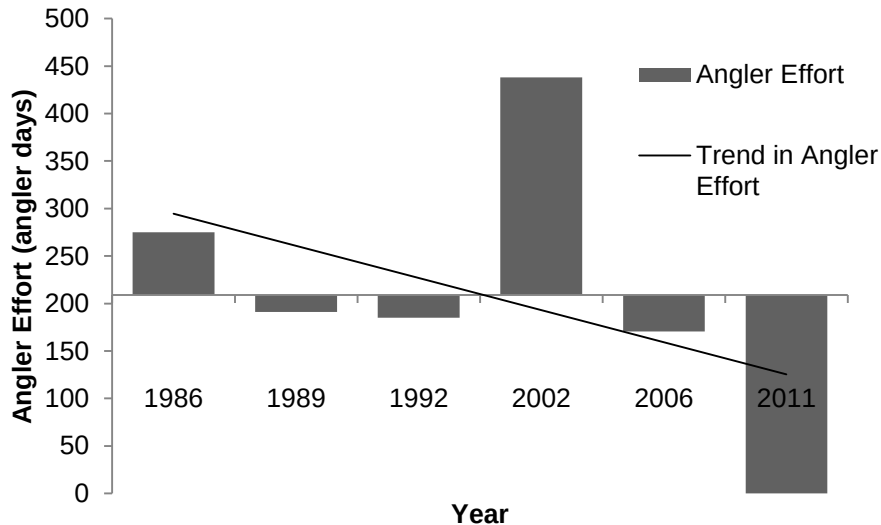


FIGURE 2. Angler effort (angler days) by year and compared to average angler effort from 1986-2011 and trend in effort at Nimpkish Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Catch and Harvest

We've shown total catch for Nimpkish Lake in Figure 3. The average total catch at Nimpkish Lake for all survey years was 335 fish. The highest catch at this lake was reported in 1986 when it's estimated that anglers caught 930 fish. In 1989, the catch dropped to 143 fish, in 1992 it rose to 360 fish, and in 2002 total catch was estimated at 170 fish. In 2011 total catch was zero corresponding to the lack of angler effort.

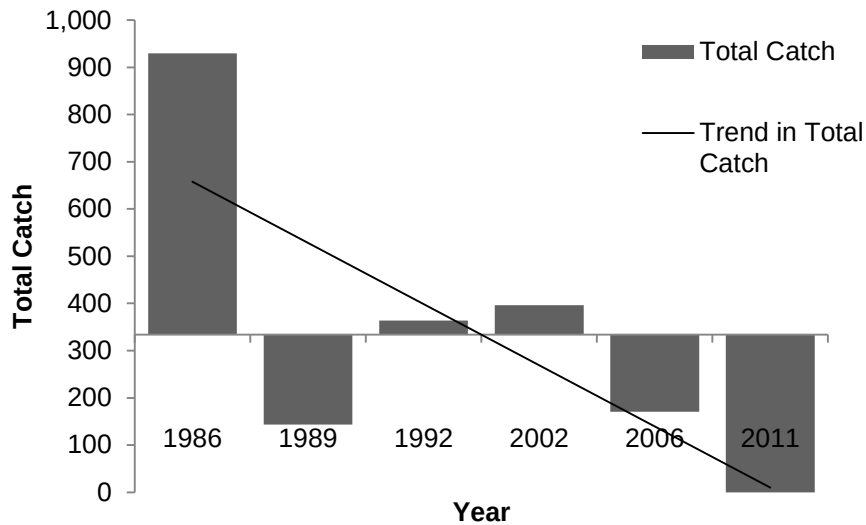


FIGURE 3. Total catch by year compared to average catch from 1986-2006 and trend in catch at Nimpkish Lake 1986 – 2011 (Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

All fish caught at Nimpkish Lake are cutthroat trout and in 2002, anglers reported harvesting ~20% of their catch (Table 3) (Andrews, 2007).

TABLE 3. Total catch and harvest and percent of harvest of fish at Nimpkish Lake 2002. All fish caught at Nimpkish Lake are cutthroat trout (Source: Andrews, 2007).

Catch	Harvest	% Harvest
170	34	20

Angler Success

Angler success has averaged ~1.3 fish/day since 1986, just slightly less than the regional success objective of 1.6 fish/day (Figure 4). In 1986, the second highest angler effort recorded at this lake produced an angler success of ~3.4 fish/day. In 1989, angler success at Nimpkish Lake was 3.3 fish/day but in 1989 the success rate fell to <1 fish/day. In 1992 angler success rose again to almost 2 fish/angler day but by 2002, the angler effort had increased to ~440 angler days and angler success was <1 fish/day. In 2006 success fell to ~1 fish/day, there was no angler effort in 2011, and overall there has been a downward trend in angler success.

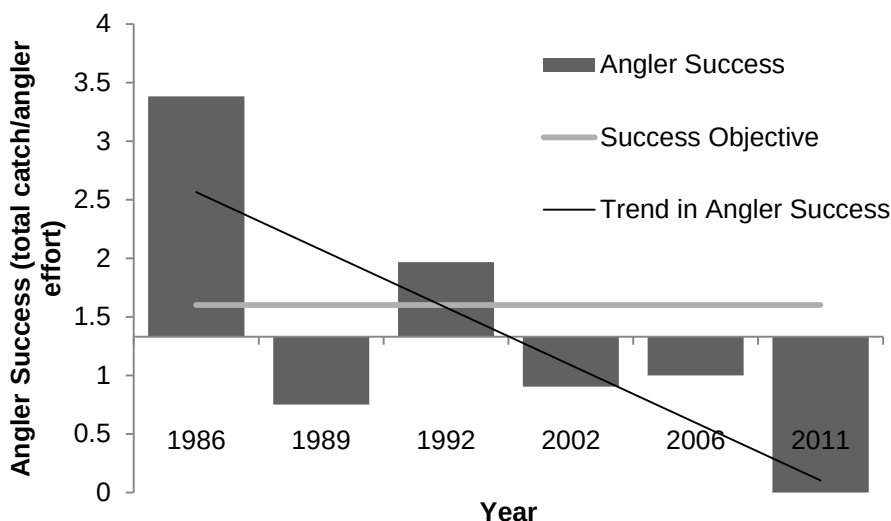


FIGURE 4. Angler success (total catch/total angler effort in angler days) and trend in angler effort compared to average angler success and the objective for angler success (1.6 fish/angler day) at Nimpkish Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

4.0 Stock Status Indicators

Little data exists on cutthroat and Dolly Varden populations in Nimpkish Lake. There is no information on the life history of these species, and the stock status is unknown. Angler effort on the lake is low and, as a result, catches are low. However, the lake is ultra-oligotrophic and with a TDS of 17 ppm these populations are believed to be severely nutrient limited and susceptible to overharvest (Reid G, 2011, pers. com.).

Data Gaps

The only data that exists for Nimpkish Lake is data gathered through the VILQ. There is no bathymetric profile for the lake, and while some stream surveys for lake tributaries exist, the data is >10 years old and needs updating (Table 4). There is no information on fish stocks in Nimpkish Lake and no snorkel surveys or juvenile abundance data for cutthroat trout.

TABLE 4. Summary of data gaps for Nimpkish Lake required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Bathymetric Profile			X
Gillnetting			X
Angler Creel Survey			X
VILQ	X		
Snorkel Surveys			X
Acoustic Surveys		X	
Electrofishing (streams)			X
Lake/Limnology Inventory		X	
Stream Habitat Inventory		X	
Water Quality/Lake Productivity		X	
Instant Angler Counts or Box Creels			X

5.0 Fisheries Objectives and Management Strategies for Nimpkish Lake

Existing Regulations

Nimpkish Lake is covered by the Region 1 general regulations of a daily quota of four fish/day but not more than one >50 cm or two hatchery fish from streams. All wild trout and wild steelhead must be released from streams, and all Dolly Varden must be released.

There is no fishing above the Davie River, a tributary to the Nimpkish River, or the tributaries December 1 - May 15. All other tributaries are covered by the regional general regulation of a bait ban and single barbless hook all year.

Maximum Catch and Effort, Harvest and Yield at Current Regulations

We were unable to estimate maximum and optimum angler effort and catch as there is considerable variability in the relationship between these statistics ($R^2 < 0.5$) (Appendix 18). As a result of the low level of nutrients in this lake, predicted yield is <0.5 lb/acre (Appendix 8). Even so, yield based on the highest level angler harvest recorded at this lake is still only 5% of the very low predicted theoretical yield.

In 2006, there was a low harvest of 34 fish and in 2011 no fish were harvested at Nimpkish Lake so we conclude that harvest is not currently a problem. Nonetheless, we are concerned that Nimpkish Lake stocks are susceptible to over-harvest given the extremely low nutrient levels at this lake. It's also possible that stocks may have already declined but the lack of any fish biological data makes it impossible to determine that.

We have no information on how often the general quota of 4 fish/day is achieved, therefore, we cannot draw any conclusions on the effectiveness of the regulations at Nimpkish Lake. Angler success becomes an unreliable predictor of stock status at low angler effort, though such low angler effort would indicate the stock is probably stable. Given the low angler effort and catch, existing regulations may protect cutthroat stocks and it's unlikely regulations need to be changed immediately. In addition, angler effort has been declining for the past three survey periods and this will likely continue if region-wide declines also persist.

We've outlined an operational model for Nimpkish Lake in Figure 5. We recommend continuing to monitor the fishery using the VILQ as long as angler effort is <400 angler days/year which, despite the variability in the data, is the optimal angler effort level we identified (Appendix 18) and gillnetting according to the schedule in Table 16; Chapter 1. We recommend a minimum size limit or slot limit depending on the stock status data if conservation regulations are required following a review of gillnetting and angler statistics (Section 11; Chapter 1). If stock declines continue, we recommend moving to catch-and-release at this lake.

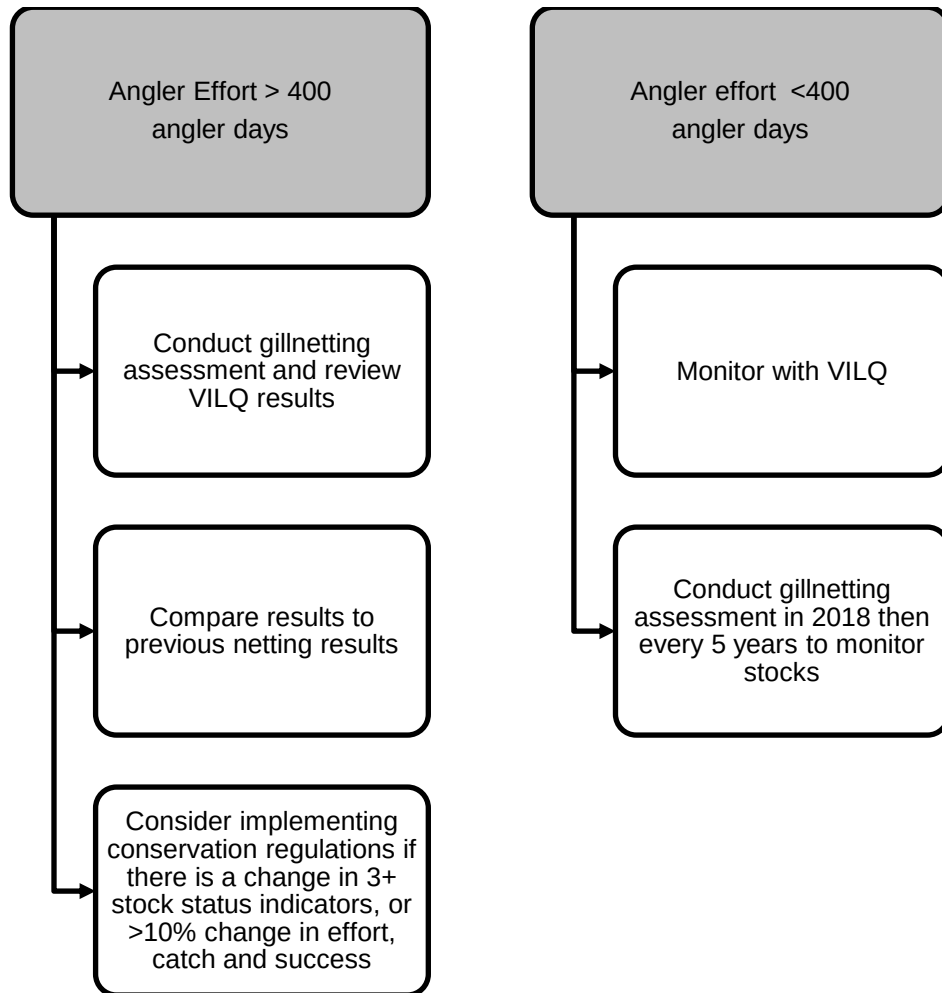


FIGURE 5. Operational management model for Nimpkish Lake. Nimpkish Lake is a low priority large lake and does not require targeted management until the VILQ indicates increases in angler effort. Gillnetting can proceed in 2018 with other lower priority lakes.

Operational Management Plan for Nimpkish Lake

We've provided an Operational Management Plan for Nimpkish Lake in Table 5. In addition to conducting gillnetting when angler effort >400 angler days (or in 2018) as per the netting schedule in Table 16; Chapter 1, we recommend conducting snorkel surveys and juvenile assessment in the Woss River and establishing partnerships with the Port Alice Fish and Wildlife Association (PAF&WA), and the Namgis First Nation to assist with monitoring trout and char stocks at Nimpkish Lake.

TABLE 5. Operational management plan for Nimpkish Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Conduct gillnetting assessment to collect stock status data; review in light of data from VILQ.	As per Figure 5 or 2018 and repeat every 5 years (Table 16; Chapter 1)
Fisheries Monitoring	Conduct snorkel surveys and juvenile assessments in the Woss River to establish timing and baseline numbers for adults and densities of juveniles.	2018
Regulations	Develop conservation regulations based VILQ results – see recommendations in Section 11 Chapter 1 or move to catch-and-release	As per Figure 5
Review Management Plan	Determine if any changes to proposed management plan are necessary given VILQ and netting data results.	2018
Long Term Monitoring	Establish partnership with the PAF&WA and/or the Namgis First Nation to assist with monitoring trout and char stocks.	2018+
VILQ	Evaluate changes in fisheries statistics every three years.	Ongoing

Chapter 13. Nitinat Lake

Lake	Nitinat
Planning Unit	West Coast
Watershed	Nitinat
Surface Area (ha)	2,748
Mean Depth (m)	No data for mean depth; maximum depth ~200 m
Key Tributaries	Nitinat, Little Nitinat Rivers and Caycuse Creek
Freshwater Fish Species	Cutthroat Trout, summer and winter-run Steelhead
Limits to Production	Logging
Regional Priority*:	14
<u>Angling Statistics 2011</u>	
Angling Effort	42 angler days
Total Catch	125 fish
Angler Success	2.9 fish/angler day
Current Harvest Rate	44%
Optimum Sustainable Effort	Unable to determine
Optimum Sustainable Catch	Unable to determine
Angler Success at Optimum	Unable to determine
Stock Status	Anglers report having caught trout in Nitinat Lake, however, only incidental observations of trout exist from past snorkel and electrofishing surveys. A past gillnetting survey documented only marine species in the lake.
Data Gaps	There is essentially no lake or stream data for this watershed. In addition, anglers do not require a freshwater fishing licence as Nitinat Lake is tidal, consequently, VILQ data likely under-represents the fishery at this lake.
Operational Plan Priorities	Confirm species presence and stock status in Nitinat Lake and work with DFO to determine if fisheries monitoring efforts can be coordinated for the lake.
Potential Partners	DFO

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Nitinat Lake Watershed

General Information

Nitinat Lake is a tidal fjord located within the Coastal-Hemlock biogeoclimatic zone on the south west coast of Vancouver Island in the West Coast PU (Figure 1). This lake, which is located in the West Coast Trail Unit of the Pacific Rim National Park Reserve, is 23 km long and 1.2 km wide, has a surface area of 2,748 ha and a maximum depth of ~200 m (Table 1).

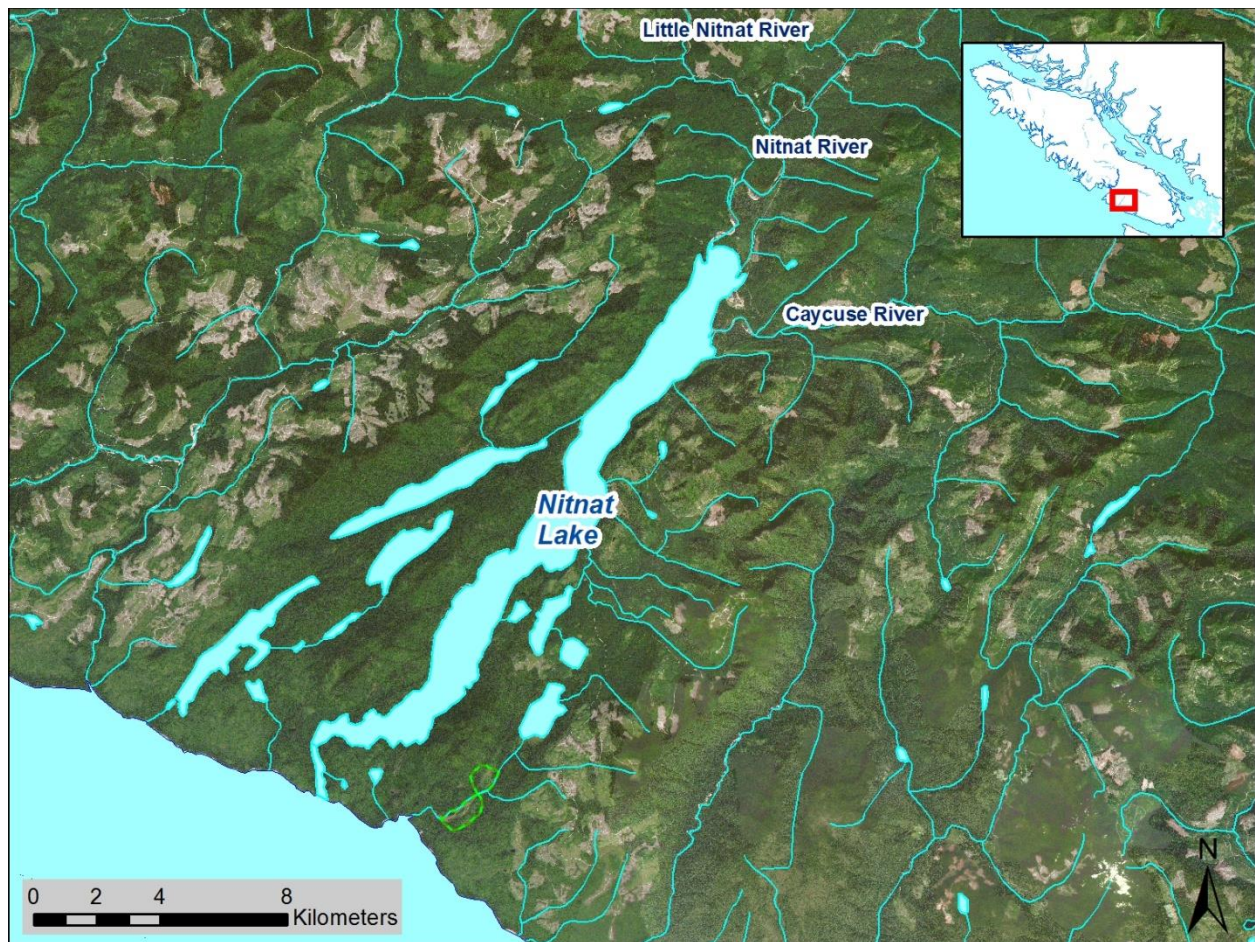


FIGURE 1. Map of Nitinat Lake and tributaries; a bathymetric profile is provided in Appendix 19 (Source: iMap).

TABLE 1. Location, size, depth and water quality parameters at Nitinat Lake; there is presence of hydrogen sulphide (H_2S) in all water samples >30m (Source: FLNRO files, Nanaimo; FISS; Northcote et al. 1964).

PU	ID	Surface Area (ha)	Perimeter (km)	Max Depth (m)	Mean Depth (m)	pH	TDS**	Secchi Depth (m)	~Length (km)	Survey Years*
WC	00056SANJ	2,748	56	~200			<10	7.5	23	1964

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

**estimated from profiles in Northcote et al. 1964

Nitinat Lake joins the Pacific Ocean via Nitinat Narrows, a narrow tidal passage three km long and 2.5 m deep at low tide. In contrast to most inlets along the mainland coast of BC, Nitinat Lake appears to be physically similar to some shallow-silled Norwegian fjords. No BC inlet shows the extreme and extensive oxygen depletion evident in all water >30 m apparent in Nitinat Lake. Northcote et al (1964) speculate that Nitinat Lake may represent an intermediate stage between an inlet whose stable, saline and largely deoxygenated bottom water is periodically flushed, and a low-lying lake with a surface layer of fresh water.

All components of the biota of Nitinat Lake are marine, brackish, or euryhaline forms¹⁰ and although Nitinat Lake is ~200 m deep, only the upper 20–30 m appear to be oxygenated (Northcote et al. 1964). A thermocline and halocline occur in the upper 10 m while waters below 20–30 m are permanently anoxic (Northcote et al (1964). Hydrogen sulphide (H_2S) is present in water >30 m although Northcote et al (1964) noted a strong H_2S odour at 20 m, and other researchers have identified high H_2S concentrations at 7 m –10 m (Bell, 1970).

The presence of hydrogen sulphide periodically results in fish kills at this large lake (Reid, G, 2010, pers. com.). In October 1970, DFO investigated a kill of marine species including bivalves, flat fish, jellyfish and eels, salmon and trout. Researchers concluded this multi-species kill was due to H_2S which is a highly toxic respiratory poison, and/or a combination of anaerobiosis and sulphide (Bell, 1970). Investigators further speculated that the top several meters of the lake inverted bringing toxic conditions including detritus and poisons from lower layers to normally unaffected areas (Bell, 1970).

Tributaries

The most important stream and the main inlet to Nitinat Lake is the Nitinat River (Table 2). Other important tributaries include the Caycuse River, Doobah Creek which drains Doobah Lake, Worthless Creek and Hobitan River which drains Hobitan Lake. Hobitan Lake has an important sockeye salmon population which is a food source for the Nitinat Native Band.

Tributaries to the Nitinat River include Jasper, Worthless, Parker, Red Bed, Heather, Hooper, West Fork, West Fork and Middle Fork Creeks. Complete summaries of the habitat in these creeks, as well as information on additional lake tributaries can be found in Clozza and Witt, 1980.

¹⁰ Euryhaline species are able to tolerate a wide range of salinity

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Nitinat Lake (Source: FLNRO files, Nanaimo, Fedorenko, 1979; Clozza and Witt, 1980; Griffith, 1992).

Tributary	Order	Length and/or Drainage Area	Other Information
Nitinat River	3	~50 km	Located 25km southeast of and parallels the Alberni Inlet; flows to the southwest emptying into Nitinat Lake; set of falls at ~18.5km upstream of lake is a barrier to salmon and winter steelhead; watershed is heavily logged and river is subject to flash flooding.
Little Nitinat River			tributary to the Nitinat River; flows southeast into the Nitinat River ~5km from lake inlet; anadromous fish restricted to ~2km section of stream by 25m falls; accessible portion divided into two reaches – lower is similar to Nitinat River, 2 nd is a bedrock canyon; rearing habitat limited in both.
Caycuse River	3	36.8 km; 171 km ²	Nitinat Lake inlet; flows southwest into east side of lake; deeply incised and flows through steep-walled bedrock canyon for most of its length; logged watershed and no barrier falls on the creek; creek has one wide, unconfined reach with poor rearing habitat and 2 nd reach of bedrock canyon where trout-rearing habitat is excellent but spawning habitat is limited; falls and cascades in the canyon may restrict access; main tributary is McClure River.
Hobitan River	2	15 m ²	Located 6 km from the head of Nitinat lake; 12m wide; substrate of 15% bedrock; 30% boulder; 30% cobble; 20% fines; no major tributaries; beach spawning for sockeye; heavy food fishery off the mouth.
Doobah Creek Worthless Creek	2	Nitinat Lake inlet Enters the mainstem ~10km from the lake and contains excellent spawning and rearing areas.	

Species Composition

Chinook, chum, coho, pink and sockeye salmon, coast range and prickly sculpin, and threespine stickleback are present in Nitinat Lake. Chum and Chinook salmon dominate the fish populations, and there is a native and commercial fishery for chum outside the mouth of the Nitinat River. The lake is the rearing area for chum and Chinook fry, and coho and sockeye juveniles are present during their out-migration after spending a year in the tributaries (Fedorenko, 1979). While sockeye do enter the lake, they migrate into Hobitan Lake to spawn and rear (DFO Regional Office, Pt. Alberni *In*: MFLNRO files, Nanaimo).

Anadromous and resident forms of rainbow trout and cutthroat are found in Nitinat Lake. Steelhead trout move through the lake to spawn in the Caycuse and Nitinat Rivers along with the cutthroat trout (Clozza and Whitt 1980). A study by Fedorenko in 1979 found insignificant numbers of trout in the lake, and there is no information on char in the watershed.

Nitinat Lake is not utilized by sockeye salmon juveniles for rearing. The sockeye populations in the lake spawn and rear in Hobitan Lake, then migrate through Nitinat Lake to the ocean. During their migration, sockeye juveniles may be available as prey for cutthroat trout, but this is speculation and there is no supporting data.

The Nitinat River has sockeye salmon and the river supports a sport fishery for winter and summer steelhead, coho, and Chinook salmon (FLNRO files, Nanaimo). Snorkel surveys indicate that although the falls on this river is a barrier to salmon and winter steelhead, at least some summer steelhead manage to negotiate these falls successfully (Griffith, 1992). A chum

and Chinook hatchery was established on the Nitinat River in the 1970's by DFO to support an intensified commercial fishery in the late 1970's (Clozza and Witt, 1980). The Ministry used this hatchery to stock small numbers of steelhead into the river during the 1990's (FLNRO files, Nanaimo).

Summary of Work and Reports

Fedorenko (1979) studied the water quality, benthos and zooplankton of Nitinat Lake in 1979 including setting up beach seining sites at 19 different locations on the lake through the spring and early summer. Clozza and Witt (1980) conducted a steelhead inventory report of the Nitinat watershed for the Fish and Wildlife Branch in 1980, and Lucas conducted a water quality inventory of the Nitinat River watershed in 1997. Habitat summaries for some Nitinat watershed tributaries can be found in the Catalogue of Fish and Stream Resources of Area 23 (FLNRO files, Nanaimo).

2.0 Limits to Fish Production

Logging

Parts of the watershed with the exception of the West Coast Trail have been extensively logged and there have been impacts on stream habitats as a result of this land use. A moratorium on logging in this area was ordered by the Provincial Government in 1972 (FLNRO files, Nanaimo).

Water Quality

A number of water quality issues limit fish production at Nitinat Lake including the presence of a shallow sill which restricts exchange between the ocean and the lake, and anoxic layers and the accumulation of H_2S below 20 m in the lake. Although freshwater from the Nitinat River and runoff produce a strong halocline, salinities close to those of oceanic water occur from 40 m to the lake bottom (Adams, 1966). The combination of one or more of these factors has been cited as responsible for multi-species fish kills at the lake (Northcote et al, 1964; Bell, 1970).

Water >20 m deep is permanently anoxic and dominated by high saline and hydrogen sulphide levels which eliminate the possibility of kokanee rearing in the lake and providing a forage base for sport fish such as cutthroat. It appears sport fish only use the lake as a conduit to ascend the system and escape to key spawning and rearing tributaries (Reid, G, 2011, pers. com).

3.0 Angling Statistics

Angler Effort

Angler statistics have been reported for all years for Nitinat Lake (Figure 2). Mean angler effort is ~179 angler days/year but effort has been declining throughout the survey period. Angler effort was 70 angler days in 1986, increased to 364 angler days in 1989, then began falling. In 1992, angler effort was 311 angler days, in 2002 it was 198 angler days, in 2006 angler effort was 79 angler days, and in 2011 angler effort fell to 42 angler days.

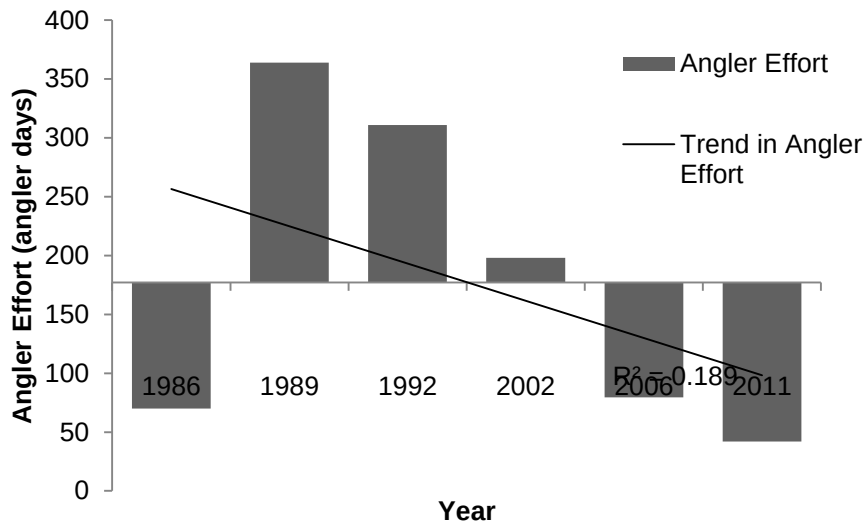


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Nitinat Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Catch

As with angler effort, total catch rose in the late 1980's but has declined since (Figure 3). Average catch is 280 fish for all survey years. In 1986, total catch was estimated at ~100 fish but in 1989, catch rose to 590 fish. In 1992, total catch dropped to 477 fish, in 2002 catch dropped to 323 fish, and in 2006 total catch was estimated at 34 fish. In 2011, catch rose slightly to 125 fish.

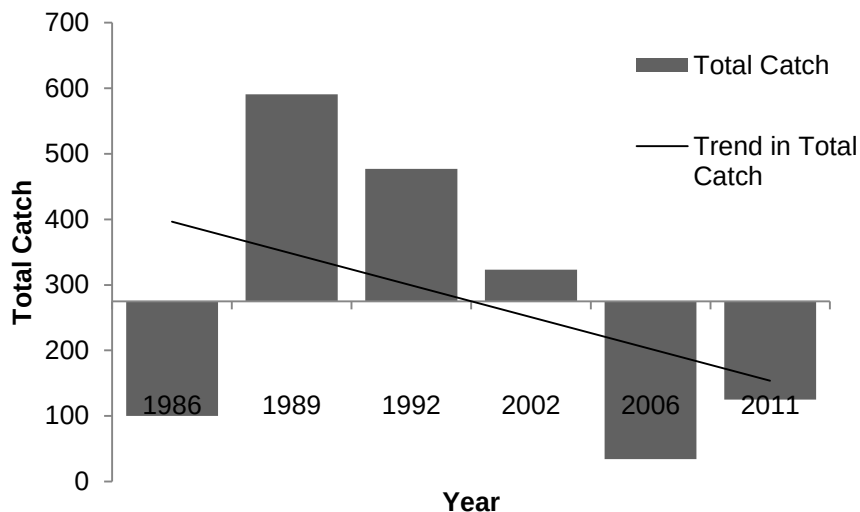


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Nitinat Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Almost 70% of the total catch in 2006 was cutthroat trout (23 fish) and ~32% was rainbow trout (11 fish) (Table 3). In 2011, those statistics reversed with ~33% of the catch comprised of cutthroat trout (42 fish) and ~67% comprised of rainbow trout (84 fish).

TABLE 3. Catch of rainbow and cutthroat trout at Nitinat Lake 2006 and 2011 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	23	67.6	42	33.3
Rainbow	11	32.4	84	66.7
Total	34		125	

Angler Success

With the exception of the last two survey periods, angler success has changed very little over the past 25 years and the average angler success at Nitinat Lake (1.6 fish/day) corresponds to our regional objective for this statistic (Figure 4). In 1989, angler success was 1.4 fish/day and over the next three survey periods angler success remained stable at ~1.6 fish/day. In 2006, however, angler success dropped to <0.5 fish/day but increased to ~3 fish/day in 2011.

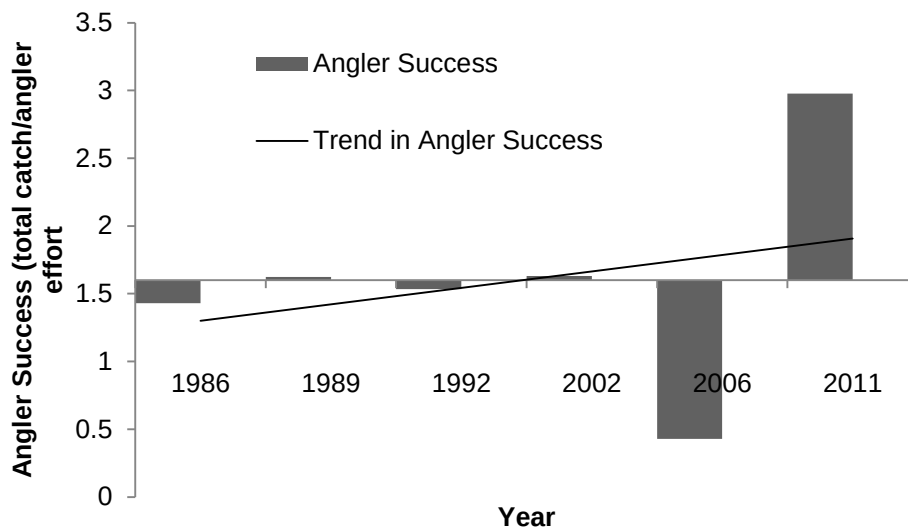


FIGURE 4. Angler success (total catch/total angler effort in angler days) compared to average angler success) at Nitinat Lake 1986 – 2011. Note that the average angler success at Nitinat Lake is 1.6 fish/day which corresponds to the regional success objective (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Harvest

No harvest of fish was reported from Nitinat Lake in the 2006 VILQ, though in 2011, anglers harvested ~67% of the cutthroat trout (42 fish) and ~33% of the rainbow trout caught (84 fish) (Table 4). Overall, the harvest rate is ~44% at Nitinat Lake.

TABLE 4. Catch, harvest and percent harvest of rainbow and cutthroat trout at Nitinat Lake 2006 and 2011. (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	Catch	Harvest	% Harvest
Cutthroat	42	28	66.7
Rainbow	84	28	33.3
Total	125	56	44.4

4.0 Stock Status Indicators

Relative Abundance

Northcote et al. (1964) make reference to gillnetting in Nitinat Lake in 1961. These authors provide no data; only a notation on catching marine species including Pacific herring, shiner and sea perch in the nets set at the head of Nitinat Lake (FLNRO files, Nanaimo). These authors also conducted some sampling in the mouth of Campus Creek where they caught stickleback, flounder and sculpins, and in the Nitinat River where they captured juvenile coho, threespine stickleback, prickly and Aleutian sculpins (FLNRO files, Nanaimo).

Fish and Wildlife staff have conducted a snorkel surveys in the Nitinat River and documented rainbow trout juveniles scattered in small groups, in the Caycuse River where rainbow trout estimated at 0+, 1+ and 2+ years old were observed, and the Little Nitinat River where a ~2 lb rainbow was seen in the lower bridge pool (Fish and Wildlife files, Nanaimo).

Data Gaps

Limited fish information exists for Nitinat Lake tributaries (Northcote, 1961) and Nitinat Lake (Northcote, 1964), and there is no detailed information on the extent or timing of the sport fishery (Table 5). Although a snorkel survey of the Nitinat River conducted in 1987 makes reference to one large and some juvenile rainbow trout, this survey and an electrofishing survey in 1979 only make reference to trout and coho juveniles. In addition to not providing individual fish data, these surveys are >10 years old. There has never been a hydroacoustic survey at Nitinat Lake.

TABLE 5. Summary of data gaps for Nitinat Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Gillnetting			X
Angler Creel Survey			X
VILQ	X		
Snorkel Surveys		X	
Acoustic Surveys			X
Electrofishing (streams)		X	
Lake/Limnology Inventory		X	
Stream Habitat Inventory		X	

5.0 Fisheries Objectives and Management Strategies for Nitinat Lake

Existing Regulations

Nitinat Lake is considered tidal water, consequently, tidal regulations apply and a federal Tidal Waters Sport Fishing Licence is required to fish this lake.

Federal regulations for trout in tidal waters allow for 1 fish/day >50 cm for hatchery steelhead, cutthroat and Dolly Varden. This regulation is in effect all year. There is a minimum size restriction of 30 cm.

The Nitinat River including tributaries is closed all year above Parker Creek. There is no fishing between boundary signs ~100 m upstream of and downstream of “Red Rock Pool” ~2 km south of the Nitinat River bridge August 25 – December 31. There is no fishing between boundary signs ~50m upstream of and downstream of the Nitinat River bridge August 25–October 15. There is fly fishing only above and including Hatton Creek on the Caycuse River.

Fisheries Objectives and Management Strategies

It appears as though Nitinat Lake is under-fished because all angler effort and catch points are on the ascending limb of the polynomial so we couldn't project a maximum or optimum angler effort or catch (Figure 5). The VILQ data may under-represent the fishery at this lake, however, as anglers do not require freshwater fishing licences. It also appears this regulation is not widely known as we've received responses to the VILQ for each survey year since its implementation. Given questions regarding the completeness of the VILQ, we did not determine yield for Nitinat Lake, and we could not predict a theoretical yield because there is no mean depth available for this lake.

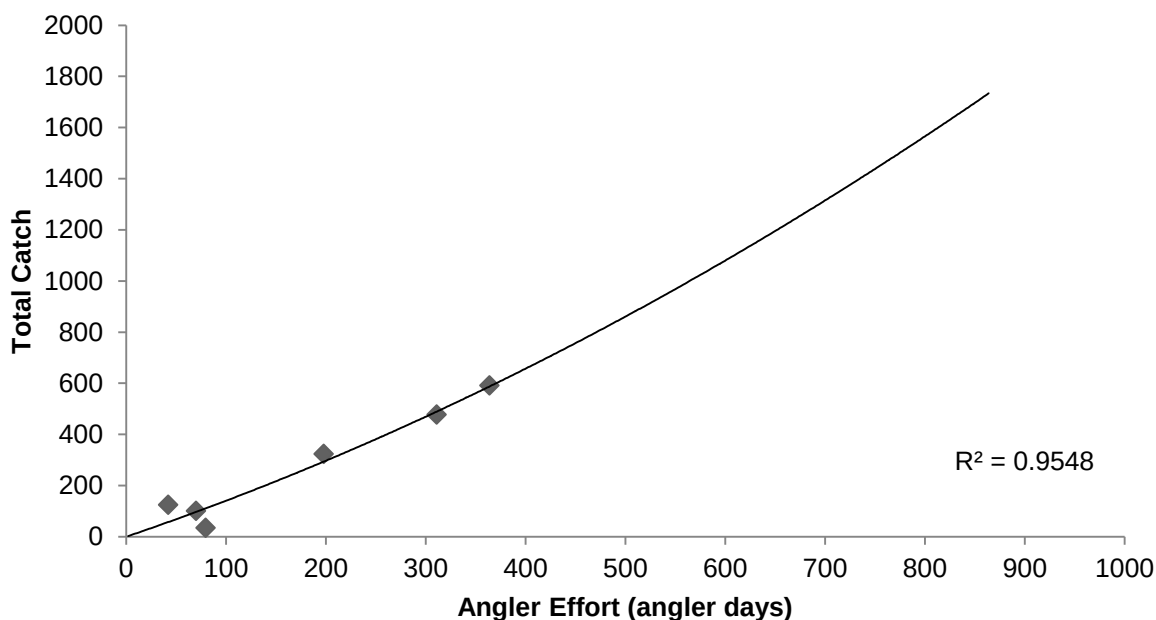


FIGURE 5. Angler effort (angler days) vs. total catch at the current regulations and trend in angler effort and total catch (2nd order polynomial) at Nitinat Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Apart from the questions regarding the completeness of the VILQ, the data available indicates that angler catch has been in proportion to the days fished and, until recently, angler success has been consistent indicating stable populations of angler caught sport fish. In 2011, angler success increased as would be expected with the decrease in angler effort but these statistics are not proportional. We've speculated the decrease in angler effort may be a reflection of anglers becoming aware there is no requirement to have a freshwater angling licence at this lake but there is no way to know this for sure.

Anglers have reported catching trout despite the fact that incidental gillnetting data suggests there are no trout in Nitinat Lake. We suspect a recreational fishery does exist at Nitinat Lake but if so this fishery is very small and may occur during the migration of salmon smolts from the Nitinat and Caycuse Rivers, and Hobitan and Doobah Creeks during the spring. This is speculation as such a fishery has never been documented or studied in detail.

Our major concern at Nitinat Lake is that harvest rate may be too high if total catch is higher than what is estimated through the VILQ. In addition, given the licensing situation, VILQ data may not accurately represent the fishery and is likely not the best mechanism to monitor the fishery. In addition, there is no stock status data for the lake, and the single snorkel and electrofishing surveys do not provide individual fish data.

We've outlined a management model in Figure 6 which includes gillnetting Nitinat Lake to collect stock status data, and developing a fisheries monitoring program with DFO which may monitor the tidal and recreational fishery at the mouth of Nitinat Lake. We've also suggested working with DFO to review any past data they've collected and coordinating future monitoring programs to gather data on trout caught in the lake. This work should be done in concert or after Nitinat Lake has been gillnetted. The need for additional surveys including snorkel surveys and electrofishing assessments can be identified once the extent of the fishery is determined.

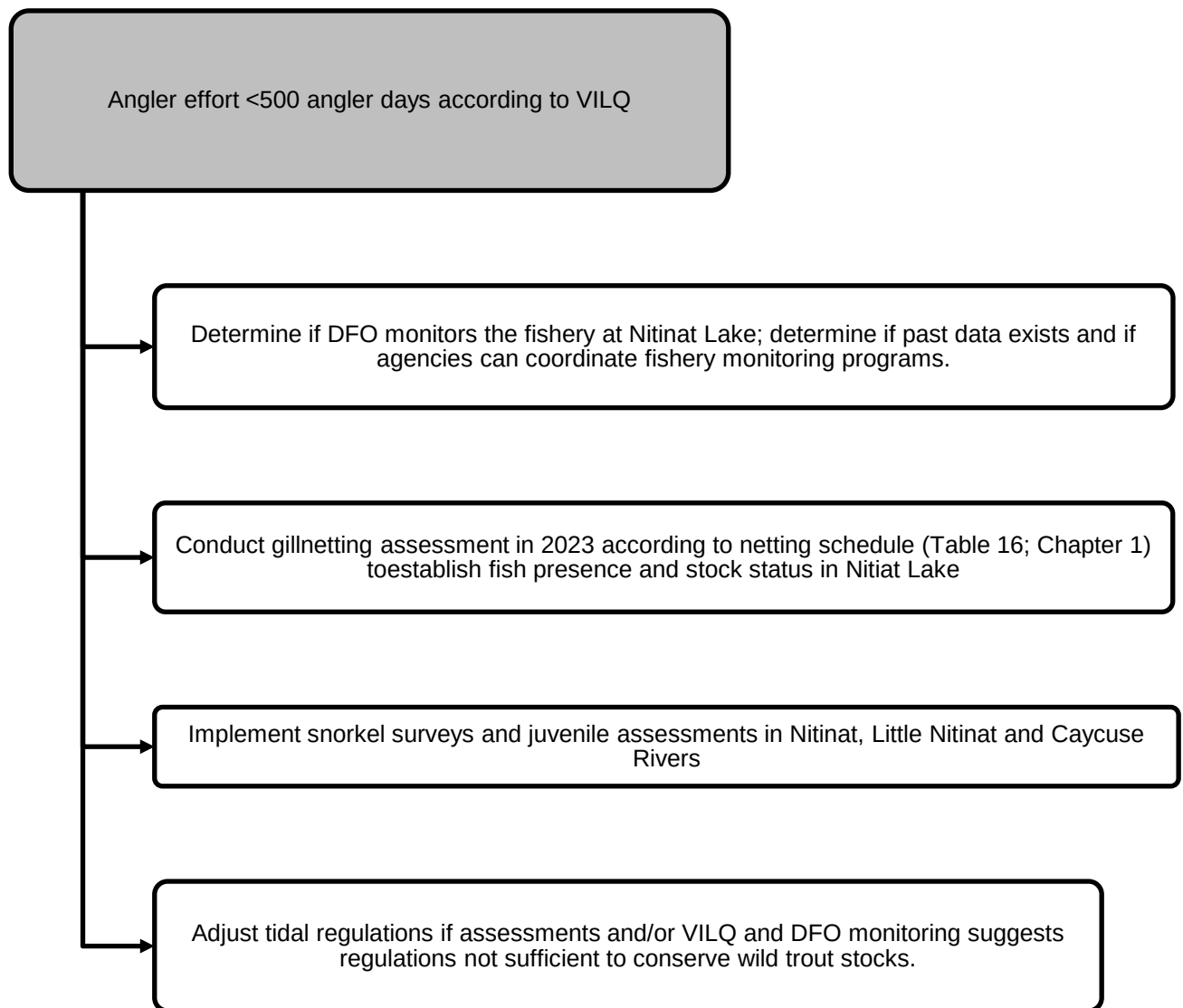


FIGURE 6. Operational management model for Nitinat Lake. Nitinat Lake is a low priority large lake and does not require gillnetting can proceed in 2023. Note there is no requirement for anglers to purchase a freshwater fishing licence as this is a tidal lagoon so the VILQ is not the best way to monitor the fishery here. We've suggested working with DFO to jointly monitor recreational angling at this lake.

Chapter 14. Sproat Lake

Lake	Sproat
Planning Unit	West Coast
Watershed	Stamp/Somass
Surface Area (ha)	3,775
Mean Depth (m)	195
Key Tributaries	Taylor River, Sutton and Gracie Creeks.
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden
Limits to Production	Logging throughout the watershed; all tributaries have been logged; lake-shore development, particularly on the Klee (West) Arm.
Regional Priority*:	3
<u>Angling Statistics 2011</u>	
Angling Effort	4,970 angler days
Total Catch	6,516 fish
Angler Success	1.3 fish/angler day
Current Harvest Rate	15%
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	A mandatory release regulation for cutthroat trout and size limits for rainbow trout appears to be effective at protecting these species.
Data Gaps	Gillnetting data is >10 years old and must be updated; stock status parameters including length-at-age and length-at-maturity must be updated. There are also no electrofishing assessments to provide baseline data for juvenile fish; angler creel surveys do not exist and data on angler-caught fish is limited.
Management Objectives	Maintain current regulations for cutthroat trout; investigate reason for discrepancy in rainbow trout maximum size regulations (i.e. both >50 cm and >60 cm regulations exist).
Operational Plan Priorities	Implement gillnetting survey and continue annual snorkel surveys; conduct electrofishing survey to gather baseline data on juvenile fish; implement roving and box angler creel surveys; review DFO stocking plan for the watershed and monitor resident carp population. Habitat assessment and restoration/enhancement studies are also suggested.
Potential Partners	Port Alberni Fish and Game Association, Island Timberlands, Nuu-chla-nuth District Council.

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Sproat Lake Watershed

General Information

Sproat Lake is located ~10 km northwest of Port Alberni and lies within the Coastal-Douglas Fir biogeoclimatic zone in the West Coast PU (Figure 1). The lake has a surface area of 3,775 ha, a perimeter length of 90.8 km, an average depth of 66.5 m, a maximum depth of 195 m and is situated 32 m above sea level (Table 1). Sproat Lake was assessed by Provincial Fisheries staff in 1951, 1955, 1975 and 1986. The lake is cold and oligotrophic and has a TDS of 32 ppm, a pH of 7.1 (McGarvie, 1996), and a secchi depth of 14.6 m.

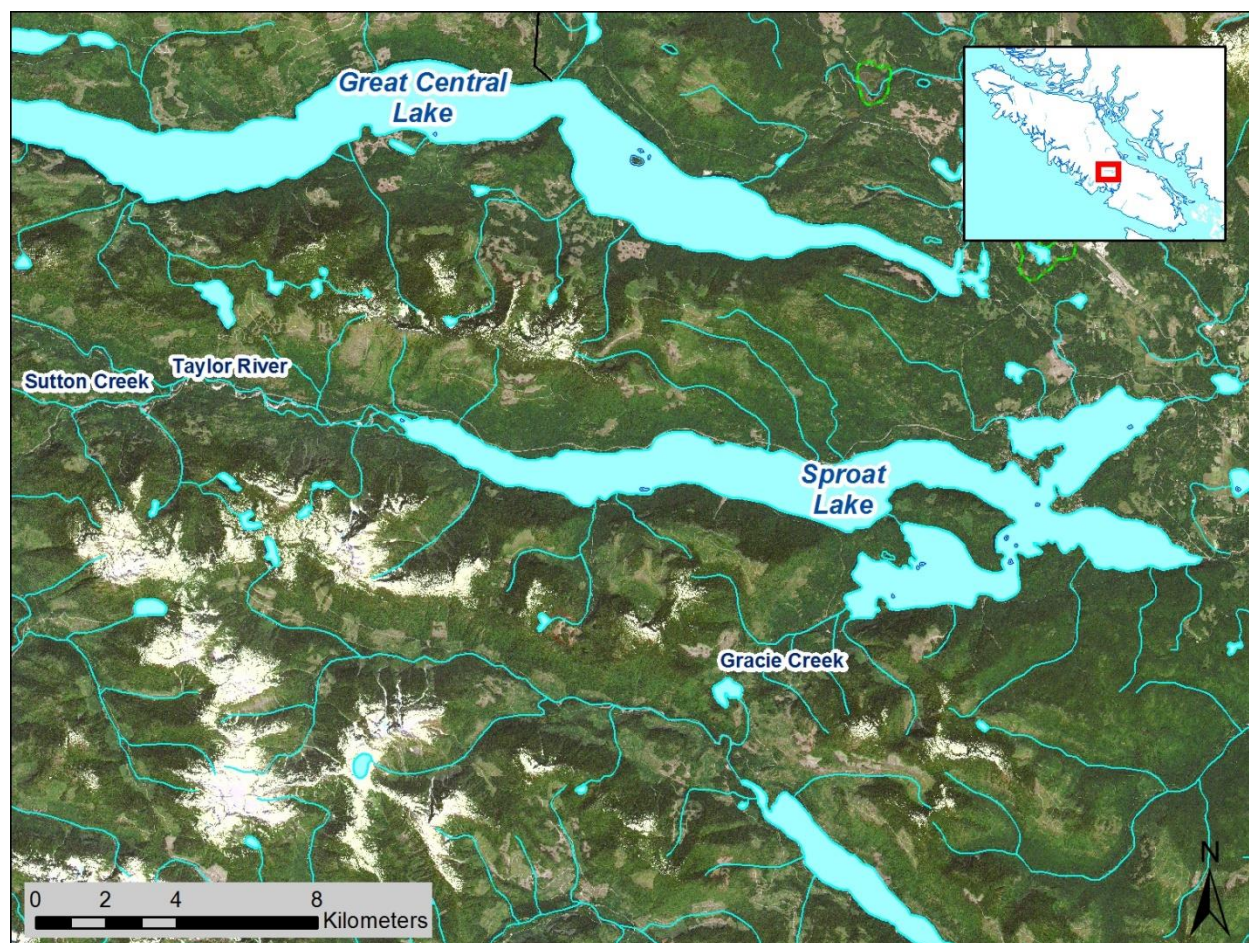


FIGURE 1. Map of Sproat Lake and tributaries; a bathymetric profile is provided in Appendix 20 (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Sproat Lake (Source: McGarvie, 1996; FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
West Coast	01128ALBN	3,775	90.8	195	74	7.1	32	14.7	1951, 1955, 1975, 1986

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Tributaries

After entering the lake, coho, steelhead and cutthroat trout proceed to the numerous tributaries around Sproat Lake to spawn. The Taylor River and the beaches to the south as well as the shores of Stirling and Two Rivers Arms are the principal spawning areas for trout and salmon. Following emergence, fry disperse throughout their native streams as well as in Sproat Lake and the Sproat River to rear.

Tributaries to Sproat Lake include the Sproat River, which is the lake outlet that flows into the Somass River and eventually Alberni Inlet, Sutton Creek which has a canyon ~60 m above the logging bridge and is used by coho for spawning and rearing, and the Taylor River which has cutthroat and rainbow trout and sparse distributions coho (Table 2). Gracie Creek is also an important stream for coho and cutthroat while Antler and Snow Creeks are very cold and provide limited habitat for coho.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Sproat Lake (Source: Reid, 1972; Lough, 1991; FLNRO files, Nanaimo).

Tributary	Other Information
Sproat River	Outlet stream; flows into the Somass River and Alberni Inlet; falls between Sproat Lake outlet and the Somass River limit anadromous fish passage during high water years.
Somass River	The Stamp River and Sproat River join to form the Somass River; drainage basin of the Somass is ~1,412 km. ² The word "somas" comes from the Nuu-chah-nulth word meaning "washing."
Taylor River	Cold and unproductive, however, this is an important river for Sproat Lake cutthroat. Large groups of cutthroat use the highway pool to spawn and collection of Taylor River broodstock was done in this area historically. Dolly Varden were documented in the upper reaches of the Taylor River during a snorkel summary conducted by Ministry staff in the early 2000's.
Panther Creek	Provides habitat for coho and adfluvial cutthroat and has a series of high falls ~300 m above a backfilled log jam.
Winter Creek	Stream Impacts from highway construction including riparian sloughing, sediment deposition over the natural boulder gravel substrate were noted during a 1972 reconnaissance. Spawning habitat for cutthroat and coho; substrate in these streams is mainly gravel; >15m falls.
Snow Creek	Substrate mainly boulders and rubble with gravel near the mouth; the stream is used by coho for spawning; logging on both sides of the steam was evident in 1972 but no evidence of significant stream damage; upper limit is a falls ~15m just above the logging bridge.
Antler Creek	No evidence of fish during 1972 reconnaissance; substrate heavily compacted from sediment and eroded rock; much debris in the stream from logging; upper limit is series of >6 m falls above bridge.
Sutton Creek	No evidence of cutthroat but old coho redds noted during a 1972 reconnaissance; anadromous limit is ~400 m from mouth at a series of narrow cascades and falls; substrate mainly boulders and rubble turning to boulders and bedrock above logging bridge; west fork discharge exceeds that in Sutton Creek mainstem; very low water temperatures (<4°C) in both streams in April so there may be late spawning in these areas.

The Taylor River is an extremely important fishery in the region and the large Taylor River cutthroat are a unique population of Vancouver Island sport fish. A number of these fish are caught off the river mouth during each spring spawning migration (Reid, G., 2011, pers. com.;

McCulloch, M., 2013, pers. com.) with very few of these fish caught in the summer fishery in the lake. Cutthroat fry likely reside in the cold and unproductive Taylor River for their first year before recruiting to Sproat Lake (Lough, 1991). Taylor River cutthroat likely first become catchable at three years of age in this cold system and are susceptible to fishing over a further three to four years (Reid, G., 2012, pers. com).

There are a number of unnamed tributaries to Sproat Lake, one of which has a 5 m falls upstream of the logging bridge located on the south side of the Taylor River. Other creeks that provide good habitat for coho and Sproat Lake (adfluvial) cutthroat include: an unnamed stream at the Sproat Lake Park; Shuhum Creek which may be an important producer of Sproat Lake cutthroat; Ward Creek, which although the lower reaches may dry in most years provides some habitat for coho and cutthroat; and Clutesi Creek which is accessible to a series of falls ~6.5 km upstream. Other creeks include Panther Creek which provides habitat for coho and adfluvial cutthroat and has a series of high falls ~300 m above a backfilled log jam, and Wienan Creek which goes underground on the floodplain 60 m below a logging road crossing. Numerous coho and cutthroat fry have been observed above this point and below a swamp in this watershed. The Taylor River, Antler, Snow, Panther, Gracie, Alice, Ward, and Fish Creeks are the best producers of cutthroat and steelhead trout and coho salmon in the system.

Species Composition

Eyed sockeye eggs and fry from Henderson Lake hatchery were planted in Sproat Lake tributaries from 1921 until 1932 (Lough, 1991) and Sproat Lake sockeye were an important component of the Barkley Sound fishery with returns 2nd only to those of Great Central Lake (Shortreed et al., 2001). Sockeye escapements to Sproat Lake reached unprecedented levels of 250,000 in 1983, although returns declined in subsequent years (Hyatt and Steer, 1987). In the 1990's, sockeye escapements to Sproat Lake were relatively consistent and averaged ~163,000 (Hyatt and Leudke, 1999).

Cutthroat and rainbow trout, Dolly Varden, steelhead, coho, sockeye, kokanee, prickly sculpin, and three spine stickleback are present in Sproat Lake. Hybrids of rainbow and cutthroat trout exist in Sproat Lake as evidenced by Lough (1991) who analyzed scales taken during a derby at Sproat Lake in May 1989 and found that adult trout often exhibited characteristic traits of both cutthroat and rainbow and hyoid teeth had to be used to discriminate between the species. Atlantic salmon were stocked into Sproat Lake in the early 1920's, and a population of common carp have existed in the lake for at least the last ten years.

Summary of Work and Reports

MOE has performed several general habitat assessments and reconnaissance and mapping surveys of Sproat Lake tributaries and some of these assessments include recommendations for habitat enhancement. Staff also took water samples and conducted general water quality assessments of some tributaries during the more general habitat assessments. These reports can be found in the Ministry files in Nanaimo.

Lough (1991) analyzed fish scale data from samples taken in 1989 from 140 resident Sproat Lake rainbow and cutthroat trout, and 56 Taylor River juvenile trout. He compared his ageing data with historical lake ageing data collected in 1951-2, 1972 and 1980 to determine life history characteristics of Sproat Lake cutthroat and rainbow trout. In 1972, the Ministry conducted an angler questionnaire survey to determine the preferences and opinions of anglers who fish

Sproat Lake. The objective of this survey was to assess the factors which might influence short- and long-term management of the Sproat Lake fishery (Reid and Hazledine, 1976) (Appendix 20).

Detailed limnological sampling was carried out between 1981 and 1986 (Shortreed and Stockner, 1990) and the lake's limnetic fish community was sampled every year for most of the period from the 1970's until 2000 (Hyatt and Leudke, 1999).

2.0 Limits to Fish Production

Nutrients

Sproat Lake and tributaries are cold and unproductive. Hyatt (in Shortreed et al. 2001) notes that Sproat Lake has extremely limited primary production and phosphorous runs out in the late spring at the time when primary production would normally be increasing. In addition, the lake becomes de-stratified during the winter months and this de-stratification releases phosphorus.

The Taylor Arm of Sproat Lake was fertilized in 1985 and for the first half of the growing season (May – July) in 1986 (Shortreed et al., 2001). The lake responded positively to fertilization with an 80% increase in chlorophyll concentration, a 2.2-fold increase in photosynthetic rate, and a 2.1-fold increase in zooplankton biomass (Shortreed et al, 2001). Shortreed et al (2001) note that although Sproat Lake is an excellent candidate for fertilization, the lake's popularity as a residential and recreational area likely make fertilizer applications socially unacceptable.

Lough (1991) found that the cold and non-productive nature of the Taylor River is reflected in the slow growth of juveniles and this often made scale analysis including identifying the first annulus difficult. Complicating the analysis further is the fact that fry do not begin to form scales until 45 mm – 50 mm, therefore, it's easy to miss the 0+ annulus.

Horncastle and Hay (1981) found the mean fork length of Sproat Lake fry in October (52 mm) was smaller than October fry from the Big Qualicum (83 mm), Quinsam (68 mm), and Ash (56 mm) Rivers. Once present in Sproat Lake, cutthroat juveniles are capable of rapid growth, however. Lough (1991) found that the mean length of 2+ juveniles sampled in Sproat Lake was 263 mm, compared to 142 mm from the Taylor River.

3.0 Angling Statistics

Angler Effort

Angler effort has averaged ~6,000 angler days/year over the past 25 years, and while angler effort increased through the 1980's and 1990's, effort has declined in recent years and overall there has been a slight downward trend in this parameter (Figure 2). In 1986, angler effort was ~5,200 angler days, in 1989 angler effort rose to almost 6,800 angler days then from 1992 until 2002 angler effort remained stable at 6,700 to 7,200 angler days. In 2006, angler effort dropped to ~5,100 angler days and in 2011 angler effort dropped again to ~5,000 angler days.

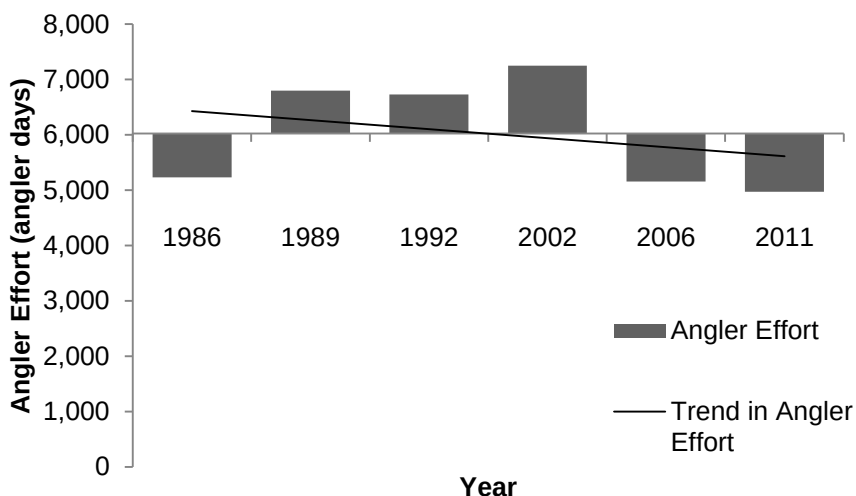


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Sproat Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Catch

Overall, the average total catch at Sproat Lake has been ~7,000 fish and there has been an increasing trend in catch at this lake. Total catch was ~4,000 fish in 1986, catch increased to almost 8,900 fish in 1989 but declined in 1992 to ~6,000 fish (Figure 3). In 2002 and 2006, total catch increased to ~8,000 and ~8,500 fish respectively, then in 2011 catch decreased to ~6,500 fish.

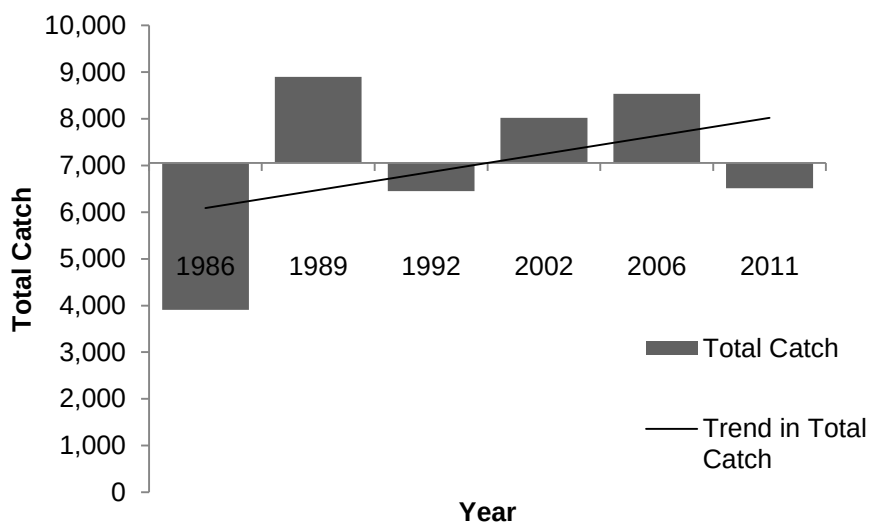


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Sproat Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Approximately 36% of the angler catch at Sproat Lake in 2002 was cutthroat trout (3,090 fish) while ~64% was rainbow trout (5,443 fish) (Table 3). The species breakdown was similar in

2011 with 34% of angler catch attributed to cutthroat (2,214 fish) and ~66% attributed to rainbow trout (4,274 fish).

TABLE 3. Catch of rainbow and cutthroat trout at Sproat Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2012 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	3,090	36.2	2,214	34.0
Rainbow	5,443	63.8	4,274	65.6
Dolly Varden	0	0.0	28	0.4
Total	8,533		6,516	

Angler Success

Although there is an increasing trend in angler success at Sproat Lake, at 1.2 fish/day the average angler success at this lake is below our regional success objective of 1.6 fish/day (Figure 4). In 1986, angler success was <1 fish/angler day but in 1989 catch success increased to 1.3 fish/angler day. In 1992 and 2002, angler success decreased to ~1 fish/day likely as a result of the increase in angler effort. In 2006, angler success increased to 1.6 fish/day and in 2011 the success rate dropped to 1.3 fish/day.

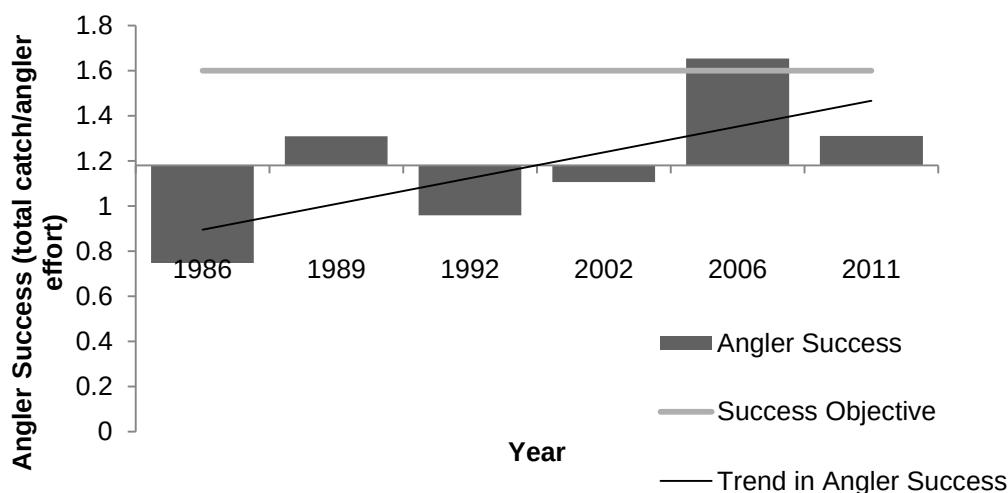


FIGURE 4. Angler success (total catch/total angler effort in angler days) compared to average angler success, trend in angler success and the regional objective for angler success (1.6 fish/angler day) at Sproat Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Harvest

Anglers report harvesting <1% of their cutthroat trout (23 fish) catch in 2006, and just over 1% of their cutthroat trout catch (28 fish) in 2011 despite the cutthroat non-retention regulation (Table 4). Anglers harvested ~37% of their catch of rainbow trout (2,000 fish) in 2006, and ~22% of their rainbow trout catch (4,272 fish) in 2011. It is possible that anglers report higher than true levels of rainbow harvest because of the no-kill regulation for cutthroat trout at Sproat Lake. Overall the harvest rate at Sproat Lake was ~24% in 2002, but dropped to ~15% in 2011.

TABLE 4. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Sproat Lake 2006 and 2011 (Source: Andrews, 2007; Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	3,090	23	0.7	2,214	28	1.3
Rainbow	5,443	2,000	36.7	4,274	933	21.8
Dolly Varden	0	0	0.0	28	0	0.0
Total	8,533	2,023	23.7	6,516	961	14.7

Fishing Derbies

We've shown the total harvest, largest fish caught, and comments from May fishing derbies held at Sproat Lake between 1985 and 1997 in Table 5. Winning fish ranged from ~1 kg to 2.5 kg for rainbow and cutthroat. In 1988, the winning fish was a steelhead ~60 cm and 2.4 kg although a 52 cm, 1.8 kg cutthroat was also caught that year.

TABLE 5. Total harvest, largest fish caught and comments from May fishing derbies held at Sproat Lake 1985 - 1997 (Source: FLNRO files, Nanaimo; Lirette, 1989).

Year	Total Harvest	Largest Fish Caught	Size	Comments
1985	35	Rainbow	0.9 kg	few cutthroat caught.
1986	59	Cutthroat	2.5 kg	75% of fish caught were <1 kg rainbow trout.
1988	50	Steelhead	59 cm; 2.4 kg	largest cutthroat was 52 cm and 1.8 kg.
1989	70	Rainbow	54 cm	resident fish eight years old; angler success estimated at 0.5 fish/day.
1990	24	Trout	1.6 kg	small cutthroat (0.2 kg – 0.6 kg) dominated the catch
1993	35	Trout	~1.5 kg	105 entries; limited data.
1997	96	Rainbow	1.2 kg	rainbow dominated the catch; mean size was 0.6 kg.

Sproat Lake Angler Preference Survey

Reid and Hazeldine (1976) conducted an opinion and preference survey of Sproat Lake anglers in 1976 (Appendix 20). Anglers were asked to provide a comparison between the different types of fishing they participated in (i.e. lake vs. stream vs. ocean), and information on how they fished and the type of fishing they preferred. Participants were also asked questions relating to why they fished Sproat Lake, their fish-size preference, and opinions on regulations. Most people (45%) said they fished Sproat Lake because it's close to their home, while 20% said they fished the lake because of the possibility of catching a large fish. Only 10% said they were in favour of catch-and-release fishing, 22% were in favour of establishing Sproat Lake as a trophy fishery, and ~54% were willing to pay \$1.00 or more for a trophy fishing stamp. Seventy-two percent of anglers favored protective regulations for trophy-sized fish, and >80% said they favoured fishing restrictions on trout spawning and rearing areas.

4.0 Stock Status Indicators

Relative Abundance

Cutthroat and rainbow trout were sampled by gillnet in 1951, 1952, 1953 and 1977 (Figure 5). Samples in 1951, 1952 and 1953 revealed a predominance of cutthroat trout in Sproat Lake comprising 67%, 76% and 80% of the samples respectively. Similarly in 1977, the gillnet sample consisted of 73% cutthroat trout. However, angler creel surveys in 1972 and 1989 showed a more equal representation of both cutthroat and rainbow trout caught by anglers, with 50% cutthroat caught in 1972 and 44% cutthroat in 1989 (Figure 6). Note that angler catch statistics determined through the VILQ suggest a higher percentage (~65%) of rainbow trout in the angler catch compared to the angler catch of cutthroat trout (~35%)(Table 3).

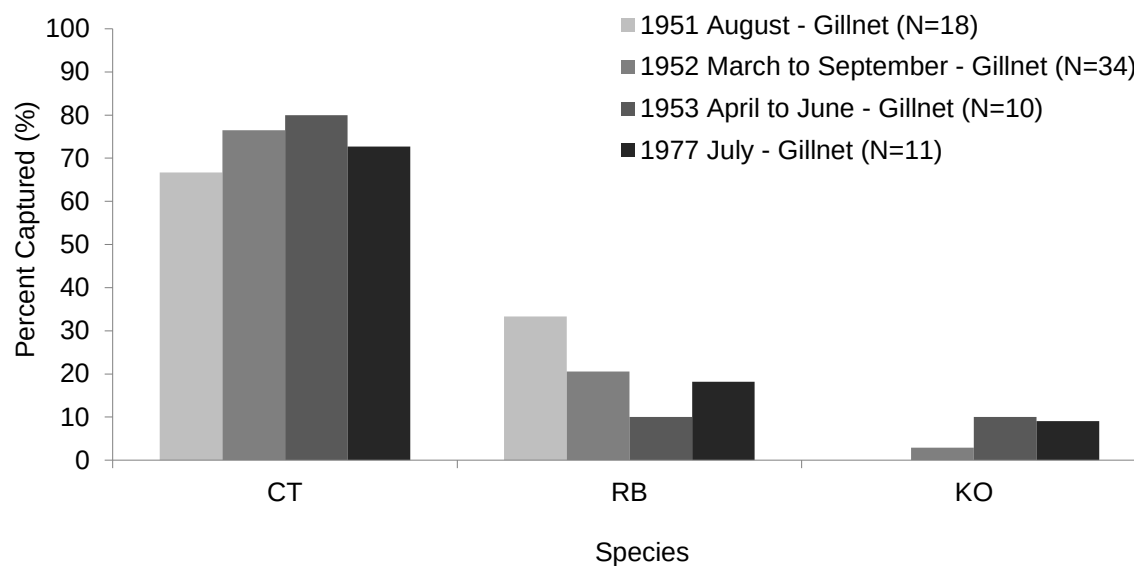


FIGURE 5. Percent cutthroat trout, rainbow trout and kokanee captured in Sproat Lake by gillnets in 1951, 1952, 1953 and 1977 (N=73) (Source: FISS and FLNRO files, Nanaimo).

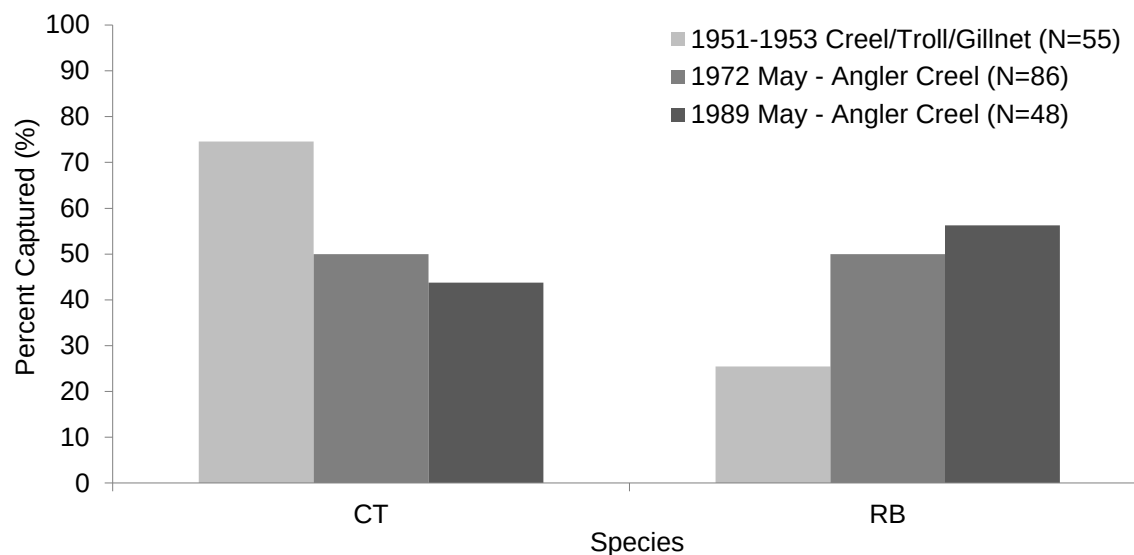


FIGURE 6. Percent cutthroat and rainbow trout captured in Sproat Lake by anglers and gillnets in 1951-53 and anglers in 1972 and 1989 (N=189) (Note: FISS reports data for the years 1951, 1952, 1953 and Lough (1990) combines data as 1951-53. It is unknown whether some of Lough's data is the same data reported in FISS so both data sets are shown (Source: FISS; Lough, 1990).

Lough (1991) examined fish samples collected between 1951-53, 1972 and 1989 to determine the relative abundance of cutthroat and rainbow trout collected by anglers and in gillnets. Although rainbow trout were present in the 1951-53 angler and gillnet samples, the total sample of 55 trout contained only 25% rainbow (Figure 6). Data from an angler creel survey in 1972 revealed that 50% of fish caught by anglers were rainbow and in 1989, 56% of the fish caught by anglers were rainbow trout (Lough, 1991).

Length and Weight

We've summarized the length and weight data for cutthroat and rainbow trout captured in gillnets and by angling in Sproat Lake in Table 6 and have provided more detailed stock status data in Appendix 20. In the 1950's, cutthroat trout captured in gillnets ranged from 180 mm to 720 mm and averaged ~416 mm. The modal length of these fish was 180 mm and the mean weight was ~1.4 kg. In the 1970's, cutthroat trout captured in gillnets ranged from 146 mm to 285 mm and averaged ~200 mm. Only eight fish were collected in this sample and no modal length or mean weight is available.

TABLE 6. Minimum, maximum, mean and modal length and mean weight for cutthroat and rainbow trout captured in Sproat Lake by gillnetting and angling by decade 1950 – 1980 (Source: FISS; Lough 1990).

Species	Decade	N	Length (mm)		Mean	Mode	Weight (Mean) (g)
			Minimum	Maximum			
<u>Gillnet</u>							
Cutthroat	1950	46	180	720	416.1	180	1,444.9
	1970	8	146	285	197.3	-----	-----
Rainbow	1950	14	120	555	387.7	460	898.6
	1970	2	197	229	213.0	-----	-----
<u>Angling</u>							
Cutthroat	1950	2	610	635	622.5	-----	3,076.0
	1970	39	290	673	432.6	370	-----
	1980	15	290	465	379.3	390	-----
Rainbow	1950	2	380	457	418.5	-----	737.5
	1970	43	320	533	446.1	457	-----
	1980	11	230	540	376.4	405	-----

Length-Weight Relationship

As with all large lakes on Vancouver Island, cutthroat trout grow also substantially larger than rainbow trout in Sproat Lake. We've shown the length-weight relationship of cutthroat and rainbow trout sampled in gillnets in 1951–1953 in Figure 7. Cutthroat trout sampled during this period attained sizes approaching 800 mm and >5,000 g, whereas most rainbow sampled were between 400 mm and ~600 g. In his study, Lough (1991) found that cutthroat exhibited more rapid scale growth than rainbow trout and he postulated that this was perhaps because cutthroat tend to be lake-residents during their second year, while the rainbow tend to remain in the streams during that year.

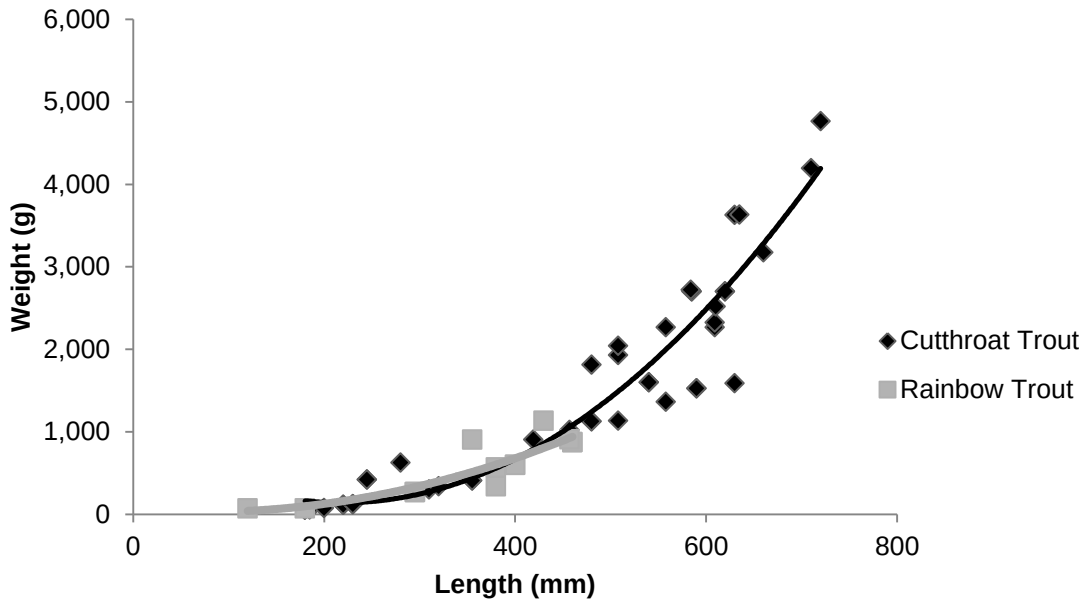


FIGURE 7. Length-weight relationship for cutthroat trout (N=46) and rainbow trout (N=13) captured in gillnets and by anglers in Sprout Lake in 1951, 1952 and 1953. Note, we removed all rainbow >500 mm from the sample as these are likely steelhead (Source: FLNRO files, Nanaimo).

Lirette (1989) reviewed derby and Ministry sampling data and expressed concern regarding the loss of larger, older fish and the harvest of immature fish prior to first spawning. Two years later, Lough (1991) reviewed angler- and seine-caught cutthroat trout scales and compared these with historical data. He found the average cutthroat trout sampled in later samples was smaller and younger than in previous years, and that the larger, older “trophy” fish for which Sprout Lake were known appeared to have been removed from the population. It’s possible that together with angler harvest of large cutthroat from Sprout Lake, hatchery collection of Taylor River broodstock which began in 1989 may have contributed to the decline of numbers of larger cutthroat trout.

We constructed length-frequency distributions for cutthroat trout sampled by anglers in the 1950’s (Figure 8A), 1970’s (Figure 8B) and 1980’s (Figure 8C) and found similar results. In the 1950’s, 47% of the angler-caught cutthroat were >500 mm and ~10% of the sample was >600 mm. In the 1980’s <30% of the angler catch was >500 mm with fish >600 mm comprising only 5% of the sample. In the 1980’s, no cutthroat >500 mm were caught. Note that the 1980’s sample consisted of only 15 fish which may account for the variability. However, our analysis is strengthened by Lough’s (1991) observation that the incidence of repeat spawners had declined from 11% in the early 1950’s, to 6% in 1989.

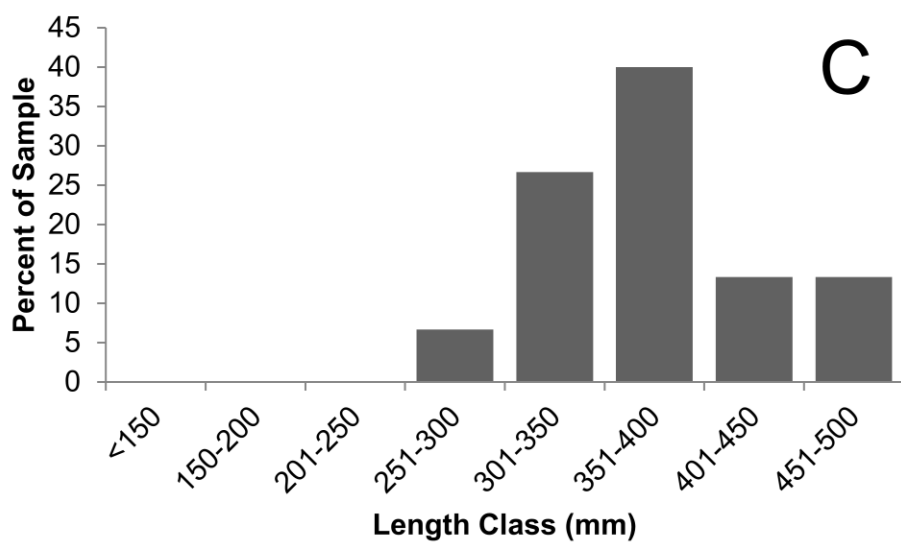
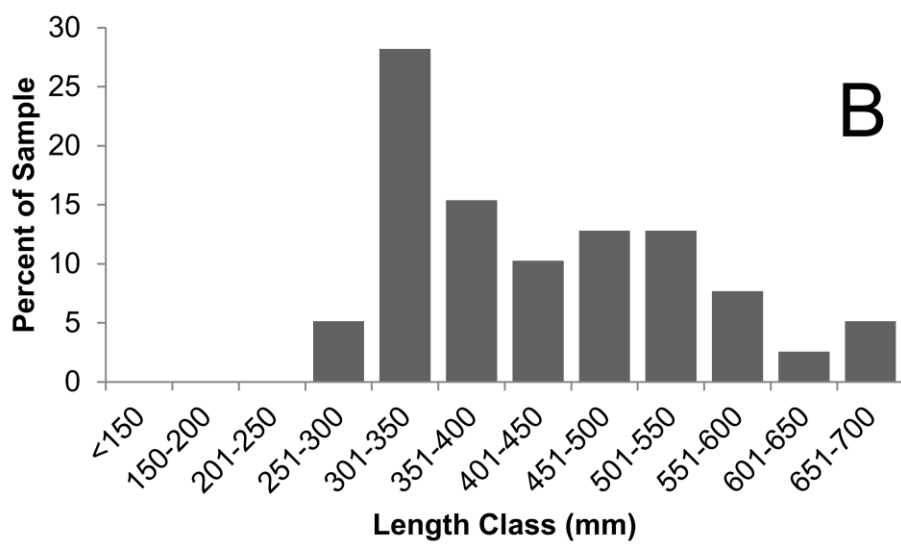
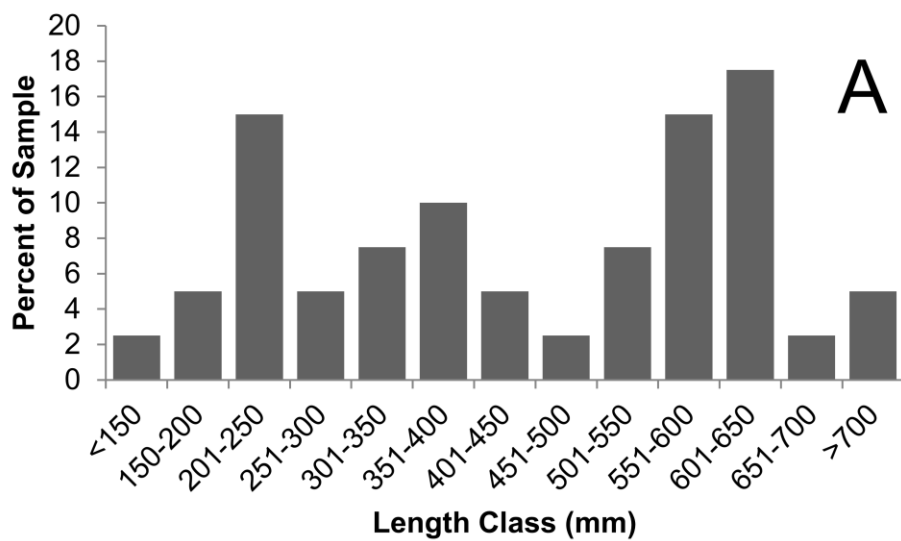


FIGURE 8. Length frequency distributions for cutthroat trout sampled by anglers (A) in the 1950's (N=40), (B) the 1970's (N=39) and the 1980's (N=15) in Sprout Lake (Source: FLNRO files, Nanaimo).

Although there is still some concern regarding the decline in size of cutthroat trout in Sprout Lake, a spawning survey of the Taylor River conducted in 2012 by Lough and Hay (2012) found large fish >700 mm still exist in the population. These investigators calibrated fish size estimated during snorkel surveys using a graduated measuring bar placed in the major spawning pool in the Taylor River and found that cutthroat were uncommonly large with the size of spawning fish ranging from 400 mm – 800 mm (Figure 9) (Lough and Hay, 2012).

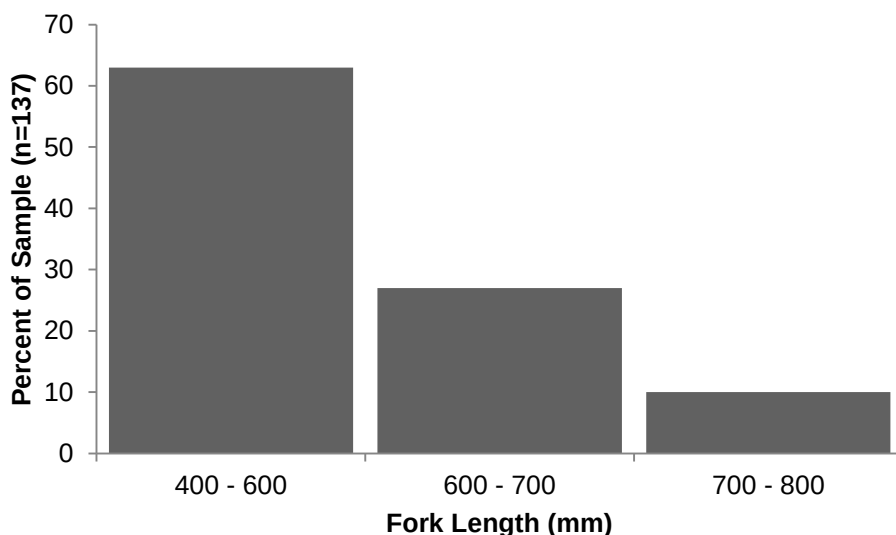


FIGURE 9. Estimated fork length of 137 cutthroat trout observed during snorkel surveys in Taylor River road pool on May 11, 2012 (Reprinted from: Lough and Hay, 2012).

Rainbow trout captured in gillnets in the 1950's ranged from 120 mm - 555 mm and averaged ~388 mm (Table 6). The modal length of this species was 460 mm and the mean weight was ~900 g. Only two rainbow trout were captured in gillnets in the 1970's and these averaged 213 mm.

Age and Growth

We constructed length-at-age graphs for cutthroat trout captured in nets and by anglers in the 1950's in Figure 10 A, the 1970's in Figure 10B, and the 1980's in Figure 10C. In the 1950's, 12 age 1+ cutthroat from 125 mm – 240 mm and averaging ~195 mm, nine age 2+ fish ranging from 185 mm – 355 mm and averaging 264 mm, six age 3+ cutthroat from 260–324 mm and averaging ~287 mm and ten age 4+ cutthroat ranging from 320 mm – 660 mm and averaging 500 mm were caught (Figure 10A). There were also eight age 5+ cutthroat from 356 mm – 609 mm and averaging 486 mm, five age 6+ cutthroat ranging from 590 mm – 711 mm and averaging 641 mm, 5 age 7+ cutthroat from 508 mm – 724 mm and averaging 614 mm and one age 9+ cutthroat 559 mm caught.

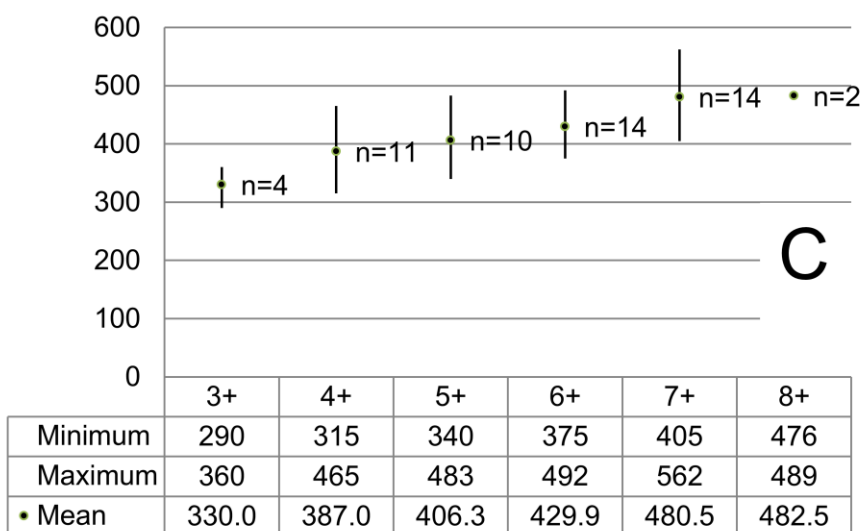
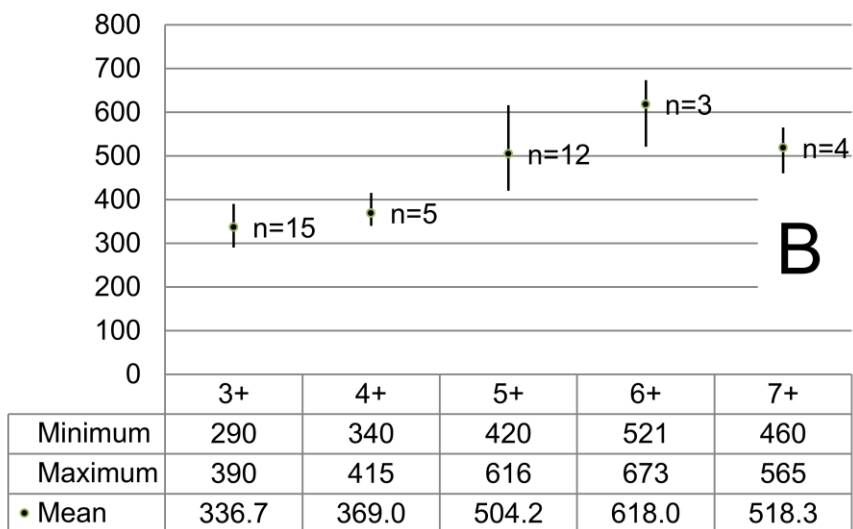
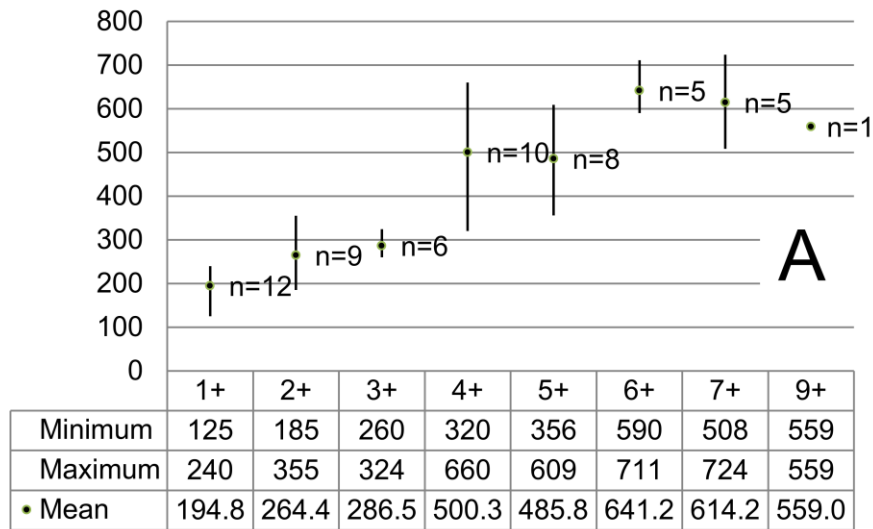


FIGURE 10. Length-at-age of cutthroat trout sampled by gillnetting and angling in (A) the 1950's (N=56), (B) the 1970's (N=39), and (C) the 1980's (N=55) in Sproat Lake (Source: FISS; Ministry Files, Nanaimo; Lough, 1991).

In the 1970's, 39 cutthroat were aged (Figure 10B). Fifteen age 3+ cutthroat ranging from 290 mm – 390 mm and averaging 337 mm, five age 4+ cutthroat from 340 mm – 415 mm and averaging 369 mm, 12 age 5+ cutthroat ranging from 420 mm – 616 mm and averaging 504 mm, three 6+ age fish from 521 mm – 673 mm and averaging 618 mm and four age 7+ cutthroat ranging from 460 mm – 565 mm and averaging 518 mm were caught.

In the 1980's four aged 3+ cutthroat ranging from 290 mm – 360 mm and averaging 330 mm, 11 age 4+ cutthroat from 315 mm – 465 mm and averaging 387 mm, ten age 5+ cutthroat ranging from 340 mm – 483 mm and averaging 406 mm, 14 age 6+ cutthroat from 375 mm – 492 mm and averaging ~430 mm, 14 age 7+ cutthroat from 405 mm – 562 mm and averaging 480 mm and two age 8+ cutthroat averaging ~483 mm were aged (Figure 10C).

Our results suggest that fish are growing slower at a younger age and it's possible the extremely cold conditions of Sproat Lake tributaries may impact the early growth of cutthroat trout. It is also possible that ageing may miss an early-age annulus. To determine if is the case, we compared the mean length-at-age of cutthroat captured at Sproat Lake with the mean of mean length-at-age data from cutthroat captured in lakes from the West Coast of the United States compiled by Carlander (1969). We found large differences in lengths of age 1+ to age 5+ cutthroat trout (Table 7). For example, the mean length-at-age of 1+ cutthroat trout in Sproat Lake was 195 mm compared to 102 from Carlander, the mean length of age of 2+ Sproat Lake fish was 266 mm compared to 185 mm from Carlander's data and the mean length of age 3+ Sproat Lake fish was 316 mm compared to 269 mm from Carlander. Age 4+ Sproat Lake cutthroat averaged 411 mm and data compiled by Carlander suggest 4+ cutthroat average 340 mm, while age 5+ Sproat Lake fish average 450 mm compared to 406 mm from Carlander. While we are still concerned that fish are growing slower at a younger age, our cursory review also suggests that cutthroat ages from Sproat Lake may be off by a year. As such, statements regarding the length-at-age of Sproat Lake cutthroat should be made with caution.

TABLE 7. Mean length-at-age of cutthroat trout captured by gillnetting and angling in the 1950's (N=56), the 1970's (N=39), and the 1980's (N=55) in Sproat Lake by the Ministry staff compared to mean of mean length-at-age of cutthroat trout captured in lakes in Wyoming, Idaho, Colorado, Utah, Montana and California (Source: Carlander, 1969).

Data Source	N	Age						
		1	2	3	4	5	6	7
FLNRO	279	195	266	316	411	450	452	457
Carlander, 1969	8,843	102	185	269	340	406	490	564

Note: length data from Ministry samples is for fork length; length data from Carlander is total length.

We've provided the length-at-age analyses for rainbow trout captured in the 1950's in Figure 11A, rainbow captured in the 1970's in Figure 11B, and in the 1980's in Figure 11C. In the 1950's, one age 2+ rainbow 280 mm and one age 3+ rainbow 279 mm were caught. Three age 4+ rainbow ranging from 355 mm – 380 mm and averaging ~372 mm, five age 5+ rainbow ranging from 381– 490 mm and averaging 415 mm, 3 age 6+ rainbow ranging from 381 mm – 430 mm and averaging ~404 mm, 1 age 7+ rainbow 457 mm and 2 age 8+ rainbow averaging 446 mm were caught.

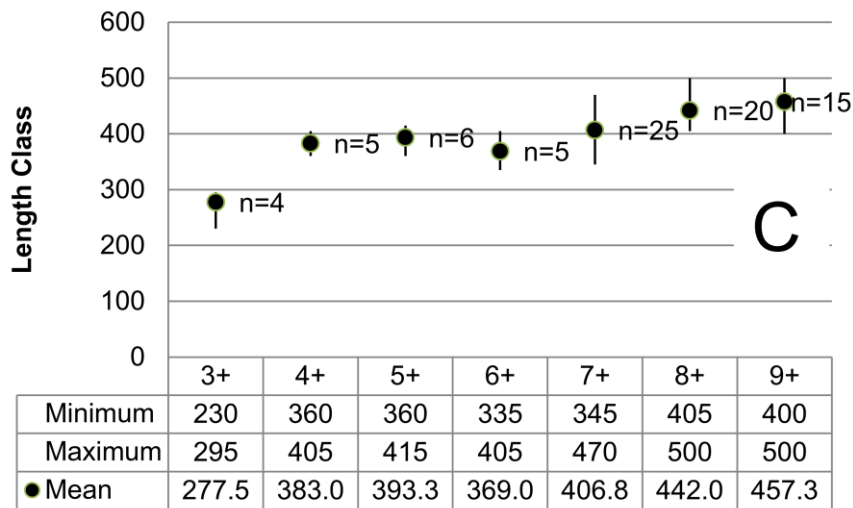
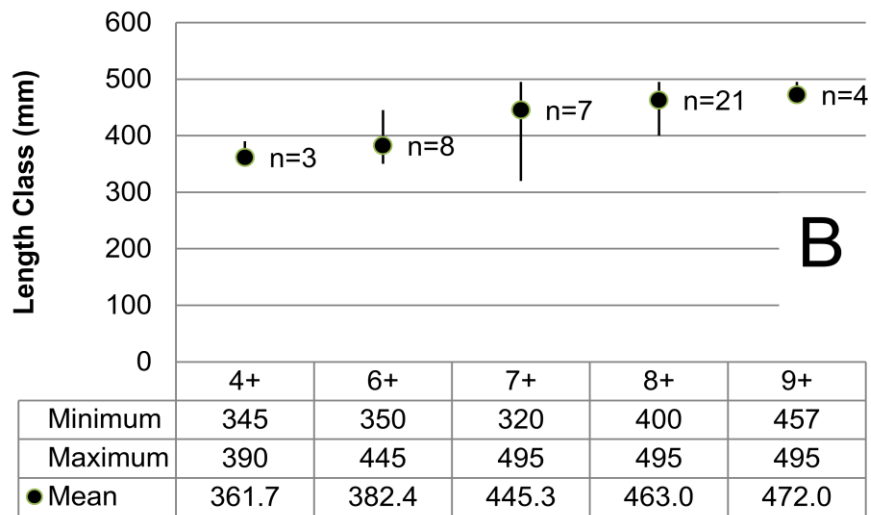
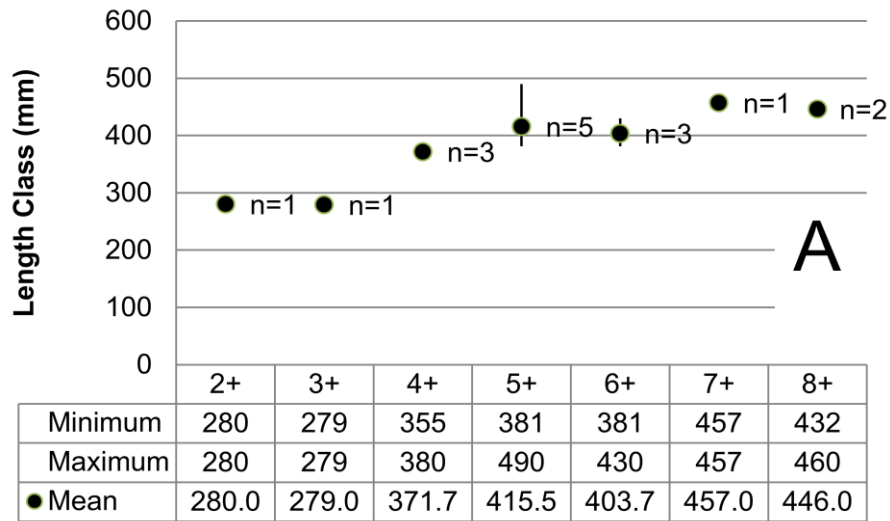


FIGURE 11. Length-at-age of rainbow trout sampled by gillnetting and angling in (A) the 1950's (N=16), (B) the 1970's (N=37), and (C) the 1980's (N=77) in Sproat Lake. Note we've removed all rainbow >500 mm as these are steelhead (Source: FISS; Ministry Files, Nanaimo; Lough, 1991).

In the 1970's 3 age 4+ rainbow ranging from 345 mm – 390 mm and averaging ~362 mm, 8 age 6+ rainbow from 350 mm – 445 mm and averaging 382 mm, 7 age 7+ rainbow from 320 mm – 495 mm and averaging 445 mm, 21 age 8+ rainbow from 400 mm – 495 mm and averaging 463 mm and 4 age 9+ rainbow from 457 mm – 495 mm and averaging 472 mm were captured (Figure 11B).

In the 1980's, four age 3+ rainbow ranging from 230 mm – 295 mm and averaging 278 mm, five age 4+ rainbow from 360 mm – 405 mm and averaging 383 mm, 8 age 5+ rainbow 360 mm – 415 mm and averaging 393 mm and five age 6+ rainbow ranging from 335 mm – 405 mm and averaging 369 mm were caught (Figure 11C). Twenty-five age 7+ rainbow ranging from 345 mm – 470 mm and averaging 406 mm, 20 age 8+ rainbow from 405 mm – 500 mm and averaging 442 mm and 15 age 9+ rainbow from 400 mm – 500 mm and averaging 457 mm were also caught.

Mean Age

In his comparison of the status of cutthroat and rainbow trout Lough (1991), said it appeared that rainbow trout were out-recruiting cutthroat trout to older age groups including spawners. We compared the mean fork length-at-age of cutthroat and rainbow trout sampled in Sproat Lake and the Taylor River to determine if there was a difference in the average length-at-age of fish sampled in the 1950's vs. the 1980's and found decreasing age-at-length in the more recent sample (Table 8). In the 1950's, age 6+ cutthroat trout were ~640 mm, age 7+ cutthroat were ~614 mm and age 9+ cutthroat were ~560 mm. In the 1980's, however, age 6+ cutthroat were ~430 mm, age 7+ cutthroat were 480 mm, and age 8+ cutthroat were ~480 mm.

TABLE 8. Mean age of cutthroat and rainbow trout captured by gillnets and angling in Sproat Lake by decade 1950 – 1980. Note, all rainbow >500 mm have been removed as these are classified as steelhead. We've also included seine samples taken from the Taylor River in the 1980's in this data set (Source: FISS; Ministry Files, Nanaimo, Lough, 1991).

Length, 1951:							
		1950		1970		1980	
Age	n	Mean Fork Length (mm)	n	Mean Fork Length (mm)	n	Mean Fork Length (mm)	
<u>Cutthroat</u>							
1+	12	194.8					
2+	9	264.4					
3+	6	286.5	15	336.7	4		330.0
4+	10	500.3	5	369.0	11		387.0
5+	8	485.8	12	504.2	10		406.3
6+	5	641.2	3	618.0	14		429.9
7+	5	614.2	4	518.3	14		480.5
8+					2		482.5
9+	1	559.0					
<u>Rainbow</u>							
2+	1	280.0					
3+	1	279.0				4	277.5
4+	3	371.7	3	361.7	5		383.0
5+	4	414.5				6	393.3

Age	1950		1970		1980	
	n	Mean Fork Length (mm)	n	Mean Fork Length (mm)	n	Mean Fork Length (mm)
6+	3	403.7	8	382.4	5	369.0
7+	1	457.0	7	445.3	25	406.8
8+	2	446.0	16	463.4	19	441.8
9+			3	472.0	13	457.3

In the 1950's rainbow trout age 6+ were, on average, ~400 mm, age 7+ rainbow were ~457 mm and age 8+ rainbow were 446 mm (Table 8). There was little difference in the mean-age-at-length of rainbow sampled in the 1980's with age 6+ rainbow averaging ~370 mm, age 7+ rainbow averaging ~407 mm and age 8+ rainbow averaging 442 mm. There were also age 9+ rainbow trout sampled in the 1980's and these averaged 457 mm.

Snorkel Surveys

During the spring of 2012 Lough and Hay carried out weekly snorkel surveys to assess the spawning activity of Sproat Lake cutthroat trout which start to spawn in mid-April and are mostly complete by late May. In summary, Lough and Hay (2012) estimated a peak count of 347 cutthroat trout (Table 9) which is similar to the highest historical counts of 300 to 450 cutthroat in this same section between 1970 and 1987 (Appendix 20). These investigators note that the reason for the dramatic decline in historical counts since that time is not clear but it's possible that a different set of identification criteria between cutthroat trout and cutthroat-rainbow hybrids may have been a contributing factor to this discrepancy (see Lough and Hay, 2012 for a more detailed discussion).

TABLE 9. Peak counts and estimated total run size for trout populations in the Taylor River during the spring spawning period of cutthroat and rainbow trout and hybrids of these species from February 27 – June 4, 2012 (Reprinted from: Lough and Hay, 2012).

Statistic	Cutthroat	Rainbow	Hybrids	Steelhead
Peak Count	347	421	72	18
Estimated Total Run	450-500	n/a	100-125	20-30

Lough and Hay (2012) estimated a peak count of rainbow trout at 421 fish on May 23rd, however, they noted they could not estimate of the total run size because the study ended soon after the peak count and a count of fresh-run rainbow trout could not be assessed (Appendix 20).

Catch Indicators

Total Catch

Sproat Lake was gillnetted in 1951, 1952 and 1953 and 1977, however, no information on the number or type of gillnets, the number of net sets, net locations or the soak times is provided in the files so we could not make comparisons of total catch or catch/unit effort.

Data Gaps

We've presented the age and availability of data from Sproat Lake in Table 10. Although snorkel surveys are conducted yearly at the Taylor River, other stock data including gillnetting, electrofishing, hydroacoustic surveys and lake and stream habitat inventories are >10 years old. The Ministry has collected some fisheries data including angler creel surveys and an angler preference survey, but these are also >10 years old.

TABLE 10. Summary of data gaps for Sproat Lake required for wild stock conservation, fishery evaluation and stock monitoring, and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Gillnetting		X	
Angler Creel Survey		X	
DNA Analysis of Taylor River stocks			X
VILQ	X		
Snorkel Surveys	X		
Acoustic Surveys		X	
Electrofishing Surveys (streams)		X	
Lake and stream habitat Inventory		X	
Level 1&2 WRP Surveys			X
Water Quality/Lake Productivity		X	
Angler Preference Survey		X	

5.0 Fisheries Objectives and Management Strategies for Sproat Lake

Existing Regulations

Lirette's (1989) observations regarding the removal of larger, older cutthroat and the increased harvest of juvenile cutthroat, and Lough's 1991 findings regarding a decrease in the incidence of repeat spawners from the 1950's to 1980's suggested an over-exploited population and lead to the implementation of the mandatory release of all cutthroat trout regulation that still covers Sproat Lake.

There is no retention of cutthroat trout at Sproat Lake and no retention of wild rainbow trout >60 cm. This lake is also covered by the general regional regulations of four rainbow trout but not more than 1>50 cm (2 hatchery steelhead > 50 cm allowed) and two from streams (must be hatchery). All wild trout and steelhead from streams, and all Dolly Varden must be released.

Tributary-specific regulations include no fishing in the Sproat River from Sproat Lake to signs 300 m below Highway #4 from June 15-November 15, and bait is allowed only from November 1-April 30. The Taylor River is fly-fishing only.

Maximum Catch and Effort, Harvest and Yield at Current Regulations

We were unable to estimate maximum and optimum angler effort and catch as there is considerable variability in the relationship between these parameters ($R^2 < 0.5$) (Appendix 20). The harvest is currently low (15%) at Sproat Lake in large part because of the no-harvest regulation for cutthroat trout. Consequently, the yield according to angler statistics is well below the theoretical predicted yield using MEI (Appendix 8).

As with other large lakes in the region, angler effort is decreasing at Sproat Lake, however, both angler catch and angler success have increased at this lake over the past 25 years. If these trends continue we've projected the total catch to approach 10,000 fish (Figure 12B) and angler success to approach ~2 fish/day by 2030 (Figure 12C).

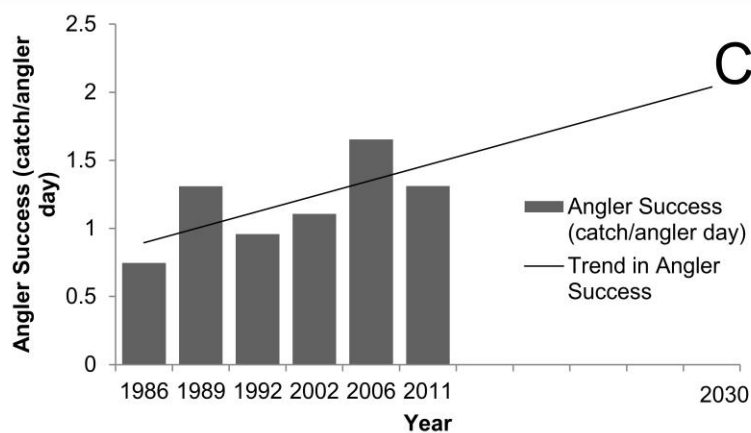
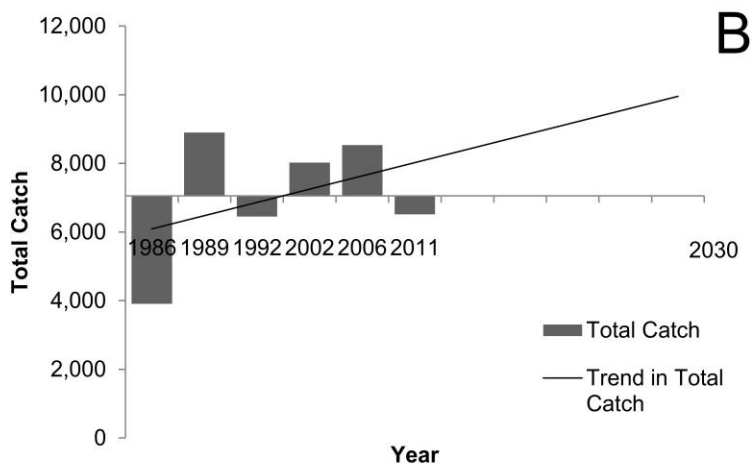
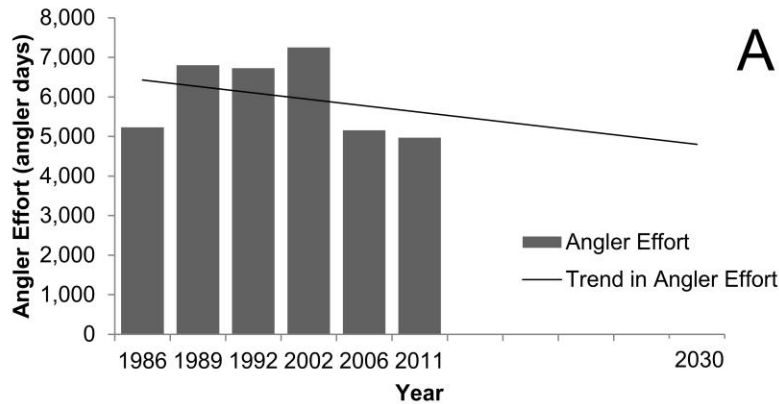


FIGURE 12. Trend in (A) angler effort; (B) total catch; and (C) angler success (catch/angler day) at Sproat Lake 1986 – 2030 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep).

Fisheries Objectives and Management Strategies and Operational Management Plan for Sproat Lake

There was a decline in the mean length of older, mature cutthroat between the 1950's and 1980's. The current angler catch and success suggest healthy, stable stocks, however, and there are still large (>700 mm) cutthroat in the population (Lough and Hay, 2012). In addition, Lough and Hay (2012) estimated peak adult cutthroat counts similar to the highest historical counts for cutthroat with >60% of the sample 400 mm – 600 mm, and ~10% of the sample 700 mm – 800 mm.

It appears the situation of declining numbers of older, larger cutthroat may have reversed itself likely as a result of the non-retention regulation. Clearly this regulation has worked and should be maintained. Our only concern is that because of this regulation some anglers may be mis-representing their catch of cutthroat to retain a portion of their catch. We suspect this may be the case given the discrepancy between the higher proportion of cutthroat trout vs. rainbow trout captured in gillnetting surveys (Figure 5), vs. the higher proportion of rainbow trout vs. cutthroat trout reportedly captured by anglers (Table 3). This could be a problem if our projected increasing catch is actually for cutthroat trout rather than, or in addition to rainbow trout.

The present harvest rate for rainbow trout is ~37%. This will be a problem if all, or a portion of this harvest is actually cutthroat trout. We've recommended roving angler creel surveys to determine if anglers are mis-representing their harvest. If catch misidentification is a problem we suggest implementing regulations to guard against harvest of large cutthroat identified as rainbow. At present, anglers are required to release rainbow >60 cm at Sproat Lake. Rainbow > 50 cm are considered steelhead and so the Sproat Lake regulation will have to be changed to be consistent with the provincial size definition. The change to this maximum size regulation will also protect against the harvest of large-bodied cutthroat trout mis-represented as rainbow trout.

The high harvest rate reported for rainbow trout is also a concern if anglers are harvesting immature fish. At present there is no information on the size of angler-caught fish and future angler creel surveys will provide this information. If anglers are harvesting large numbers of immature rainbow trout we recommend minimum size regulations be implemented to ensure adequate numbers of spawning rainbow trout and subsequent recruitment of fish to the Sproat Lake fishery. This is especially important in light of the angler pressure on rainbow trout as a result of the non-retention of cutthroat trout regulation at this lake.

One additional concern is the number of hybrid fish documented by Lough and Hay (2012). The provincial hatchery removed cutthroat trout from the Taylor River for broodstock for more than a decade beginning in 1989. Although the adult cutthroat trout removed from the Taylor River were replaced with hatchery juveniles, there were reports that hybrids started to show up in the hatchery system during this period. It would seem a reasonable conclusion that these hybrids were introduced from the hatchery system back into the Taylor River (Reid, G., 2013, pers. com). We've recommended DNA studies be conducted to estimate the extent of rainbow/cutthroat hybrids in the Taylor River/Sproat Lake watershed.

Finally, we recommend 2 snorkel surveys be conducted annually on the Taylor River: a new swim in April to monitor numbers and sizes of spawning cutthroat trout; and the traditional swim in mid/late-May to enumerate spawning rainbow trout.

1. The Sproat Lake and Taylor River fisheries are unique within the region and we recommend these fisheries be closely monitored and conserved to maintain opportunities into the future.
2. We do not recommend any changes to the catch-and-release regulation for cutthroat given the spawning estimates and size estimates the current regulations appear to be effective.
3. We are concerned about possible mis-identification of trout by anglers and recommend roving angler creel surveys to determine species and fish size of angler catches. We recommend these surveys be stratified into Taylor, Two-Rivers, and Stirling Arm and outlet areas to determine percentages of fish coming from specific areas on the lake. In addition, Hazledine (1972) noted that anglers target cutthroat off of the mouth of the Taylor River in late winter/early spring, therefore, future angler creel surveys on Sproat Lake should begin in late February and run through March.
4. Based on the results of angler creel surveys we suggest determining if additional conservation regulations (e.g. a minimum size regulation for rainbow trout) are required.
5. The current regulation regarding release of rainbow >60 cm at Sproat Lake conflicts with the regional regulation allowing 1 fish >50 cm. This situation is similar to that at Great Central Lake and was enacted to protect steelhead. We recommend bringing these regulations into line with the current provincial size definition for the species. Implementing a mandatory release of rainbow >50 cm will also protect mis-identified large-bodied cutthroat trout.
6. Gillnetting data is >10 years old and this should be repeated to update information, particularly age-at-maturity data. Sproat Lake is a high priority lake and should be netted in 2014 (Table 16; Chapter 1) and repeated every 3 years to monitor stock status.
7. Gillnetting data should be compared with results of annual snorkel surveys monitor stock status for both cutthroat and rainbow trout. Run timings are provided in Lough and Hay, 2012.
8. We recommend 2 snorkel surveys be conducted annually on the Taylor River: a new swim in April to monitor numbers and sizes of spawning cutthroat trout; and the traditional swim in mid/late May for rainbow trout.
9. We recommend regular inspections by the Conservation Officer Service (COS) to determine angler compliance with the Sproat Lake regulations.
10. We suggest erecting signs at the Taylor River rest stop and the Sproat Lake boat launches to inform anglers and the public of the regulations and provide general information on the unique cutthroat and rainbow trout stocks within the Sproat Lake watershed.

Operational Management Plan for Sproat Lake

In addition to continuing snorkel surveys we've recommended electrofishing surveys to collect baseline information on juvenile trout and, in the future, habitat surveys including Level 1 and 2 WRP surveys to identify restoration and enhancement priorities for Sproat Lake tributaries (Table 11). We've also recommended reviewing DFO stocking practices in the watershed as coho stocking will impact rearing cutthroat juveniles. In addition, a population of carp have existed in Sproat Lake for a number of years and are sighted each year in May during spawning. Ministry staff and local residents have tried to net fish without success and recent fish movements out of an historically used embayment have prevented further capture attempts. A meeting with Ministry biologists and local residents in 2011 resulted in an agreement by residents to monitor carp sightings and provide the information to regional staff. This partnership arrangement should be maintained.

TABLE 11. Operational Management Plan for Sproat Lake.

Activity	Objective	Tentative Schedule
Stock Status	Conduct a gillnet assessment to monitor stock status indicators especially age-at-length and age-at-maturity data. Conduct annual Taylor River snorkel surveys at peak times for cutthroat (mid-April) and rainbow (mid/late-May (see Lough and Hay, 2012 for details). Conduct DNA testing determine extent of cutthroat/rainbow hybrids in the Sproat Lake system.	2014 and every 3 years (Table 16; Chapter 1). 2017
Regulations	Review reasons for conflicting regulations for rainbow trout at Sproat Lake and amend if possible; consult with Vancouver Island Freshwater Fishing Regulations Advisory Committee (VIFFRAC).	2014
Fisheries Monitoring	Conduct angler creel surveys off the mouth of the Taylor River in late winter/early spring and in Sproat Lake during the remainder of the year to collect data on angler catches and effort. Use this data in concert with annual snorkel surveys to monitor stock status and determine the need for additional conservation regulations.	2014+
Public Awareness	Erect signs to advise anglers of regulations and anglers and the public of the unique cutthroat and rainbow trout stocks and fishery at Sproat Lake.	2014
Habitat – Assessment, Restoration and Enhancement	Conduct Level 1 and 2 WRP studies to identify restoration priorities for Sproat Lake tributaries; implement works and monitor effectiveness.	2017+
Other – Stocking	Request an opportunity to discuss and review DFO coho stocking in the Sproat Lake watershed. Negotiate maximum stocking levels and numbers where possible.	2013
Other – Non-native species	Continue to log information from public and Sproat Lake residents on timing and estimated numbers of carp population which has existed in the lake for the past decade.	Ongoing
VILQ	Evaluate and monitor angler statistics.	Ongoing

Chapter 15. Upper Campbell Lake

Lake	Upper Campbell
Planning Unit	Campbell Oyster
Watershed	Campbell River
Surface Area (ha)	2,978
Mean Depth (m)	12.2
Key Tributaries	Elk River, Tlools, Filberg, Cervis and Drum Creeks
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden
Limits to Production	Logging, mining in Strathcona Park; BC Hydro dam separating Upper and Lower Campbell Lakes
Regional Priority*:	4
<u>Angling Statistics 2011</u>	
Angling Effort	4,441 angler days
Total Catch	8,548 fish
Angler Success	1.9 fish/angler day
Current Harvest Rate	31%
Optimum Sustainable Effort	14,000 angler days/year
Optimum Sustainable Catch	24,000 fish
Angler Success at Optimum	1.7 fish/angler day
Stock Status	Cutthroat and rainbow trout stocks are stable. the mean size of cutthroat trout is ~300mm and the mean age is 3+ years old; the mean size of rainbow trout is ~150 mm.
Data Gaps	Snorkel surveys of smaller tributaries such as Drum, Crest and Mud Creeks could be implemented. An instant angler count to determine more a more precise estimate of angler effort would be desirable.
Management Objectives	Monitor fisheries statistics in the next VILQ and determine if there has been a decline of >10% in angler effort and catch and/or if angler success has decreased from the current rate of 1.9 fish/day to the regional objective of 1.6 fish/day. If so, implement a gillnetting program to gather stock status data and determine if conservation regulations are required. If no change in fisheries statistics, implement a gillnetting program in 2017 and repeat every three years to monitor stocks.
Operational Plan Priorities	Monitor the fishery using VILQ; implement gillnetting program; continue snorkel surveys of Elk River and implement others on smaller tributaries; consider instant angler count and box angler creel survey programs.
Potential Partners	Gold River Rod and Gun Club, Campbell River Fish and Wildlife Association, BC Hydro, BC Parks, TimberWest, Kwakwaka'wakw District Council, Campbell River Band.

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Upper Campbell Lake Watershed

General Information

Upper Campbell Lake is located ~27 km southwest of Campbell River within the Coastal Western Hemlock zone in the Campbell Oyster PU (Figure 1). The lake is situated 221 m above sea level and its headwaters lie within Strathcona Provincial Park and some of the highest mountains on Vancouver Island. Upper Campbell Lake has a surface area of 2,978 ha, an average depth of 12 m, a maximum depth of ~40 m, and the TDS is 56 ppm (Table 1).

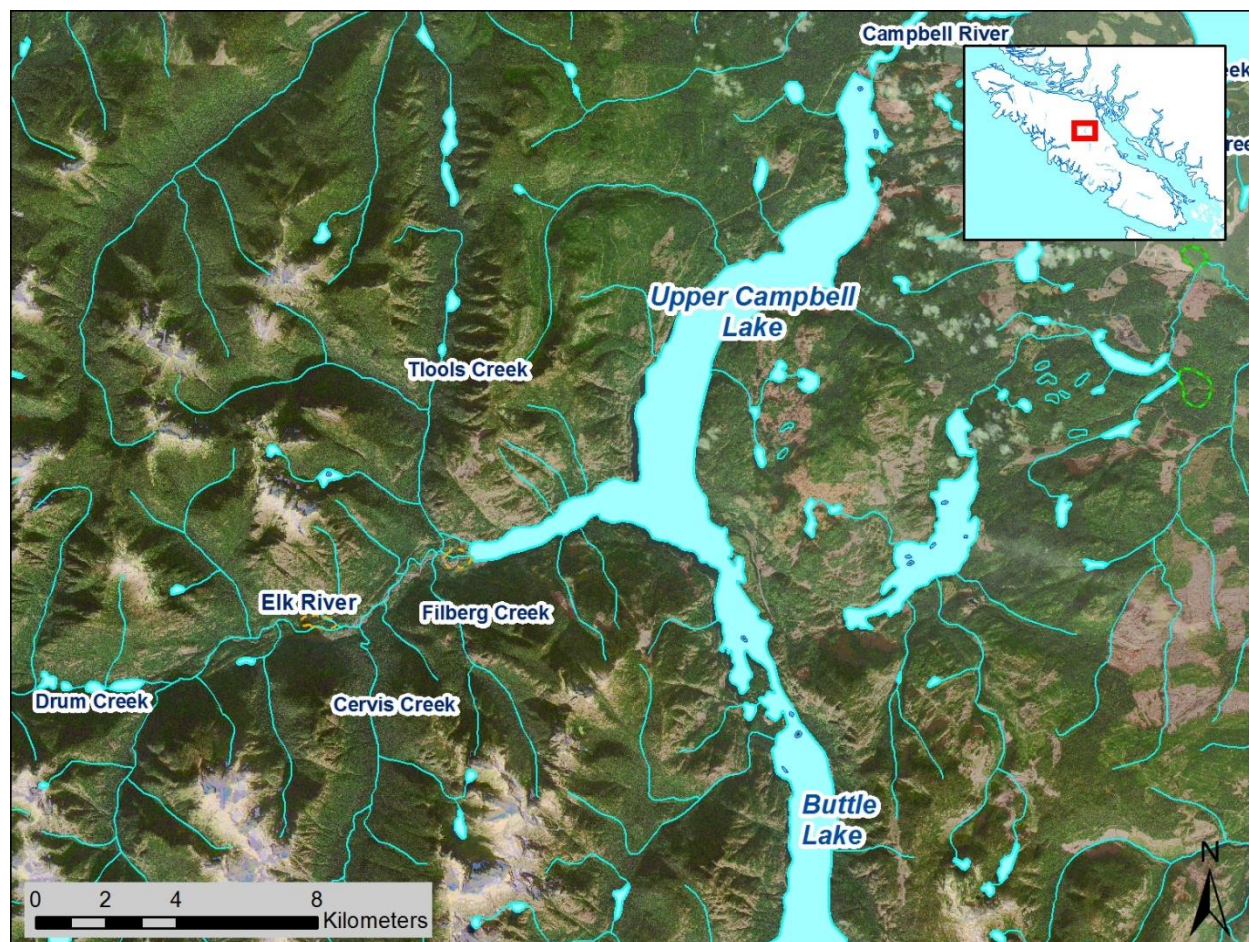


FIGURE 1. Map of Upper Campbell Lake and tributaries; a bathymetric profile is provided in Appendix 21 (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Upper Campbell Lake (Source: FLNRO files, Nanaimo; FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
Campbell Oyster	00104CAMB	2,978	21.7	39.6	12.2		56		1951, 1980

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Upper Campbell Lake is the major reservoir for a BC Hydro power complex which consists of the John Hart, Ladore and Strathcona Dams. The uppermost Strathcona Dam impounds Upper Campbell Lake and backs water into Buttle Lake.

Prior to the development of the Strathcona Dam, Upper Campbell Lake was 625 ha in extent, had a maximum depth of 40 m and a mean water retention time of 14 days (McMynn and Larkin, 1953). There was no distinguishable thermocline in the summer, and dissolved oxygen was at or near saturation throughout the water column. The plankton community was diverse, although overall productivity was estimated to be low because of nutrient limitations (McMynn and Larkin, 1953). Impoundment by the Strathcona Dam extended the surface area of the lake and removed ~65% of sport fish spawning habitat in the tributaries (McMynn and Larkin, 1953). The mean water retention time of present Upper Campbell Lake is now 3.9 months (McMynn and Larkin 1953).

Tributaries

The Elk River is the major contributor of rainbow trout populations in Upper Campbell Lake although this river has several tributaries which also provide habitat for trout and Dolly Varden (Table 2).

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Upper Campbell Lake. (Source: Lough et al, 2003; Hatfield Consultants Ltd., 1982; Tredger, 1979; McMynn and Larkin, 1953).

Tributary	Length (km)	Other Information
Elk River		Cutthroat and rainbow trout and Dolly Varden are found in this river which is the most important spawning stream in the Upper Campbell Lake watershed. McMynn and Larkin (1953) estimated the total spawning area at ~57,000 m ² . Tredger (1979) notes that spawning does not limit recruitment in the system, but substrate movement during flood events could affect the successful use of some areas. He attributed low fish densities to poor quality unstable rearing habitat in most areas; exceptions were some side channels and cobble-riffle areas. He also found that adult salmonids were not abundant in the system and the juvenile population and biomass densities were low throughout the system. Given the general absence of good stream rearing habitat, a large number of fry appear to be displaced into Upper Campbell Lake (Hatfield Consultants, 1982). Tredger (1979) estimated the late summer population of 1+ and 2+ salmonids in the Elk River to be ~12,000.
Cervus Creek	0.4 km	Cervus creek has a wetted width of 9 m and a gradient of 0.4% – 1%. The bed material is cobble and gravel. Rainbow and cutthroat trout and Dolly Varden are found here; there is a barrier to upstream migration at 0.5 km from the mouth and Dolly Varden are limited to the area below the barrier. Water temperatures and flow conditions are representative of other Elk River tributaries.
Drum Creek	~0.8 km	This creek has a wetted width of 9.5 m; a gradient of 0.2% – 2% and the bed material is cobble, gravel, sand. Drum creek drains Drum Lakes and is the route of Heber River/Crest Creek diversion. Fish habitat is primarily fast glide-riffle over cobble and gravel substrate. Overall complexity is low.
Filberg Creek	~1.2 km	This creek has a wetted width of 5 m; a gradient of 0.2% – 15% and the bed material is bolder, cobble and gravel. Filberg creek is accessible for ~1.2 km and rainbow and cutthroat trout are found here. The lower 600 m is a fairly complex environment paralleling the Elk Valley. Past 600 m the gradient increases over boulder and cobble to a point where fish habitat is no longer viable.

Tributary	Length (km)	Other Information
Tloos Creek	>7.5 km	Tloos Creek is one of the most significant Elk River tributaries in terms of accessible habitat. Tloos creek has a wetted width of 8 m and a gradient of 0.2% – 6%. The bed material is boulder, cobble and gravel and rainbow and cutthroat trout are found here. Greater than 7.5 km of this stream, up to Tloos Lake is accessible as potential fish habitat. The lowest 2.5 km is fairly high gradient boulder-cobble environment, beyond which the stream decreases in gradient to the headwater lakes. The stream is stable with moss and algae covering instream boulders. Hatfield Consultants Ltd (1982) conducted reconnaissance surveys of Buttle Lake tributaries and found the most intensive spawning activity appeared to be in Tloos creek.

Species Composition

Kamloops rainbow trout were introduced into Upper Campbell Lake prior to 1953 (McMynn and Larkin, 1953). Cutthroat trout, rainbow trout, Dolly Varden, prickly sculpin and threespine stickleback are present in Upper Campbell Lake and field studies in 1982 estimated the total fish population in the lake at ~31,000 (Hatfield, 1982b).

Summary of Work and Reports

Pre-impoundment netting by McMynn and Larkin in Upper Campbell Lake recorded rainbow trout and Dolly Varden of several age classes and sizes, and mature spawners were documented in the lake although no quantitative estimates of population sizes were recorded, and no detailed population studies were made (McMynn and Larkin, 1953; Hirst, 1991a; MFLNRO files, Nanaimo).

In 1977, BC Research conducted a survey of the limnology of Upper Campbell Lakes for BC Hydro, and in 1982, Hatfield Consultants prepared 3 reports evaluating the size and distributions of fish populations and impacts to fisheries resources in the Buttle and Upper Campbell Lakes watersheds for Westmin Resources (Hatfield Consultants Ltd, 1982; Hatfield Consultants Ltd, 1982a; Hatfield Consultants Ltd, 1982b).

Tredger (1979) and Lough et al. (2003) studied Dolly Varden distributions in the Upper Campbell Lake watershed. In the case of Lough et al (2003), field data was collected primarily through snorkel surveys on Cervus Creek, Drum Creek, Elk River, Filberg Creek and Tloos Creek. The Fisheries Branch gillnetted Upper Campbell Lake in 2010 and Lough (2012b) analyzed fish scales from sampled fish. Data and summary tables from Lough's (2012b) analysis are in the Ministry files in Nanaimo.

Ongoing stock monitoring work includes annual snorkel surveys of the Elk River and intermittent box angler creel surveys with survey boxes erected at boat launches around the lake. Data from both surveys is filed at the Ministry office in Nanaimo.

Habitat assessments in the watershed are limited, however, in 2003, Hay and Lough conducted an assessment of cutthroat trout spawning habitat in areas influenced by BC Hydro operations at Ladore and Strathcona Reservoirs for BC Hydro. Both Tredger (1979), and Hay and Lough (2003) provide descriptions of fish habitat in the areas they studied. Streamline Environmental Consulting (2004) investigated habitat conditions of the Lower Elk River in September 2004.

2.0 Limits to Fish Production

Water Withdrawal

Upper Campbell Lake is the major reservoir for the BC Hydro power complex. During the winter Upper Campbell Lake is drawn down significantly but the lake fills rapidly during the early spring. Continued inflow into Upper Campbell Lake in the early spring and summer is ensured because the lake headwaters lie within some of the highest mountains in the region and this inflow combined with spring rains contributes to the rapid filling of the lake. The lake level does not fluctuate significantly between May and September (Hay and Lough, 2003).

Participants at a BC Hydro restoration program regional workshop in 2000 identified the following factors suspected to limit fish populations within the Campbell River watershed including Upper Campbell Lake:

1. Permanently lost or seasonally reduced spawning, rearing and overwintering habitats due to dam footprint, reservoir flooding, flow diversions, or operating flows.
2. Long-term effects to shoal areas of former lakes by large reservoir drawdown regimes including frequent water level fluctuations.
3. Reduced fish access between reservoir and tributary habitat due to large drawdown regimes.

Logging

The majority of the Upper Campbell Lake watershed has been logged, however, the headwaters of the Elk River and several tributaries are within Strathcona Provincial Park and are protected from this land use.

Stream Habitat

Although no quantitative estimates of population sizes were recorded in early netting surveys, Tredger (1979) suspected a decline in fish in the Elk River and Upper Campbell Lake had occurred by the time he conducted his study in 1979. He noted that because the Elk River is the primary site for recruitment to Upper Campbell Lake, habitat destruction in this stream could account in part for the demise of stream and lake fisheries (Tredger, 1979). He also reported that Upper Campbell Lake tributaries had a severe lack of suitable spawning and rearing habitat for sport fish species such as rainbow trout and this lack of habitat was evident even in larger lake tributaries such as the Elk River where fry may be flushed out by heavy freshet flows.

Tredger (1979) found fish habitat in terms of stable channel with instream and overhanging cover was lacking throughout most of the Elk River drainage, and stable, complex areas were found only in lower reaches of some tributaries, in side channels of the upper river, and in Tloos Creek. He also found that mainstem habitat, particularly in the lower reaches, was generally without cover, as debris was not stable and flat gravel banks predominated.

Nutrients

A limnological survey in 1976 found Upper Campbell Lake to be ultra-oligotrophic and that inorganic nitrogen concentrations were very low and less than the total phosphorous concentrations which is opposite to ratios for most BC reservoirs and lakes (BC Research,

1977). This finding lead investigators to conclude the productivity of Upper Campbell Lake was limited by nitrogen (BC Research, 1977). This study also found low species diversity of phytoplankton, low chlorophyll-a values, the benthos dominated by chironomids, and the chironomid abundance severely curtailed in the drawdown littoral zones (BC Research, 1977).

3.0 Angling Statistics

Angler Effort

Angler effort at Upper Campbell Lake has averaged ~5,300 angler days/year since 1986 (Figure 2). With the exception of 2006, deviations around the mean are small. In 1986, angler effort was ~4,000 angler days. Angler effort increased to 5,700 angler days in 1989 and to 5,300 angler days in 1992. In 2002, angler effort dropped to 4,500 angler days then increased again in 2002 to its highest level of ~8,300 angler days. In 2011, angler effort dropped to ~4,400 angler days. Although it appears there is an increasing trend in angler effort, there was a large single increase in angler effort in 2006 which influences the trend line. We believe that angler effort has been relatively stable at this lake over the past 25 years.

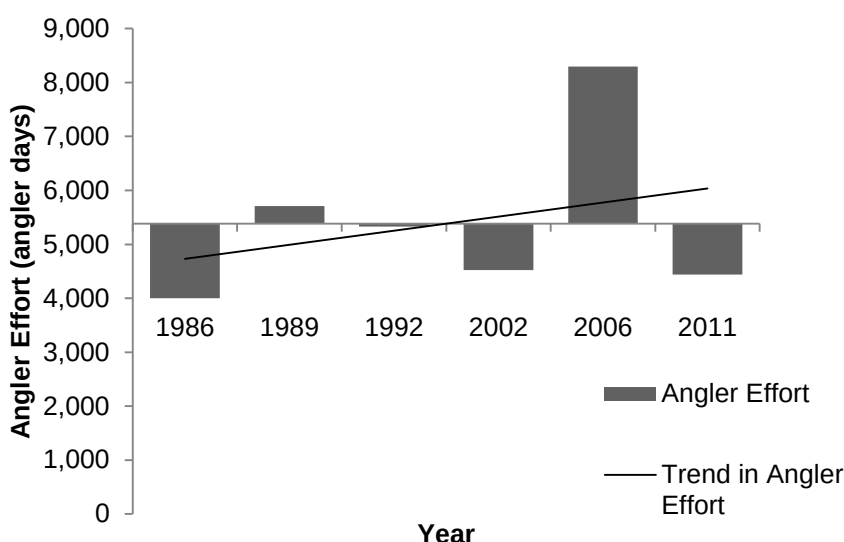


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Upper Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Catch

The average total catch/year is almost 12,000 fish and total catch shows a pattern similar to angler effort since 1986 (Figure 2; Figure 3). In 1986, the catch was ~9,000 fish and it remained between ~11,000 and 13,000 fish between 1989 and 2002. In 2006, the catch increased to ~16,000 fish but in 2011, catch was ~8,500 fish. Overall, total catch has been stable at Upper Campbell Lake over the past 25 years.

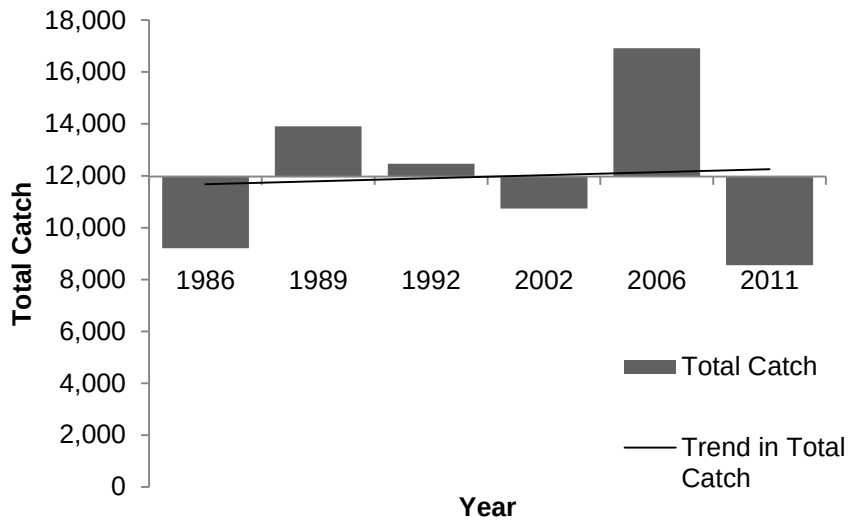


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Upper Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

In 2006, ~64% of the total catch was cutthroat trout (~10,700 fish), 26% of the catch was rainbow trout (4,375 fish) and ~10% of the catch was Dolly Varden (~1,739 fish) (Table 3). In 2011, 65% of the catch was cutthroat trout (5,555 fish), ~27% of the catch was rainbow trout (2,269 fish), and 8.5% of the catch was Dolly Varden (724 fish).

TABLE 3. Catch of rainbow and cutthroat trout at Upper Campbell Lake 2006 and 2011 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	10,739	63.7	5,555	65.0
Rainbow	4,375	26.0	2,269	26.5
Dolly Varden	1,739	10.3	724	8.5
Total	16,853		8,548	

Angler Success

Angler success has averaged ~2.2 fish/day at Upper Campbell Lake since 1986, however, this statistic has declined slightly over the survey period (Figure 4). Between 1986 and 2002, angler success remained >2.3 fish. Angler success dropped in 2006 to <2.1 fish/day reflecting the increase in angler effort that year. In 2011, angler success dropped further to 1.9 fish/day despite the drop in angler effort (Figure 2).

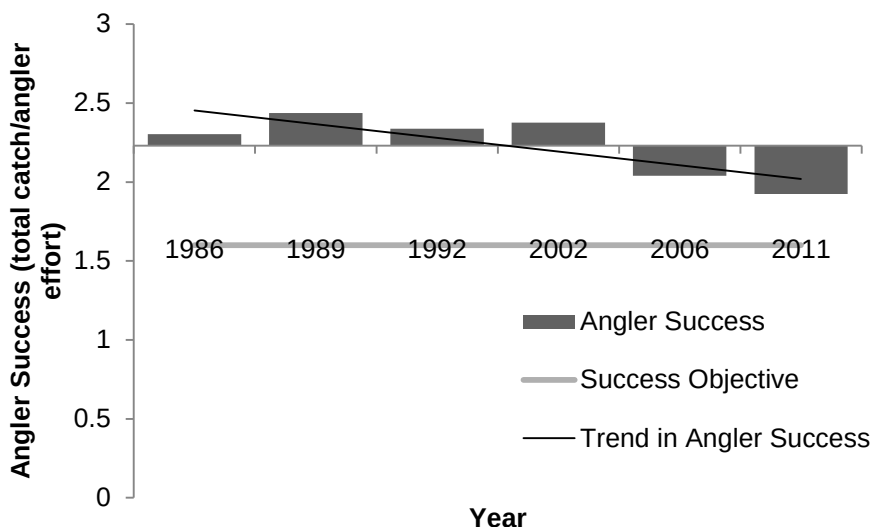


FIGURE 4. Angler success (total catch/total angler effort in angler days) and trend in angler success compared to average angler success and the objective for angler success (1.6 fish/angler day) at Upper Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Harvest

We've presented a breakdown of the total catch and harvest by species for Upper Campbell Lake in Table 4. Of the 16,900 fish caught in 2006, 10,700 were cutthroat trout, ~4,300 were rainbow trout, and 1,700 were Dolly Varden. Roughly 1/3 of the rainbow trout and cutthroat caught by anglers were harvested. Harvest on cutthroat was higher and may be a function of these being the larger fish.

TABLE 4. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Upper Campbell Lake 2006 and 2011 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	10,739	4,307	40.1	5,555	2,130	38.3
Rainbow	4,375	1,500	34.3	2,269	529	23.3
Dolly Varden	1,739	11	0.6	724	0	0.0
Total	16,853	5,818	34.5	8,548	2,659	31.1

In 2011, 38% of the cutthroat trout caught were harvested (2,130 fish) while 23% of the rainbow caught were harvested (529 fish) (Table 4). Overall, the harvest rate dropped to ~31% in 2011.

Angler Creel Surveys

The extent of recreational angling in Upper Campbell Lake prior to the impoundment by the Strathcona Dam is not documented but was probably light due in part to the limited public access at that time (Reid, G., 2011, pers. com.). The first documented angler creel survey was in 1960 when a success rate of 0.8 fish/angler hour was estimated (FLNRO files, Nanaimo). The total number of anglers and the total harvest were not estimated in that survey.

An angler creel survey conducted in 1964 found 62% of the catch was rainbow trout, 37% was cutthroat trout, and 1% was Dolly Varden (FLNRO files, Nanaimo). A study by Hatfield (1982b) estimated total angling harvest in Upper Campbell Lake in May 1982 to be ~1,500 fish (FLNRO files, Nanaimo).

Box Creels at Campbell Lakes 2010 – 2011

In 2010, Fish and Wildlife staff conducted instant angler counts by air, and implemented a box angler creel and angler satisfaction surveys at Upper and Lower Campbell Lakes (Michalski, 2011b). This survey found that >80% of the angler effort at Upper Campbell Lake occurs from May until August with <20% of the angler effort occurring from September until December (Figure 5).

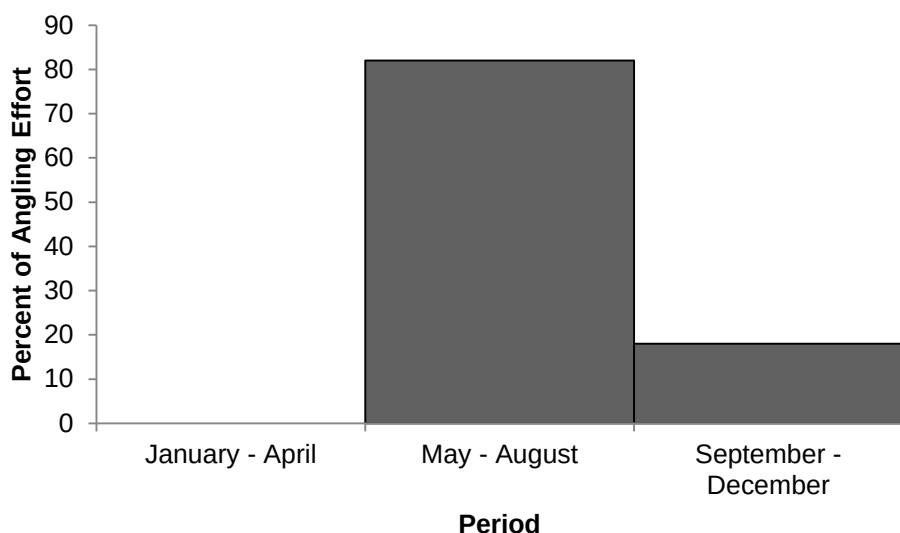


FIGURE 5. Percent of total angler effort each month determined by box creels conducted June, 2010 - September, 2011 at Upper Campbell Lake (Source: FLNRO files, Nanaimo).

Anglers reported their effort in the box angler creel survey and we've summarized these results in Table 5. The average length of an angler day at Upper Campbell Lake is 5.1 hours and angler success varied from ~1.6 fish/day in August 2010, to ~0.2 fish/day in June, 2011. Angler success was ~1 fish/day over the course of this study. It's important to note that box angler creel surveys are biased with positive catch and as such the actual angler success may be lower than indicated from these surveys.

TABLE 5. Total catch, angler hours, catch/hour, total angler days and catch/angler day determined from box angler creel surveys conducted July, 2010 – June, 2011 at Upper Campbell Lake. Note that an average angler day at Upper Campbell Lake was calculated to be ~5.1 hours (Source: FLNRO files, Nanaimo).

Month and Year	Total Catch	Angler Hours	Catch/Hour	Angler Days	Catch/Day
Jul-10	11	44.0	0.3	8.6	1.28
Aug-10	30	91.5	0.3	17.9	1.67
Sep-10	3	12.0	0.3	2.4	1.28
Oct-10	12	52.5	0.2	10.3	1.17
Nov-10	0	0.5	0.0	0.1	0.00
Jun-11	6	120.0	0.1	23.5	0.26
Total	62	320.5	0.2	62.8	0.99

The box angler creel survey found that 42% - 55% of the fish caught by anglers at Upper Campbell Lake is comprised of cutthroat trout (Table 6) while the VILQ data suggests that up to 65% of the angler catch is comprised of this species (Table 3). Most anglers who participated in the box survey said they preferred to fish for cutthroat trout rather than rainbow trout (Appendix 21) and it's likely that most anglers encounter cutthroat more often since the highest angler effort is during the summer (Figure 5) when rainbow trout are spawning and unavailable to anglers.

TABLE 6. Total catch and harvest and percent harvest of cutthroat and rainbow trout and Dolly Varden in 2010 and 2011 determined from box angler creel surveys conducted July, 2010 – September, 2011 at Upper Campbell Lake (Source: FLNRO files, Nanaimo).

Species	2010			2011		
	Catch	Harvest	% Harvest	Catch	Harvest	% Harvest
Cutthroat	31	11	35	8	0	0
Rainbow	23	15	65	11	6	55
Dolly Varden	2	-----	-----	-----	-----	-----
Total	56	26	46	19	6	32

Anglers who provided information in the box survey were asked to note the size of fish they captured. In total, 31% of the cutthroat trout caught by anglers were <200 mm, 28% were 200 mm – 300 mm, 33% were 300 mm – 400 mm, and 8% were >400 mm (Figure 6A).

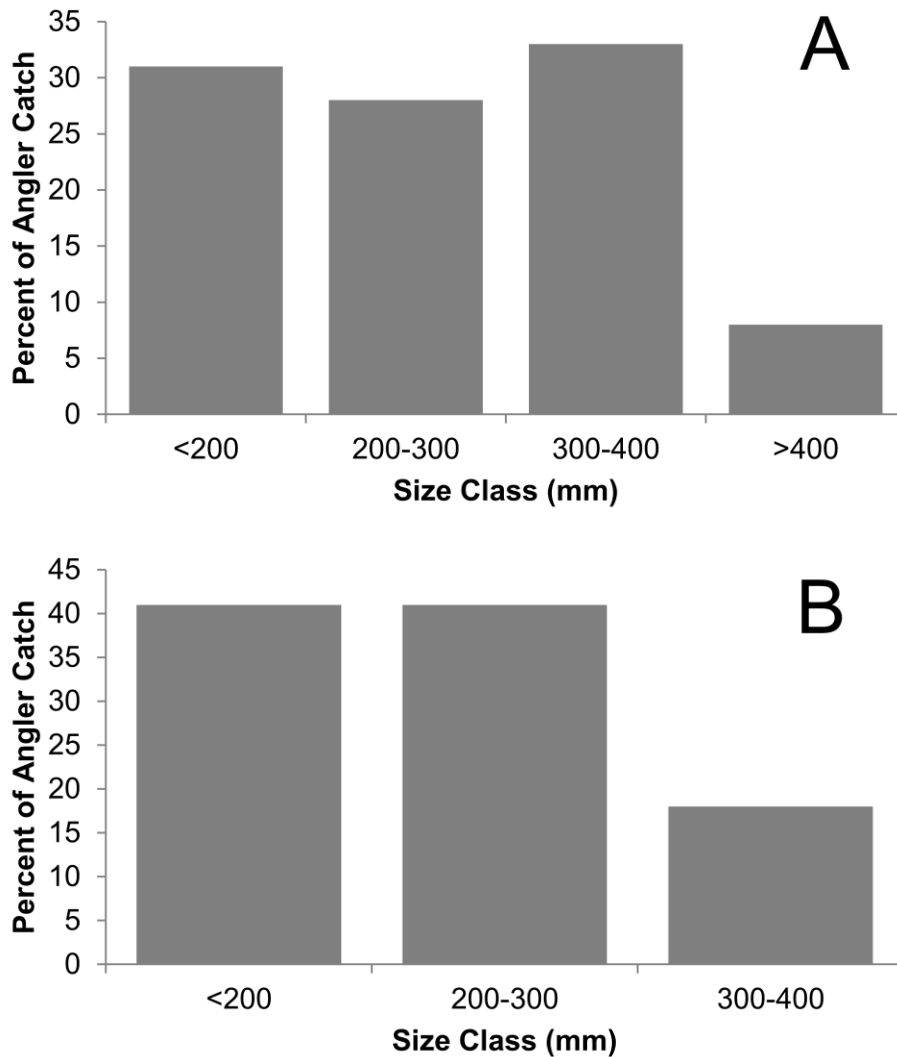


FIGURE 6. Percent of each size class of (A) cutthroat trout (N=39) and (B) rainbow trout (N=34) caught at Lower Campbell determined from box angler creel surveys conducted July, 2010 – September, 2011 at Upper Campbell Lake (Source: FLNRO files, Nanaimo).

The box angler creel also found that 41% of the rainbow trout captured by anglers were <200 mm, 41% were 200 mm – 300 mm and the remaining 18% were 300 mm – 400 mm (Figure 6B).

Angler Opinion Survey

An angler opinion survey was conducted as part of the box angler creel survey in 2010/11 and we've presented these results in Appendix 21. Seventy-eight percent of respondents thought fishing at Upper Campbell Lake was good and 22% thought fishing was poor. Forty percent of respondents said they would support size limits and 40% said they would support a reduction in the number of fish killed if a change in regulations was required to improve fishing. Less than 10% of anglers said they would support catch-and-release regulations, likely because so many anglers (70%) also said they prefer to catch fish to eat.

4.0 Stock Status Indicators

Relative Abundance

We've presented the relative abundance of sport fish from angling and gillnet catches in Upper Campbell Lake from 1951, 1980 and 2010 in Figure 7. In 1951, the assessment was conducted in June and all three species were captured in roughly equal numbers. In 1980, however, only rainbow trout were captured during the May/June gillnet set. The fact that cutthroat were absent from the 1980 sample may reflect the fact that nets were set in May and some cutthroat may still have been spawning (see Appendix 21 for information on cutthroat spawning times). In September 2010 all species were captured with rainbow comprising ~60% of the sample, cutthroat comprising ~22% of the sample, and Dolly Varden accounting for ~18% of the sample.

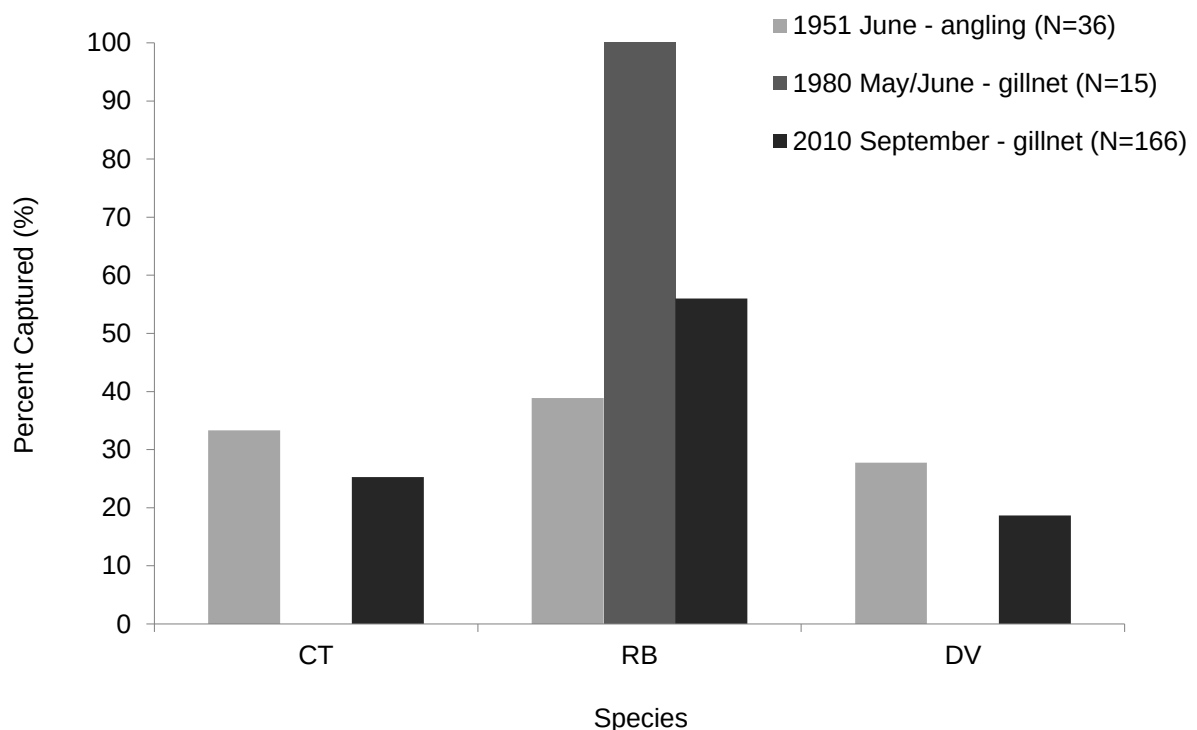


FIGURE 7. Percent cutthroat trout, rainbow trout and Dolly Varden captured in June, 1951 by angling (N=36), by gillnetting in May and June 1980 (N=15) and by gillnetting in September 2010 (N=166) in Upper Campbell Lake (Source: FLNRO files, Nanaimo).

Snorkel Surveys

Adult rainbow trout are present in the Elk River in June (Figure 8A) while cutthroat are always present in this river (Figure 8B). Cutthroat begin arriving in February with the peak spawning numbers observed in the end of March and into mid-April. Juvenile cutthroat trout are observed from July to October (Tredger, 1979) (Appendix 21), and adult cutthroat return to the Elk River in August possibly to follow pre-spawning Dolly Varden into the mainstem and tributaries (Figure 8B). Dolly Varden are present in the river to spawn in October (Figure 8C).

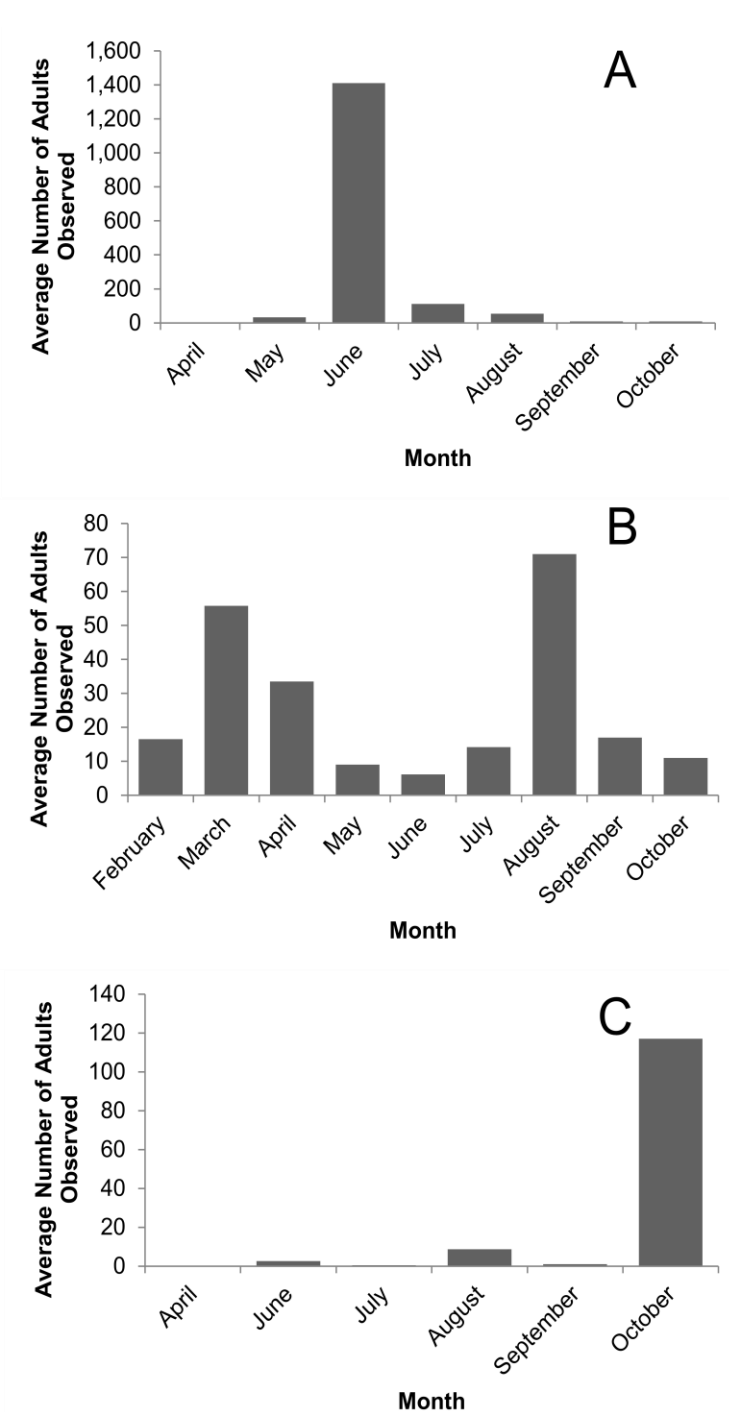


FIGURE 8. Average number of (A) rainbow trout (n=57,265); (B) cutthroat trout (n=995) and Dolly Varden (n=205) observed by month in snorkel surveys of the Upper and Lower Elk River 1990 – 2012 (N=58,465) (Source: FLNRO files, Nanaimo).

The Ministry has conducted snorkel surveys of the Elk River annually since 1990 and in most years these surveys are conducted during the first week of June to monitor rainbow trout spawning. Observers count, on average, ~3,000 rainbow trout each June in the Upper and

Lower Elk River (Figure 9). Beginning in 2004, snorkel counts increased and reached a high of ~7,000 fish in 2008, but in recent years counts have fallen to ~4,000 fish.

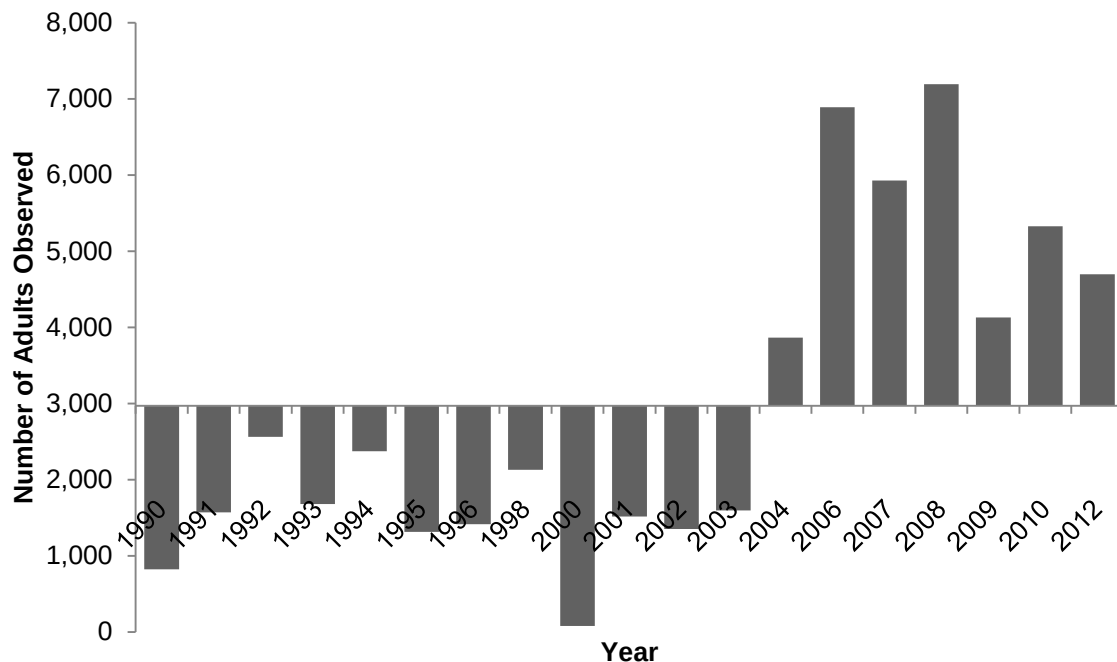


FIGURE 9. Total number of rainbow trout observed in June snorkel surveys of the Upper and Lower Elk River 1990 – 2012 compared to the average number of rainbow seen per year over the 22-year survey (N=56,440). Note that adult cutthroat spawn in the small Elk River tributaries during the spring so this species is missed in the annual rainbow trout surveys (see Figure 8B) (Source: FLNRO files, Nanaimo).

Hay and Lough (2003) conducted weekly snorkel surveys of tributaries to Upper Campbell Lake and found the majority of cutthroat entered the study streams after February 21 when water temperatures were 3⁰ – 5⁰ C and discharges were 0.26 m³/s - 4.4 m³/s. They also noted that although cutthroat began moving into streams in December and January, redds were not observed until February, and the most redds were counted in the middle and end of March (Figure 10) (Appendix 21).

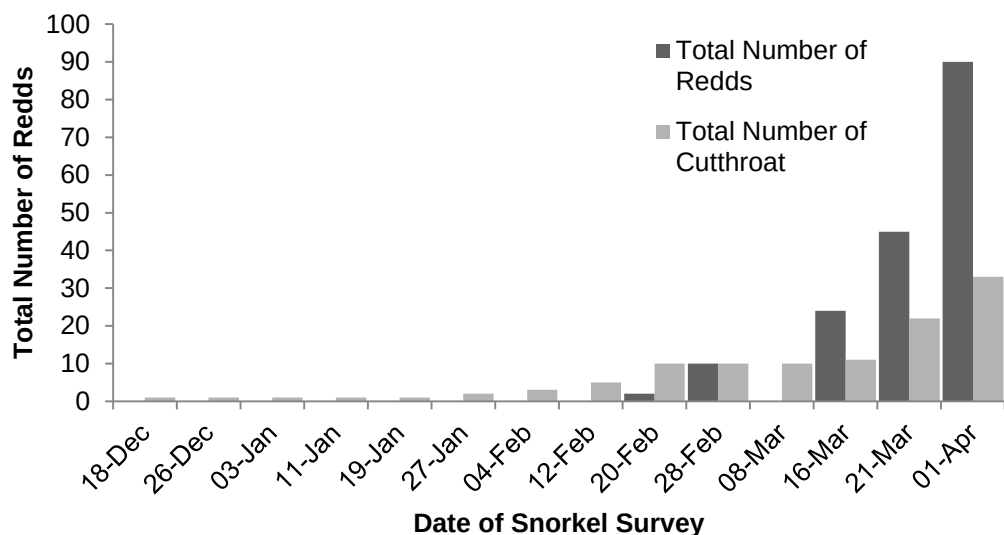


FIGURE 10. Total number of cutthroat and redds observed in snorkel surveys of Crest Creek in the Upper Campbell Lake watershed December 18, 2002 and April 1, 2003 (Reprinted from: Hay and Lough, 2003).

Lough et al (2003) conducted snorkel surveys of Cervus, Drum and Tlools Creek and the Elk River mainstem in 2001 to assess Dolly Varden spawning. In the Elk River watershed, Dolly Varden migration into the smaller spawning tributaries coincided with increased flows at a time when water temperatures declined to 6^o – 7^o C. In Cervus Creek, the highest abundance of spawners were observed during late October and early November. Peak counts, which are indicative of at least a minimum run size of Dolly Varden in the Upper Campbell system, are provided in Table 7.

TABLE 7. Peak counts of Dolly Varden spawners and redds that were observed during snorkel surveys from September 13 to November 26, 2001 (Reprinted from: Lough et al, 2003).

Stream	Peak Number of Spawners	Redds	Date
Cervus Creek	24	22	Oct 24/01
Drum Creek	1	0	Nov 7/01
Elk mainstem	28	12	Oct 25/01
Tlools Creek	14	9	Oct 24/01

Length and Weight

We've summarized the length and weight data for fish sampled by gillnets in the 2000's and angling in the 1950's in Table 8. Cutthroat trout captured by gillnets in the 2000's ranged from 120 mm – 454 mm and averaged 304 mm. The modal size of these fish was 420 mm and the mean weight was ~387 g. More than 40% of the cutthroat trout captured in gillnets were >300 mm (Appendix 21).

TABLE 8. Minimum, maximum, mean length and mean weight for cutthroat and rainbow trout and Dolly Varden by angling and in gillnets in the 1950's and 2000's in Upper Campbell Lake (Source: FLNRO files, Nanaimo; Michalski, 2011b).

		Length				
Species	n	Minimum	Maximum	Mean	Mode	Weight (Mean) (g)
<u>Gillnet</u>						
Cutthroat	42	120	454	304.4	420	386.8
Rainbow	93	105	280	149.7	120	50.4
Dolly Varden	31	105	410	218.0	125	168.9
<u>Angling</u>						
Cutthroat	12	215	445	292.9	310	291.7
Rainbow	13	175	270	231.5	220	122.3
Dolly Varden	10	225	340	252.5	240	177.0

Ninety-three rainbow trout were captured in gillnets in the 2000's and these ranged from 105 mm - 280 mm and averaged ~150 mm while 31 Dolly Varden were captured in gillnets and these ranged from 105 mm - 410 mm and averaged 218 mm in length (Table 8).

Cutthroat trout recruit to the Upper Campbell Lake fishery at ~200 mm (Figure 11) and, likely because they grow larger than rainbow trout, are preferred by anglers at this lake (Figure 11). For example, in the 1950's, angler-caught cutthroat trout ranged from 215 mm – 445 mm and averaged ~290 mm (Table 8). Just over 40% of cutthroat trout caught by anglers were >300 mm and ~5% were >400 mm (Figure 11A), whereas all rainbow caught by anglers that year were <300 mm (Figure 11B).

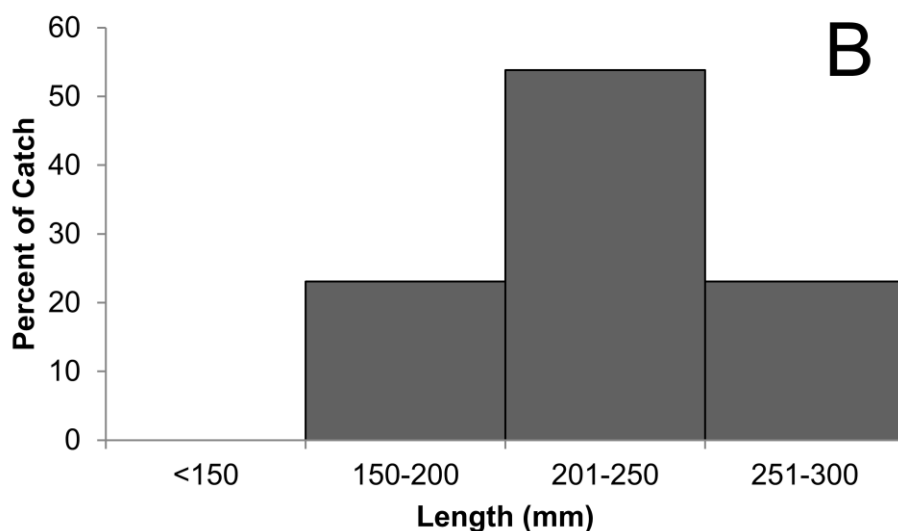
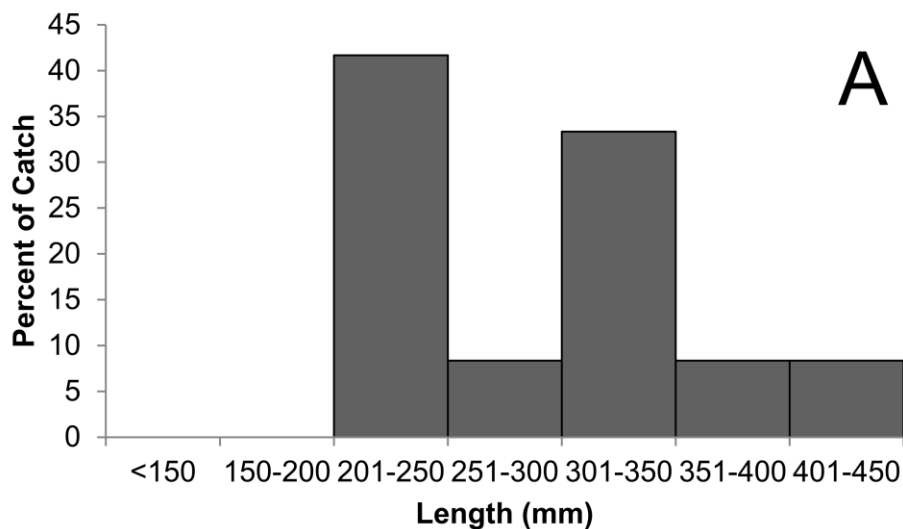


FIGURE 11. Length frequency of (A) cutthroat trout (N= 12) and (B) rainbow trout (N=13) captured by anglers in Upper Campbell Lake June, 1951 (Source: McMynn & Larkin, 1953).

Age and Growth

Tredger's (1979) findings of poor habitat quality throughout most of the Elk River drainage, the low density of juvenile biomass throughout the area he sampled, and the low temperature of these streams suggests that fry leave may leave for the lake in the early spring or late fall when the rains come. Tredger (1979) found that fry were not abundant throughout the Elk River and the highest juvenile biomass was in side-channels and tributaries indicating that cutthroat migrate into small Elk River tributaries where habitat is stable, and to the lake through the summer period in response to poor habitat quality (Table 9).

TABLE 9. Summary of migration patterns of juvenile salmonids to Upper Campbell Lake as determined by scale analysis (Reprinted from: Tredger, 1979).

Species	Year of Sample	N Readable	% Migrating to Lake		
			Fry	1.-1+	2.-2+

Cutthroat	1951	8	50	(4)	50	(4)	0	(1)
	1963-4	10	10	(1)	80	(8)	10	(2)
	1978	2	0		0		100	
Rainbow	1978	25	32	(8)	32	(8)	36	(9)
Dolly	1978	8	50	(4)	25	(2)	25	(2)
Varden								

We've presented the ageing data for cutthroat trout captured in gillnets in Upper Campbell Lake in 2010 in Figure 12. Age 1+ cutthroat trout ranged from 120 mm -182 mm and averaged 143 mm in length while 2+ cutthroat ranged from 204 mm - 290 mm and averaged 232 mm in length. Age 3+ cutthroat ranged from 275 mm - 330 mm and averaged 302 mm, age 4+ cutthroat ranged from 355 mm - 453 mm and averaged 402 mm while age 5+ cutthroat ranged from 420 mm - 454 mm and averaged 433mm.

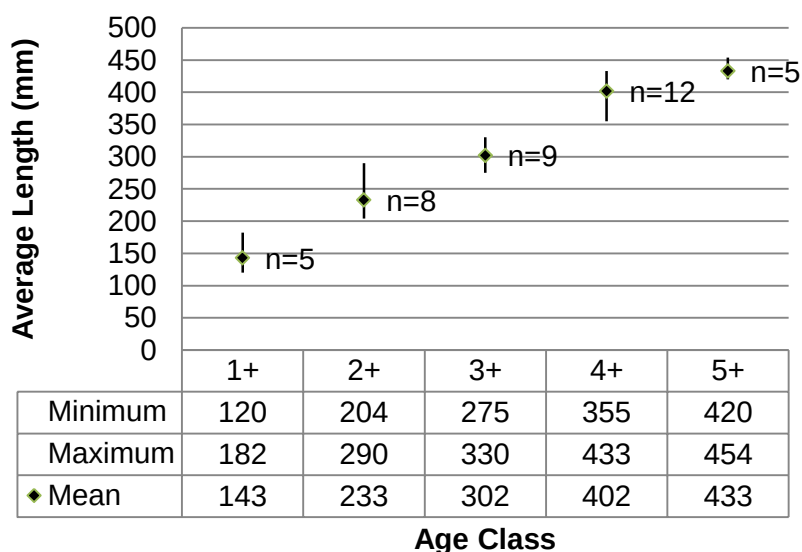


FIGURE 12. Minimum, maximum and mean length (mm) of each age class of cutthroat trout (N=39) captured in gillnets in 2010 in Upper Campbell Lake (Source: FLNRO files, Nanaimo).

We have some concerns with age interpretation given the large size of cutthroat aged at 1+ years of age. We think it's possible the first annulus was missed when these fish were aged. In view of the differences we found between length-at-age of cutthroat from Sproat Lake vs. data compiled by Carlander (1969)(see cutthroat ageing summary in Chapter 14), we suggest the ageing data from Upper Campbell Lake cutthroat trout be viewed with caution.

Twelve rainbow trout captured by anglers in 1951 were aged (Figure 13A). The 6 age 2+ rainbow averaged ~216 mm while the 6 age 3+ rainbow averaged ~247 mm. In 2010, 30 rainbow trout were captured in gillnets. Age 1+ rainbow ranged from 105 mm - 165 mm and averaged 128 mm, age 2+ rainbow ranged from 160 mm - 215 mm and averaged 185.6 mm while age 3+ rainbow ranged from 240 mm - 280 mm and averaged ~262 mm (Figure 13B).

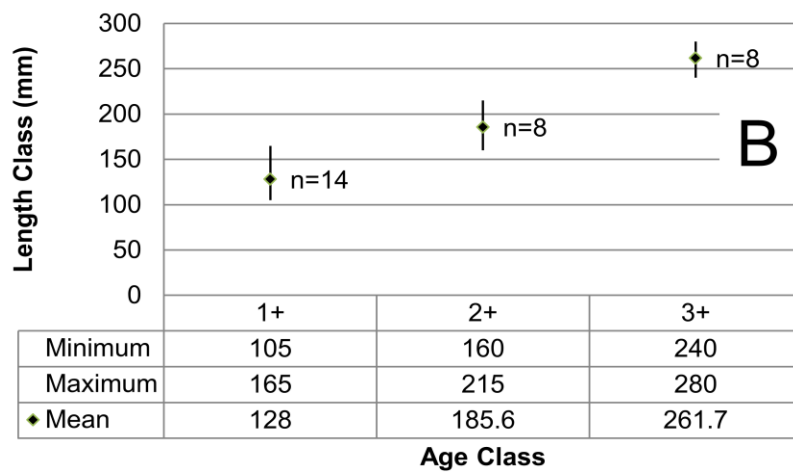


FIGURE 13. Minimum, maximum and mean length (mm) of each age class of (A) rainbow trout captured by anglers in 1951 (N=12) and (B) in gillnets in 2010 in Upper Campbell Lake (Source: FLNRO files, Nanaimo).

Ministry staff aged 9 Dolly Varden captured by angling in 1951 (Figure 14A). One age 1+ fish was 230 mm, the 5 aged 2+ Dolly Varden averaged 238 mm, and the 3 aged 3+ Dolly Varden averaged ~288 mm.

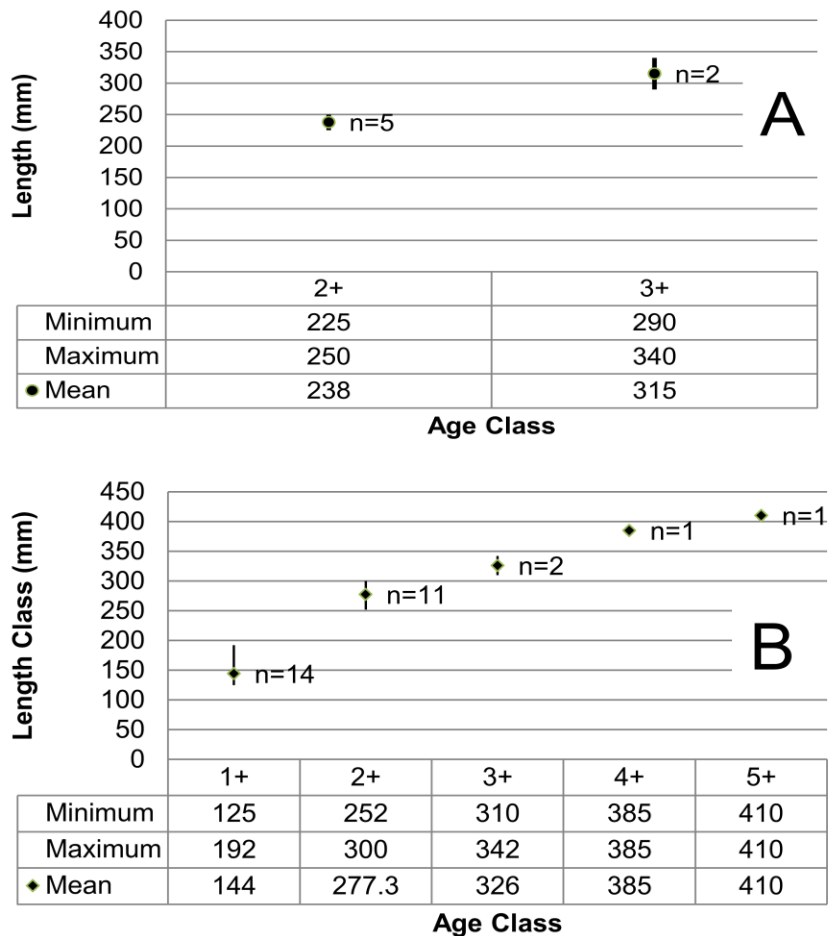


FIGURE 14. Minimum, maximum and mean length (mm) of each age class of (A) Dolly Varden captured by anglers in 1951 (N=7) and (B) in gillnets in 2010 in Upper Campbell Lake (N=29) (Source: FLNRO files, Nanaimo).

Twenty-nine Dolly Varden captured in gillnets were aged in 2010 (Figure 14B). Age 1+ Dolly Varden ranged from 125 mm - 192 mm and averaged 144 mm, age 2+ Dolly Varden ranged from 252 mm to 300 mm and averaged 277 mm, age 3+ Dolly Varden ranged from 310 mm - 342 mm and averaged 326 mm. One 4+ Dolly Varden was 385 mm, and one 5+ Dolly Varden was 410 mm.

Age and Maturity

We reviewed age-at-maturity and average age-at-length data and found that, at Upper Campbell Lake, mature cutthroat trout are 3+ years old and average ~383 mm (Table 10). This is slightly larger than the size at which cutthroat mature in other large lakes in the Vancouver Island region (Appendix 6). We also found that rainbow trout are mature at ~280 mm and 2+ years of age, while mature Dolly Varden are, on average, ~300 mm and 2+ years old at Upper Campbell Lake.

TABLE 10. Mean age of cutthroat and rainbow trout and Dolly Varden captured by angling in 1951 and in gillnets in 2010 in Upper Campbell Lake. Rainbow trout numbers include fish captured in gillnets in 1980 (Source: FLNRO files, Nanaimo).

Maturity	N	Mean Length	Mean Age

<u>Cutthroat</u>			
Immature	38	282.4	2+
Mature	7	383.1	3+
<u>Rainbow</u>			
Immature	36	178.9	1+
Mature	23	280.1	2+
<u>Dolly Varden</u>			
Immature	27	203.9	1+
Mature	9	311.1	2+

Catch Indicators

Total Catch

A total of 42 cutthroat trout (3/hour), 93 rainbow trout (6/hour), and 31 Dolly Varden (2/hour) were captured in sinking and floating gillnets set in Upper Campbell Lake in September, 2010 (Table 11).

TABLE 11. Total catch and catch/hour of cutthroat trout, rainbow trout and Dolly Varden sampled in gillnets in Upper Campbell Lake in September 2010. One sinking net was set for 16 hours and 1 floating set for 14.5 hours. Both nets were set just outside the Elk River inlet (Source: FLNRO files, Nanaimo).

Species	Total Catch	Average Catch/Hour
Cutthroat	42	3
Rainbow	93	6
Dolly Varden	31	2
Total	166	11

Data Gaps

Although there is recent gillnetting and angler creel survey data, limnological data is >10 years old and while some electrofishing and stream habitat inventories have been done in the Elk River, that information is 20 years old (Table 12). There are annual snorkel surveys on the Elk River for rainbow trout, however, there is only one snorkel survey on Drum, Crest and Mud Creeks and this survey does not provide sizes of spawning fish. There are also no annual snorkel surveys for cutthroat trout.

TABLE 12. Summary of data gaps for Upper Campbell Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Gillnetting	X		
Angler Creel Survey	X		
Instant Angler Counts		X	
Angler Preference Questionnaire			X
VILQ	X		
Snorkel Surveys	X		
Acoustic Surveys			X
Electrofishing (streams)		X	
Lake/Limnology Inventory		X	
Stream Habitat Inventory		X	
Water Quality/Lake Productivity		X	

5.0 Fisheries Objectives and Management Strategies for Upper Campbell Lake

Existing Regulations

Upper Campbell Lake is covered by the general regional regulations of 4 trout but not more than 1 >50 cm and 2 from streams. All wild trout and steelhead from streams and all Dolly Varden must be released. The Elk River is fly-fishing only and all streams are covered by the region-wide single barbless hook, bait ban regulation.

Maximum Catch and Effort at Current Regulations

The maximum angler effort at the current regulations is ~22,000 angler days and the maximum catch is ~28,000 fish (Figure 15). The optimum sustainable angler effort at the current regulations is ~14,000 angler days and optimum sustainable catch is ~24,000 fish. At the optimum, anglers would have a catch rate of 1.7 fish/day.

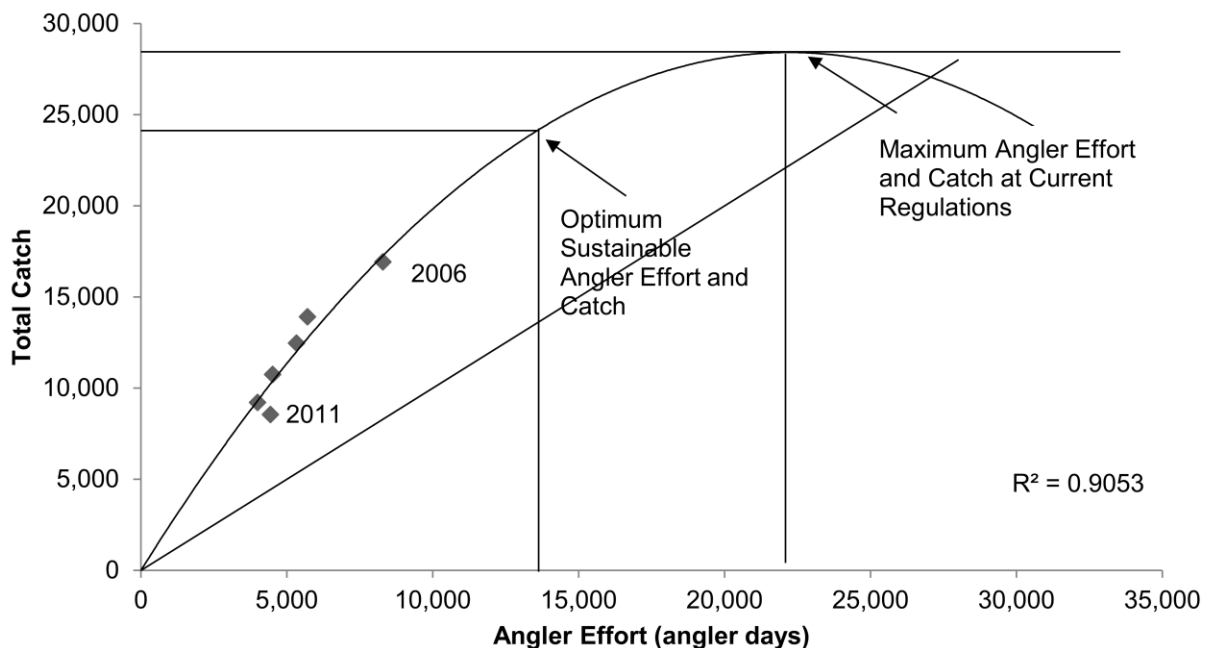


FIGURE 15. Angler effort (angler days) vs. total catch at Upper Campbell Lake 1986 – 2011 and maximum angler effort and catch and optimum sustainable angler effort and catch at current regulations (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

At present, angler effort is only 4,400 angler days/year and all of the catch is on the ascending limb of the curve, well under the defined optimum. Catch and maximum catch and, therefore, fish populations are stable. There is an increasing trend in angler effort (Figure 2) and catch (Figure 3) at Upper Campbell Lake, although we project that continued increases will not exceed optimum or maximum levels (Figure 16; Figure 17). In addition, the current harvest rate is 31% at Upper Campbell Lake and the yield is 0.3 lb/acre compared to a theoretical yield predicted by the MEI of >2 lb/acre (Appendix 8). Even at the highest total catch, yield at Upper Campbell Lake was less than half that predicted by the MEI.

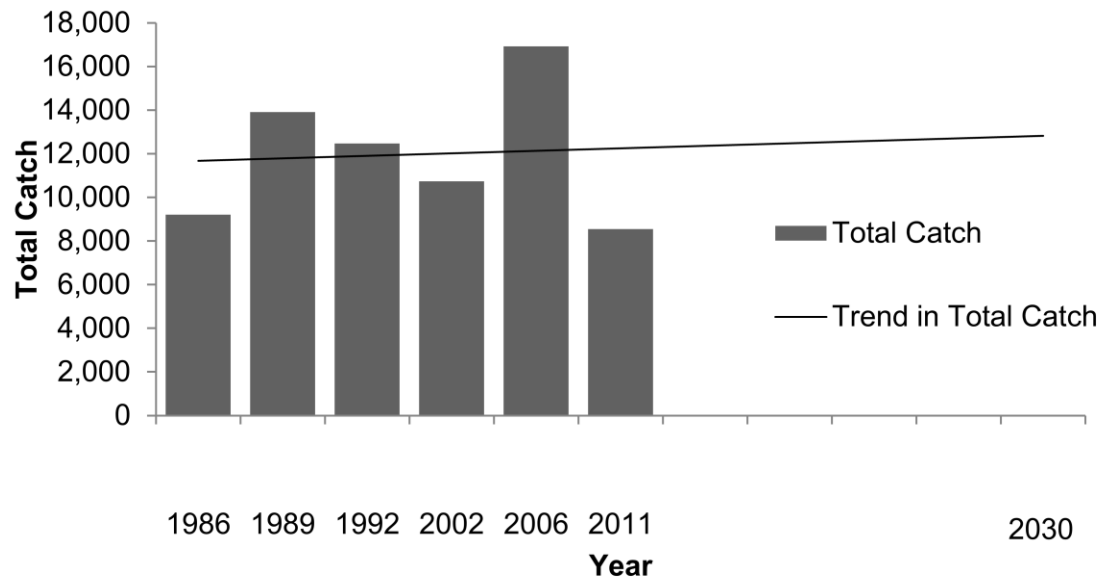


FIGURE 16. Total catch by year compared to average catch from 1986-2011 and trend until 2030 in catch at Upper Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

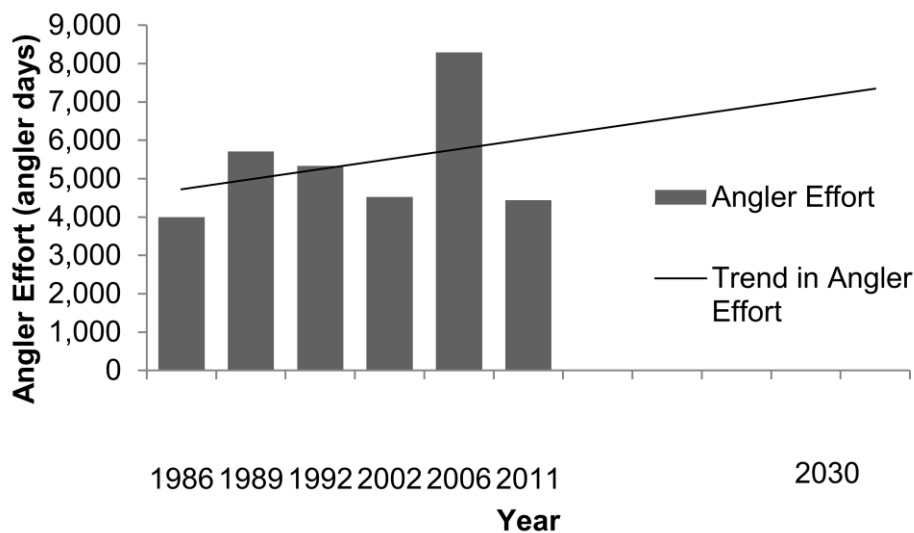


FIGURE 17. Total angler effort by year and trend in angler effort until 2030 at Upper Campbell Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

Almost 80% of the anglers in the 2010 angler survey thought angling at Upper Campbell Lake was good (Appendix 21) and the results of the VILQ support this position. We are concerned, however, that angler success declined in 2011 despite a decline in angler effort, and that the true angler success rate may be closer to 1 fish/day as suggested by the box angler creel

surveys, rather than 1.9 fish/day suggested by the VILQ. Despite the decrease in angler effort in 2011 (Figure 2) there is an increasing trend in angler effort overall and although it is well short of optimal effort, we recommend this statistic and angler success be monitored using the VILQ. We also recommend gillnetting the lake according to the priority schedule (Table 16; Chapter 1) if angler success rate falls to less than the regional objective of 1.6 fish/day, or if catch and angler effort approach the optimum or maximum levels.

Recent gillnetting data confirms there are still large (>400 mm) cutthroat in the population and angler catch and success statistics suggest stable populations of this species. Experience at other large lakes such as Comox Lake demonstrates that it is possible to over-fish larger size classes of cutthroat trout and given the angler preference and focus during summer months on cutthroat trout we recommend implementing maximum size regulations to ensure long-term opportunities for large cutthroat at Upper Campbell Lake (Section 11; Chapter 1). We also recommend implementing additional conservation regulations if angler effort increases are accompanied by declines in catch and/or angler success. Finally, we recommend surveys to address data gaps including determining numbers of spawning cutthroat, and juvenile cutthroat trout in the Elk River watershed.

1. Fisheries management efforts should focus on cutthroat which are preferred by anglers and comprise 45% - 65% the angler catch.
2. Implement a maximum size regulation for cutthroat trout to protect large fish remaining in the cutthroat population.
3. Monitor the effectiveness of the management objectives and regulations using the VILQ.
4. Implement additional conservation regulations (e.g. a minimum size limit) if angler effort increases by >10% and that increase is accompanied by a decline in catch of $\geq 10\%$, or if angler success rate falls to 1.6 fish/day, or if the catch and angler effort increase to the optimal or maximum levels.
5. Gather angler catch data and monitor angler opinions regarding the fishery by repeating the box angler creel survey program every 3 years. An instant angler count to determine a more precise estimate of angler effort would also be useful.
6. Upper Campbell Lake is a high priority lake and is scheduled for gillnetting in 2014 (Table 16; Chapter 1). Future gillnetting programs should follow the timing and location guidelines established in Michalski, 2010. As we have concerns regarding ageing of young fish, we also recommend all ageing data be quality-checked to ensure accuracy.
7. Continue with annual snorkel surveys to monitor rainbow trout in the Elk River and implement snorkel surveys in Crest, Drum and Mud creeks to provide baseline and monitoring data for spawning cutthroat trout. These surveys should be conducted in early – mid-April.
8. Conduct electrofishing surveys of Elk River tributaries to determine numbers of juvenile cutthroat trout.
9. Develop a partnership with the Gold River Rod & Gun Club (GRR&GC) and the Campbell River Fish & Wildlife Association (CRF&WA) to assist with future fisheries and stock monitoring programs and to facilitate communication with anglers.
10. Implement a signage program focused on regulations and fish identification to assist anglers at Upper Campbell Lake.

Operational Management Plan for Upper Campbell Lake

We've provided an operational management plan for Upper Campbell Lake in Table 13. In addition to monitoring fisheries and changing the regulations, we've recommended developing a partnership with the GRR&GC to help monitor stocks and implement a public awareness

campaign at Upper Campbell Lake. Access to Upper Campbell Lake is excellent as Highway 19 to Gold River parallels the lakeshore for 90% of the length of the lake and a gravel logging road parallels the lake with numerous small access points on the north side of the lake. There are numerous campsites and small car-top boat launches directly off the highway at which public information signs providing information on the stocks and regulations at Upper Campbell Lake can be posted. Finally, we've recommended some habitat assessment and restoration programs in the Upper Campbell Lake watershed. These programs can be implemented in partnership with the GRR&GC.

TABLE 13. Operational Management Plan for Upper Campbell Lake.

Activity	Objective	Tentative Schedule
Fisheries and Stock Monitoring	Conduct gillnetting according to schedule and at time and location established in 2010.	2014
	Implement snorkel surveys of Drum, Crest and Mud Creek to monitor red abundance and estimate size of spawning cutthroat; repeat Hay and Lough (2003).	2014
	Continue annual snorkel surveys to monitor rainbow trout spawning.	
	Implement electrofishing surveys on Elk River tributaries to determine numbers of juvenile cutthroat trout.	2014/15
Regulations	Implement a maximum size regulation to protect large cutthroat trout.	2015
VILQ	Evaluate changes in angler effort and catch; introduce additional conservation regulations (e.g. minimum size limit) if angler effort increases by >10% and that increase is accompanied by a decline in catch of $\geq 10\%$, or if angler success rate falls to 1.6 fish/day.	2014
Fisheries Monitoring	Re-run the box angler creel survey program using forms and box locations from 2010 to collect data on angler-caught fish and angler opinions.	2015+
	Implement an instant angler count program to assess angler effort and compare to estimates from the VILQ.	2015+
Public Awareness	Establish partnership with GRR&GC to help conduct fisheries and stock monitoring programs and implement public awareness projects.	2015+
Habitat – Assessment	Conduct a Level 1 WRP assessment including riparian assessment of Lower Elk River; conduct a Level 2 restoration prescription and priority ranking for restoration in Lower Elk River.	2017+
Habitat – Restoration	Implement and monitor the effectiveness of habitat restoration projects in the Lower Elk River.	2020+

Chapter 16. Victoria Lake

Lake	Victoria
Planning Unit	West Coast
Watershed	Marble River
Surface Area (ha)	1,576
Mean Depth (m)	43.3
Key Tributaries	Link, Teihsum and Upper Marble Rivers
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden
Limits to Production	Logging, Water Withdrawal
Regional Priority*:	10
<u>Angling Statistics 2011</u>	
Angling Effort	835 angler days
Total Catch	1,866 fish
Angler Success	2.2 fish/angler day
Current Harvest Rate	27%
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	Unknown but there is cause for concern – last gillnetting assessment in the 1990's found most cutthroat (>95%) <30 cm. Declining angler catches and angler success rate suggest maximum catch may have been exceeded in the late 1990's-2002.
Data Gaps	Gillnetting and spawner and juvenile surveys especially for cutthroat trout but also rainbow trout to determine distribution in the watershed.
Management Objectives	Develop protective regulations based on gillnet assessment conducted in 2013; out-of-cycle conservation regulation may be required in 2014. Re-net in 2016 to determine if more restrictive regulations are required.
Operational Plan Priorities	Gillnetting and regulations; establish partnership with Port Alice Fish and Game Association
Potential Partners	Port Alice Fish and Game Association

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Victoria Lake Watershed

General Information

Victoria Lake is located 5 km east of Port Alice near the northern end of Vancouver Island. This large mountain-trough lake, which is accessed by a logging road from Port Alice, is fed by limestone enriched water from the Marble River drainage system (Figure 1). Victoria Lake is ~15 km in length and, on average, <1 km wide (FLNRO files, Nanaimo). The surface area is ~1,575 ha, the lake has an average depth of 43 m and a maximum depth of ~110 m (Table 1).

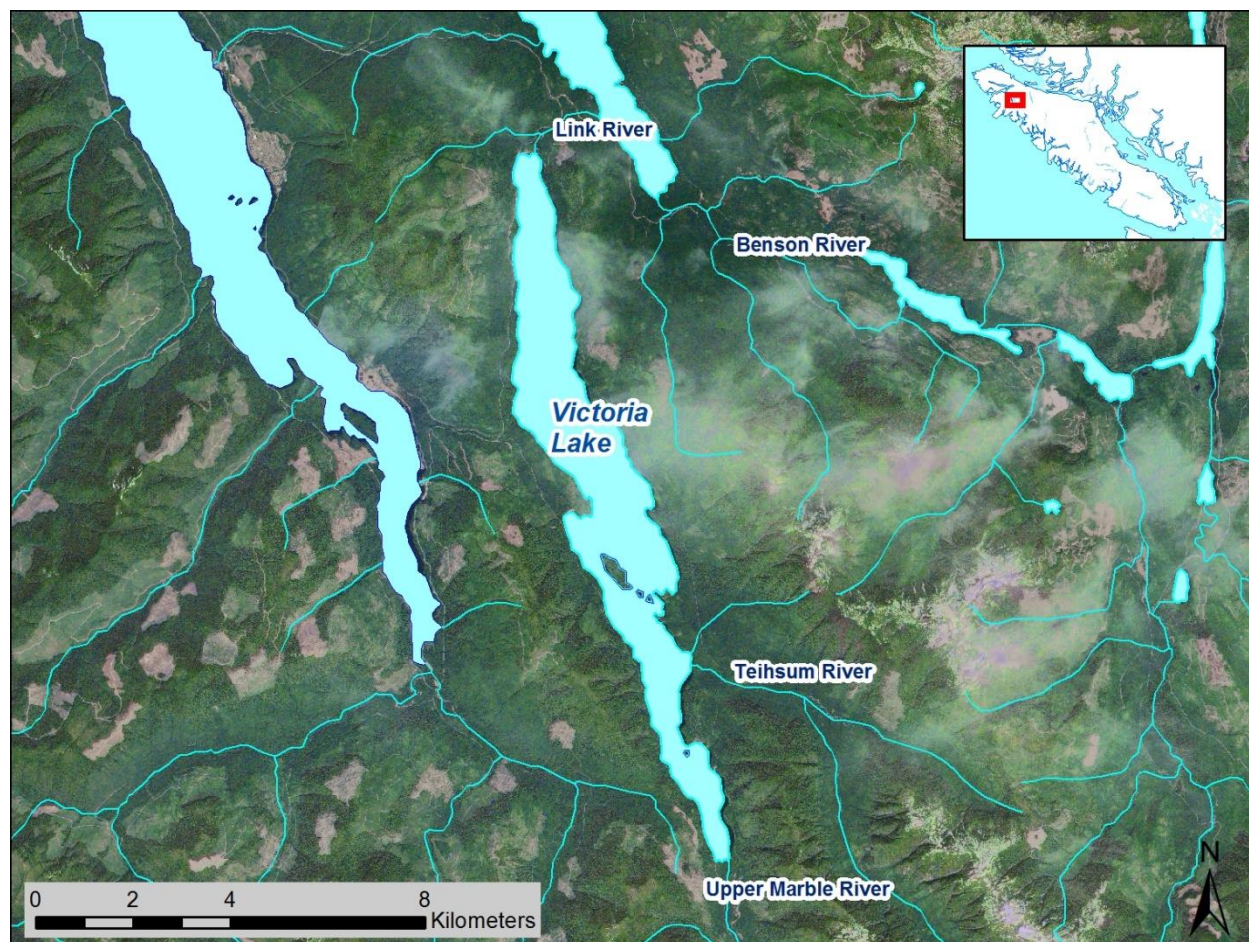


FIGURE 1. Map of Victoria Lake and tributaries; a bathymetric profile is provided in Appendix 22. (Source: iMap BC).

TABLE 1. Location, size, depth and water quality parameters at Victoria Lake. (FLNRO files, Nanaimo, FISS).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
West Coast	00195BRKS	1,576	37.6	109.7	43.3	6.9	35	7.3	1969

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters.

Tributaries

Tributaries to Victoria Lake include the Link, Marble and Teihsum Rivers, and Jeune and Sorenson creeks (Table 2). The Link River is the largest tributary and flows for 1.7 km from Victoria Lake to Alice Lake. The lower 30% of this river was logged ~35 years ago while the upper area was logged within last 20 years (Fielden, 1998). Jeune Creek lies south of Sorenson Creek and joins the Link River at Link River falls. Except for patches in the upper watershed, these streams were almost completely logged ~35 years ago.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Victoria Lake (Source: Fielden, 1998; Law, 1996).

Tributary	Length (km) and/or Drainage Area (km ²)	Other Information
Link River	140 km ² ; 1.7 km	Three reaches – Reach 2 is entrenched in a steep walled canyon with some limestone deposits; anadromous access through Reach 2 but Reach 3 fish are likely stream resident trout and char as cascades at Victoria Lake outlet would not be passable; also an old concrete and wood dam that raised Victoria Lake by 1 m.
Jeune Creek	4.5 km ² ; 4.4 km	Three reaches – barrier at bottom of Reach 1 prevents anadromous access and fish sampled above this are probably stream resident; gradient increases to 24% in Reach 3.
Teihsum River	29.5 km ² ; 8.8 km	Four reaches – Reach 1 has excellent Dolly Varden habitat, cutthroat also present in this reach; Reach 2 entrenched in canyon and has good trout habitat; Reach 3 has low water and logging destabilized banks and deposition; Reach 4 also impacted by logging – channel unstable; high bedload; gradient increases to 27% in Reach 6.
Teihsum River Unnamed Tributary	5.4 km	Flows west to join Teihsum River 2.5 km upstream of mouth; valley bottom extensively logged; anadromous access in Reach 1; Reach 2 has numerous barriers; gradient increases to 26% in Reach 4; all roads in this watershed washed out or overgrown.
Upper Marble River	35.7 km ² ; 8 km	Three reaches– Reach 1 has had extensive damage from logging including destabilized banks and wide, simple channel, Reach 1 used by Victoria Lake Dolly Varden, cutthroat and rainbow.
Green Creek		Green Creek is likely the major spawning stream for Victoria Lake cutthroat.
Victoria Lake Unnamed Tributaries		There are 23 unnamed tributaries to Victoria Lake marked on the 1:20,000 TRIM map; some have no channel and many are steep with intermittent flows; some logged many years ago; some with good habitat including marsh/low gradient areas at mouths; some tributaries sampled for fish but no fish found although information from residents suggest some areas have of have had fish.

The Upper Marble River flows from the north to south end of Victoria Lake and the majority of timber has been logged from the valley bottom of this watershed within last 30 years. The Teihsum River is a large tributary that flows northwest for 8.8 km to the eastern shore and into Victoria Lake. The upper reaches and the main tributary of this river have been extensively logged (Fielden, 1998). Access to the Teihsum is limited, and a gate is kept locked at the bottom of the road to protect elk.

Species Composition

Victoria Lake does not contain salmon (Chambers, 1988(b)). The 6 m high Link River Falls north of the lake and 1.5 km up the Link River blocks anadromous fish from ascending to Victoria Lake (Fielden, 1998). In addition, a concrete weir located at the north end of the lake constructed in 1913 for the logging industry was a barrier to upstream fish movement. The dam washed out in 1987 and it's unknown whether the remaining structure continues to impede migration into the lake.

Resident fish species in Victoria Lake include cutthroat and rainbow trout, and Dolly Varden. Local residents also report kokanee in the lake (FLNRO files, Nanaimo).

Summary of Work and Reports

Between 1992 and 1996, the Port Alice Fish and Game Association (PAF&GA) conducted lake netting at Victoria and Benson Lakes under the direction of the Nanaimo Fish and Wildlife Branch staff that later compiled and analyzed the data (FISS). This project was discontinued in 1996 after baseline numbers and stock status parameters at this lake were established.

In addition to fish sampling data, there are also brief summaries by Ministry staff outlining the fish and habitat at the lake in response to a 1990 hydro development project by MJG Enterprises. Detailed information on tributaries to Victoria Lake is included in the fish and fish habitat inventory of the Marble River conducted by Fielden (1998).

A summary of fish sampling in response to a proposal in 2005 by Stolt Sea Farm to locate a finfish aquaculture facility at Victoria Lake is also included in the Ministry files as is a Canadian Environmental Assessment Act (CEAA) Screening Report completed by DFO in 2002 for the same purpose (Department of Fisheries and Oceans, 2002). The CEAA report does not contain any biological or biophysical data on the lake, however, it does provide summaries of general and anticipated environmental impacts by the proposed facility.

2.0 Limits to Fish Production

Water Withdrawal

A concrete weir constructed in 1913 for the logging industry located at the north end of Victoria Lake washed out in the lake 1980's. Following this event the lake level was lowered by 1 m – 1.5 m which may have affected the availability of spawning areas along the shore adjacent to the streams (Watson, 1991).

Logging

A significant portion of the forest along the Victoria Lake shoreline was harvested from the mid-1960's until the mid-1980's. These areas now support a 2nd growth forest dominated by hemlock, Douglas fir, and Sitka spruce (FLNRO files, Nanaimo).

Aquaculture

In 2005, Stolt Sea Farm proposed relocating its Keogh Lake salmon farm to Victoria Lake. The Fish and Wildlife Branch raised concerns that the project would impact the value of the sports fishery in Victoria Lake. Moreover, staff was troubled the facility would pose an ecological risk to the system and the fish stocks in the lake which are sensitive to human impacts due in part to their unique life-history characteristics (FLNRO files, Nanaimo). Branch staff also noted the potential for impacting escapement into the Marble River and staff from the Water Quality Branch raised concerns over nutrient loading and the potential harm to fish habitat because of the deposition of wastes (Davis, 2003).

Regardless of the concerns of Provincial staff, the aquaculture facility was subsequently located on the lake and in 2010 the Fish and Wildlife Branch received reports of the facility being abandoned and Atlantic salmon having been released into Victoria Lake. The Branch forwarded these reports to the DFO, however, no field investigations were conducted.

Fish Stocking

In 1988, the Fish and Wildlife Branch raised concerns with DFO over proposed headwater stocking of coho into Victoria Lake. Law (1988) requested information regarding the proposed salmonid enhancement program and noted that although Alice and Victoria Lakes did not support a large freshwater fishery, their catch rates were the highest among Vancouver Island Lakes. DFO responded that they had approved stocking but would limit numbers stocked to 75,000 and would place fish in the lower 2/3 of the lake to address the Ministry's concern regarding cutthroat/coho competition (Bates, 1988). It's not known how long stocking continued, however, a recent review of DFO stocking lists did not include Victoria Lake.

Stream Habitat

In his detailed habitat inventories of tributaries to Victoria Lake, Fielden (1998) found that Reach 1 of the Teihsun River and the upper Marble River are critical spawning and rearing areas for Victoria Lake cutthroat trout, rainbow trout and Dolly Varden. He also noted that other than these areas, there is very little spawning and rearing habitat in the Victoria Lake watershed due to the steep nature of the area. Law (1998) also pointed out that Victoria Lake has steep foreshore areas which limit the utility for fish using most inlets to this lake other than Green Creek and the Upper Marble River. Law suspected that Green Creek was the major spawning stream for Victoria Lake cutthroat.

Victoria Lake is one of the most important sports fishing lakes on Vancouver Island but in contrast to Law (1998) and Fielden (1998), Rimmer (2002) suggested it was the number of relatively good spawning and rearing tributaries which resulted in excellent recruitment of juvenile fish. He also noted that the occurrence of fresh water shrimp in the lake likely also contributed to the good fishing.

As part of his fish and fish habitat inventory of the Marble River, Fielden (1998) noted a number of Fisheries Sensitive Zones (FSZ)¹¹ in the Victoria Lake watershed including Reach 1 of the Teihsun and the upper Marble Rivers, and Victoria Lake Tributary 6, which is a small cutthroat

¹¹ Fisheries Sensitive Zones (FSZ) are off-channel aquatic habitats lying within the floodplain of a main stream channel that are important fish habitat (Ministry of Environment, 1995).

stream flowing through a swamp. Fielden (1988) also identified a number of areas that have wide flood plains and have the potential to have FSZ, but noted these areas had not been fully investigated.

Recreational Use

There are ~70 cabins located toward the north and west side of Victoria Lake and some of these cabins are on the floodplain (FLNRO files, Nanaimo). Cabins are on land leased from the Lands Branch of MFLNRO and residents pay an annual fee to maintain leased sites.

Nutrients

As in most oligotrophic coastal lakes, the sediments of Victoria Lake have very few benthic organisms although local knowledge suggests there is a healthy population of shrimp in the lake (FLNRO files, Nanaimo). On Vancouver Island, freshwater shrimp are found only in lakes where limestone is present. Rimmer (2002) postulated that the underlying geology of the Victoria Lake basin which is primarily limestone dissolves and provides a rich flow of nutrients to the lake and that this is the reason for the abundance and diversity of fish food organisms including freshwater shrimp.

3.0 Angler Statistics

Angler Effort

Angler effort increased from 1,195 angler days in 1986 to ~2,000 angler days from 1989 until 2002 (Figure 2). In 2002, angler effort reached its highest level of 2,104 angler days then declined to 1,250 angler days in 2006, and to 835 angler days in 2011, the lowest level recorded by the VILQ for this lake. Overall, there has been a decreasing trend in angler effort at Victoria Lake over the past 25 years.

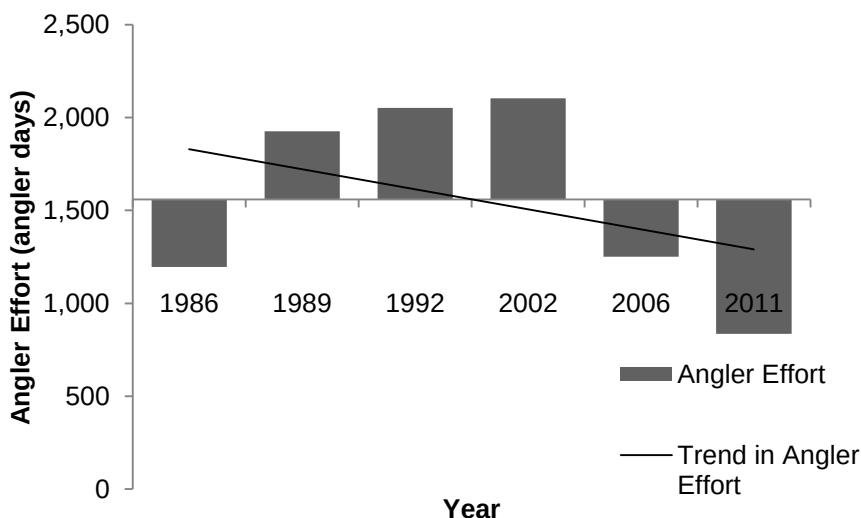


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Victoria Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Catch

The average catch over the past 25 years is ~3,500 fish (Figure 3). Total catch at Victoria Lake was highest in 1986 when it reached 6,300 fish then began to decline to ~3,800 in 1989 and 1992. Total catch fell again to ~2,000 fish in 2002 but increased in 2006 to ~3,200 likely because of the concomitant decrease in angler effort during the same period (Figure 2). In 2006, total catch increased to ~3,200 fish but in 2011 catch fell to its lowest level of 1,866 fish.

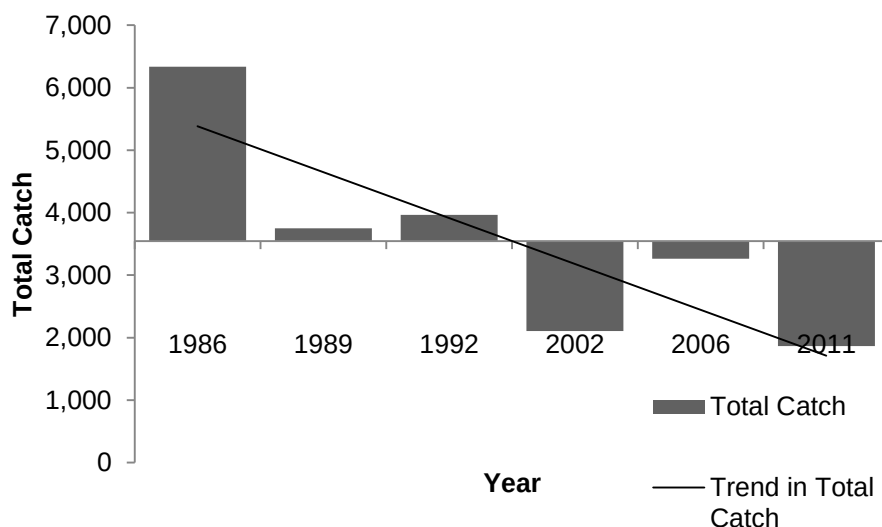


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Victoria Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

In 2006, almost 90% (2,909 fish) of the angler catch at Victoria Lake was comprised of cutthroat and ~10% (295 fish) of rainbow trout (Table 3). In 2011, however, cutthroat comprised only ~60% of the catch (1,100 fish) and rainbow comprised 30% of the catch (557 fish). The catch of Dolly Varden also rose from 1.7% of the catch in 2006 (57 fish), to 11.2% of the catch (209 fish) in 2011.

TABLE 3. Catch of rainbow and cutthroat trout at Victoria Lake 2006 and 2011 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	2006		2011	
	Catch	% of Total	Catch	% of Total
Cutthroat	2,909	89.2	1,100	59.0
Rainbow	295	9.0	557	29.9
Dolly Varden	57	1.7	209	11.2
Total	3,261		1,866	

Angler Success

Rimmer noted that in 2002 Victoria Lake was among the most important sports fishing lakes on Vancouver Island as it consistently ranked either 1st or 2nd in terms of angler success (Rimmer, 2002). At an average success rate of almost 2.3 fish/day, Victoria Lake ranks 2nd to Buttle Lake in terms of angler success (Figure 4). Angler success declined from a high over >5 fish/day in

the late 1980's, to 1 fish/day in 2002. In 2006, angler success increased to 2.6 fish/day but in 2011 the success rate dropped to 2.3 fish/day despite a decrease in angler effort (Figure 2).

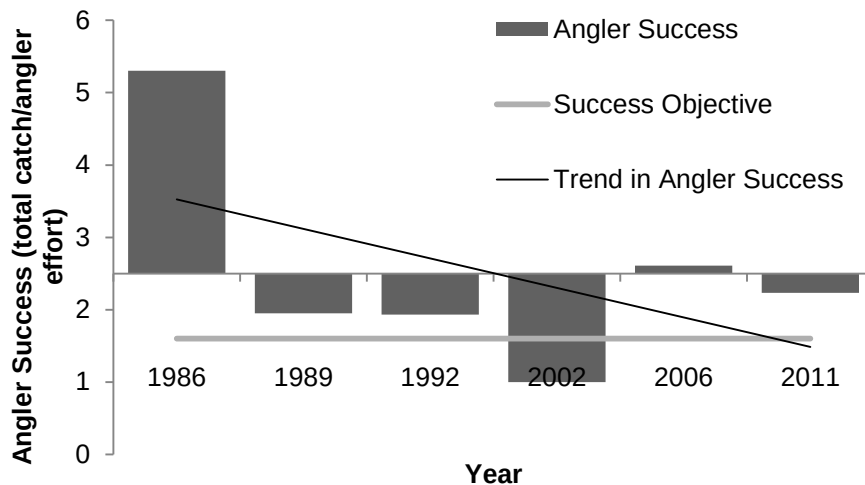


FIGURE 4. Angler success (total catch/total angler effort in angler days) and trend in angler success compared to average angler success and the objective for angler success (1.6 fish/angler day) at Victoria Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Harvest

Anglers harvested 25% of the cutthroat and 73% of the rainbow trout caught in 2006 (Table 4). Despite the region-wide mandatory release of Dolly Varden, anglers also reported harvesting 40% of their catch of this species. Overall, the harvest rate at Victoria Lake in 2006 was 30%.

TABLE 4. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Victoria Lake 2006 and 2011 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	2006			2011		
	Catch	Harvest	Percent	Catch	Harvest	Percent
Cutthroat	2,909	739	25.4	1,100	418	38.0
Rainbow	295	216	73.2	557	84	15.0
Dolly Varden	57	23	40.4	209	0	0.0
Total	3,261	978	30.0	1,866	501	26.9

In 2011, anglers harvested 38% of their cutthroat and 15% of their rainbow (Table 4). No anglers reported harvesting Dolly Varden that year and overall the harvest rate was ~27%.

Stock Status

Relative Abundance – All Species

Cutthroat, rainbow trout and Dolly Varden were captured during gillnet assessments of Victoria Lake between 1992 and 1996 (Figure 5). In 1992 and 1993, cutthroat comprised ~90% of the

samples, however, in 1994 cutthroat made up only 10% while Dolly Varden comprised 20% of the sample.

Rainbow trout were only sampled in Victoria Lake in 1994 and 1995 (Figure 5). In 1994, rainbow made up >60% of the sample and in 1995 rainbow accounted for ~20% with cutthroat and Dolly Varden comprising the remaining 80% of the sample (40% each). In 1996, the gillnet sample again included only cutthroat (40%) and Dolly Varden (60%).

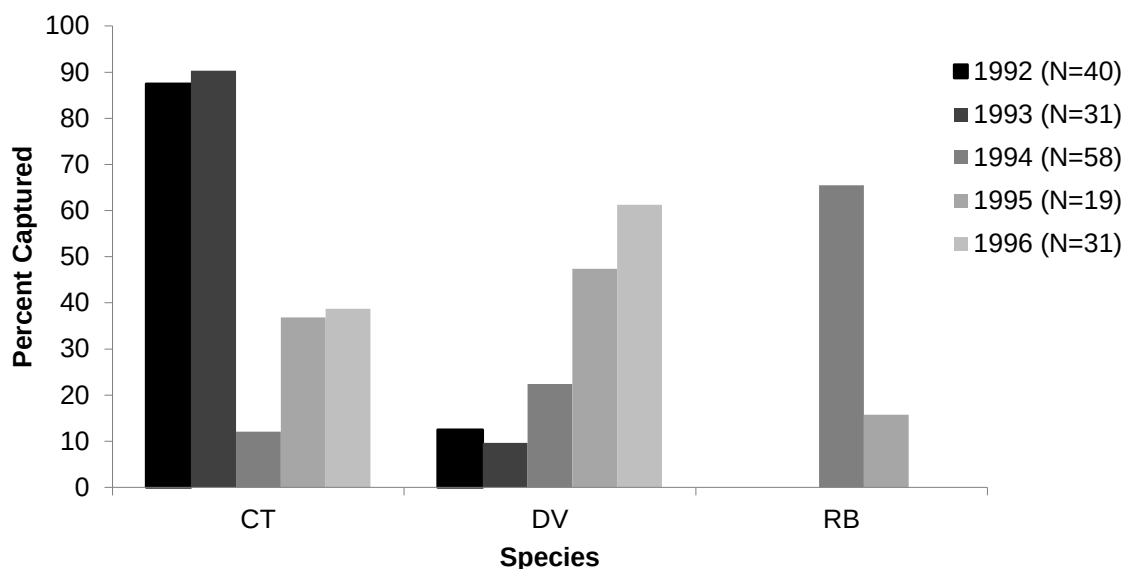


FIGURE 5. Percent cutthroat trout, rainbow trout and Dolly Varden captured in gillnets in Victoria Lake in April 1992 – 1996 (Source: FLNRO files, Nanaimo).

Length and Weight

We've summarized the length and weight data for fish sampled in gillnets in Victoria Lake from 1992 until 1996 in Table 5 and have provided yearly fish sampling data and length frequency distributions in Appendix 22. Eighty-nine cutthroat trout were sampled between 1992 and 1996 and these ranged from 75 mm - 390 mm and averaged 217.8 mm in length. The modal length was 210 mm over the 5-year period and mean weight was ~95 g. Of note is the fact that 97% of the cutthroat sampled in the 1990's were <300 mm (Figure 6; Appendix 22). It's likely growth of cutthroat trout in Victoria Lake are limited by a short, colder growing season and these fish likely exhibit a life history pattern similar to that found in Upper Campbell and Buttle Lakes where fry emergence is in August, and most fry spend 1-3 years in the tributaries before moving into Victoria Lake.

TABLE 5. Minimum, maximum, mean and modal length and mean weight for cutthroat and rainbow trout and Dolly Varden captured in gillnets in April in Victoria Lake 1992 - 1996 (Source: FISS; FLNRO files, Nanaimo).

Species	Length (mm)					Weight (g)
	N	Minimum	Maximum	Mean	Mode	Mean
Cutthroat	89	75.0	390.0	217.8	210	94.7
Rainbow	41	175.0	260.0	217.6	225	83.1
Dolly Varden	49	110.0	250.0	188.3	200	65.3

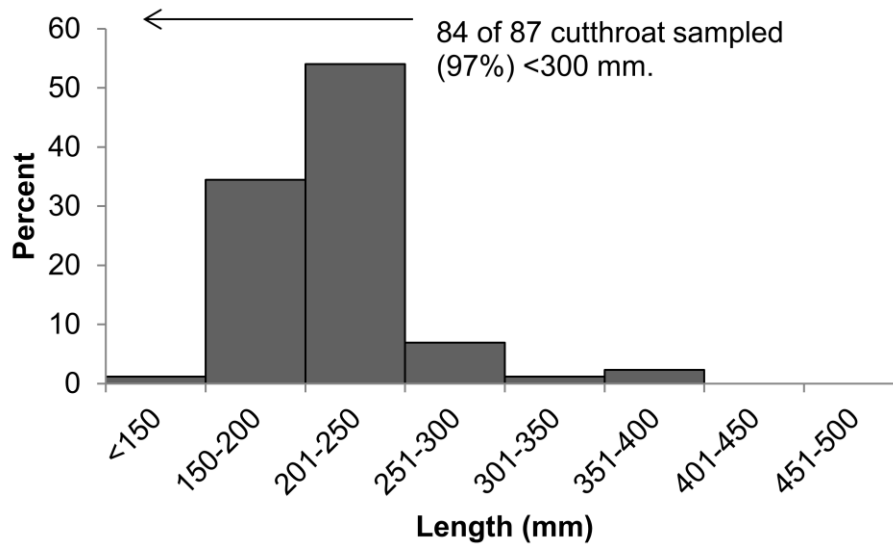


FIGURE 6. Percent cutthroat trout in each length class sampled in gillnets in Victoria Lake 1992 – 1996 (N=87) and percent of total sample <300 mm (Source: FLNRO files, Nanaimo).

A total of 41 rainbow trout were captured during the 5 years the lake was netted and these fish ranged from 175 mm - 260 mm and averaged 217.6 mm in length (Table 5). The modal length of rainbow trout was 225 mm, and the mean weight was 83.1 g.

Forty-nine Dolly Varden were sampled between 1992 and 1996 and these fish ranged from 110 mm - 250 mm and averaged 188.3 mm in length (Table 5). The modal length of Dolly Varden was 200 mm, and the mean weight was 65.3 g.

Maturity

No ageing data was captured during the sampling period, however, PAF&GA volunteers noted maturity of fish caught in gillnets (Table 6). Immature cutthroat trout were, on average, ~207 mm while mature cutthroat were 221 mm. Immature rainbow trout averaged 217 mm while mature rainbow averaged just slightly larger at 219 mm. Immature Dolly Varden averaged 178 mm while mature Dolly Varden averaged 207 mm.

TABLE 6. Mean fork length of immature and mature cutthroat trout (N=76), rainbow trout (N=32) and Dolly Varden (N=30) captured in gillnets in April in Victoria Lake 1992 -1996 (Source: FISS; FLNRO files, Nanaimo).

Maturity	n	Mean Fork Length (mm)
Cutthroat		
Immature	57	207.4
Mature	19	221.0
Rainbow		
Immature	23	217.2
Mature	9	219.4
Dolly Varden		
Immature	28	178.2
Mature	2	207.5

Catch Indicators

Total Catch

There is no information in the Branch files regarding how many and what types of gillnets were set, their locations or soak times during the sampling program at Victoria Lake. We assumed the same procedure was followed every year, however, so have compared the total and average catch of each species in Table 7. During this period, the catch of cutthroat trout ranged from seven fish in 1995, to 36 fish in 1992 and averaged 18 fish/year while the catch of Dolly Varden ranged from three fish in 1993, to 19 fish in 1996 and averaged ten fish/year. Rainbow trout were only sampled in 1994 (seven fish) and 1995 (four fish).

TABLE 7. Total catch and average catch/year of cutthroat and rainbow trout and Dolly Varden caught in gillnets in April in Victoria Lake by year 1992 – 1996. We have presented total catch because there is no information in the files regarding how many nets were set each year (Source: FLNRO files, Nanaimo).

Year	Total Catch		
	Cutthroat	Rainbow	Dolly Varden
1992	36		5
1993	27		3
1994	8	37	13
1995	7	4	8
1996	12		19
Average Catch/Year	18	21	10

Data Gaps

Lake inventory data, water quality and general stream inventories are >10 years old (Table 8) and although Fielden (1998) conducted a detailed fish and fish habitat inventory of the Victoria Lake watershed as part of his Marble Creek inventory in 1998, he noted that several data gaps existed including juvenile rearing densities, fish species compositions, and size-age distributions in the Teihsun and Upper Marble Rivers. Although some work has been conducted on the Marble River, other tributaries including Green Creek, which is a major cutthroat spawning stream, have had no assessment. With the exception of the VILQ, there is no information on the fishery at Victoria Lake

TABLE 8. Summary of data gaps for Victoria Lake that are required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Lake Inventory		X	
Water Quality/Lake Productivity		X	
Stream Inventory (general)		X	
Level 1 & 2 WRP Surveys			X
Fisheries Sensitive Zones			X
Fish Assessment (streams)		X	
Electrofishing Surveys (Marble River)		X	
Snorkel Surveys (Marble River)			X
VILQ	X	X	
Angler Creel Survey			X
Fishery Data and Angler Preferences			X
Gillnetting		X	
Acoustic Surveys			X

5.0 Fisheries Objectives and Management Strategies for Victoria Lake

Existing Regulations

Victoria Lake is covered by the general regional regulations of 4 trout but not more than 1 >50 cm. There is no data on how often these goals are achieved. All wild trout and steelhead from streams, and all Dolly Varden must be released.

The Marble and Link Rivers and tributaries between Victoria and Alice Lakes are fly-fishing only. The remaining tributaries to Victoria Lake including Teihsum Creek are covered by the regional regulations of two fish from streams and mandatory release of all wild trout and steelhead from streams. There is a bait ban and single barbless hook restriction in all streams, all year.

Maximum Catch and Effort at Current Regulations

Angler catch in 1986 was almost double that of succeeding years and we believe this point skewed the data and provided an erroneous result when we calculated maximum and optimum angler effort (Appendix 22). We removed the 1986 effort and catch data points, however, there was still too much variability ($R^2 < 0.5$) to provide an estimate of maximum and optimum angler effort and catch for Victoria Lake.

Fisheries Objectives and Management Strategies and Operational Management Plan for Victoria Lake

The average angler success rate at Victoria Lake is 2.3 fish/day which is higher than our regional success objective of 1.6 fish/angler day. Total catch has been declining over the past 25 years and is now at an all-time low which although it may be related to low angler effort, is a concern given angler success also declined in 2011.

Gillnet catches at Victoria Lake found mostly small (<250 mm), albeit mature cutthroat trout. Incidental notes in the Fish and Game Branch state that Victoria Lake tributaries are very cold which affects trout and char growth and life history in this watershed. Although it is not a high priority lake, we recommend Victoria Lake be netted in 2013 (Chapter 1) as there is no recent gillnetting data to determine if stocks have declined.

1. Current declines in total catch are a concern, therefore, we recommend Victoria Lake be gillnetted immediately to examine stock status.
2. Develop conservation regulations if necessary. We recommend the approach outlined in Chapter 1 for both species but we've moved the minimum size limit down because of the small size of maturing fish at Victoria Lake. We recommend this size limit be confirmed during the gillnetting:
 - a. a minimum size regulation of 250 mm to protect immature fish and allow them to spawn once before entering the fishery.
 - b. a maximum size limit of 400 mm to protect large fish but still allow anglers to catch a fish.
3. Note a similar situation exists at Alice Lake (Chapter 2) and we've recommended the same regulations, if appropriate, at both lakes to make things easier for anglers since these lakes are within the same PU and in close proximity.
4. The current harvest rate at Victoria Lake is 27% which is conservative. However, we recommend moving to catch-and-release fishing if gillnetting in 2017 and the next VILQ indicate stock declines.
5. Snorkel surveys and electrofishing assessments should be implemented to gather information on spawning and juvenile life history phases of cutthroat and rainbow trout and Dolly Varden.
6. Finally, we recommend contacting the PAF&GA to determine if volunteers are interested in assisting with future stock and habitat assessments and restoration projects (Table 9).

Operational Management Plan for Victoria Lake

We've outlined an operational management plan for Victoria Lake in Table 9. In addition in gillnetting immediately, we've recommended conducting a reconnaissance to determine if snorkel surveys can be conducted on the Marble and Teihsun Rivers and Green Creek to document and monitor cutthroat spawning. We've also recommended that Fielden's (1998) suggestions regarding determining juvenile rearing densities, fish species compositions and size-at-age age distributions be implemented in the Upper Marble and Teihsun Rivers (see Fielden, 1998 for details).

We've recommended re-establishing the partnership with the PAF&GA as volunteers may be interested in assisting with future fisheries and stock monitoring and habitat assessment and restoration projects.

Finally, we recommend discussing coho stocking practices with DFO. Cutthroat fry likely move directly into Victoria Lake with fall rains and at this stage fish are small and vulnerable to large concentrations of stocked coho. It's critical to determine if stocking coho into Victoria Lake continues and, if so, to gather better information on spawning run timing (i.e. snorkel surveys), stream temperature during incubation, and emergence time (i.e. electrofishing surveys) to determine potential impacts to Victoria Lake trout from stocked coho.

TABLE 9. Operational management plan for Victoria Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Conduct gillnetting assessment to determine stock status. Conduct reconnaissance surveys of Marble and Teihsum Rivers and Green Creek to determine if snorkel surveys are possible during next netting (2017). Electrofishing surveys to determine juvenile rearing densities of cutthroat and rainbow trout and Dolly Varden in Teihsum and U. Marble River (see recommendations in Fielden, 1998).	2013 2013 recon. 2017 survey 2017
Regulation Change (possible)	An out-of cycle conservation regulation may be necessary depending on results of the gillnetting survey; consider minimum size; slot limit or catch-and-release regulation; consult with the PAF&GA and VIFFRAC about any proposed changes.	2015
Partnership with Port Alice Fish and Game Association	There have been no angler creel surveys on Victoria Lake so no detailed, recent data regarding effort and catch of cutthroat and Dolly Varden. An angler creel survey may be possible with volunteers from the PAF&GA; surveys should be conducted the same years as gillnetting so comparisons can be made.	2015
Habitat - Assessment	Fielden (1998) found most tributaries are steep, have little fish habitat and the majority of spawning/rearing habitat for trout and char is restricted to Reach 1 of Teihsum and U. Marble; some tributaries that flow across flood plain of U. Marble could be investigated for fish and fish habitat; flood plains of Reach 1 of Teihsum, Benson, Link and U. Marble Rivers could be investigated to determine if they are FSZ.	2017+
	There are general concerns regarding climate change impacts on all large lakes; consider temperature monitoring by PAF&GA to track lake temperatures.	2017+
Habitat - Restoration	Fielden (1998) suggested restoration projects to mitigate impacts of logging including logging road deactivation, slope stabilization at higher elevations in the watershed and instream work focused on bank stabilization, placement of LWD and boulder clusters. He suggested tributaries and/or reaches to Lippy, Sorenson and Howlall Creeks, and Benson, Link, Marble and Teihsum Rivers be considered. These are projects the PAF&GA may be interested in implementing.	2019+
Other	Reports of Atlantic salmon were released into lake in 2010 by defunct salmon farm not followed-up, partner with PAF&GA to sample lake during gillnet assessment.	2013
VILQ	Evaluate changes in fisheries statistics every three years; review in conjunction with results of gillnetting assessments to determine if more restrictive regulations are required.	Ongoing

Chapter 17. Woss Lake

Lake	Woss
Planning Unit	Nimpkish
Watershed	Nimpkish
Surface Area (ha)	1,366
Mean Depth (m)	81
Key Tributaries	Woss and Nimpkish Rivers
Freshwater Fish Species	Cutthroat and Rainbow Trout, Dolly Varden, kokanee
Limits to Production	Logging
Regional Priority*:	9
<u>Angling Statistics 2011</u>	
Angling Effort	0 angler days
Total Catch	0 fish
Angler Success	Unavailable
Current Harvest Rate	Unavailable
Optimum Sustainable Effort	Unable to calculate
Optimum Sustainable Catch	Unable to calculate
Angler Success at Optimum	Unable to calculate
Stock Status	Unknown, no stock status data and ongoing declines in catch and angler success suggest stock declines.
Data Gaps	No recent gillnetting data and existing data does not provide stock status indicators; no spawning or juvenile assessments; no data on the fishery with the exception of the VILQ.
Management Objectives	Conduct gillnetting assessment and determine if conservation regulations are required; repeat netting in 3 years and evaluate with new VILQ results to determine if additional regulations are required.
Operational Plan Priorities	Gillnet assessment; snorkel and juvenile assessment; box angler creel survey and derby monitoring are recommended. Habitat assessment and enhancement projects are also suggested.
Potential Partners	Port Alice Fish and Game Association; Alert Bay Band, Nimpkish First Nations, DFO Lake Enhancement Unit

* see Appendix 5 for information on how we prioritized Vancouver Island large lakes.

1.0 Overview of the Woss Lake Watershed

General Information

Woss Lake, which drains via the Nimpkish River into Nimpkish Lake (Figure 1), is the 2nd largest lake in the Nimpkish River system. As with most lakes near the BC coast, Woss Lake is warm and monomictic¹² (Shortreed et al. 2001). Woss Lake has a mean depth of 81 m (Table 1) and an average thermocline depth of ~18 m. Woss Lake is highly oligotrophic and water clarity is greater here than for most coastal BC lakes (Shortreed et al. 2001).

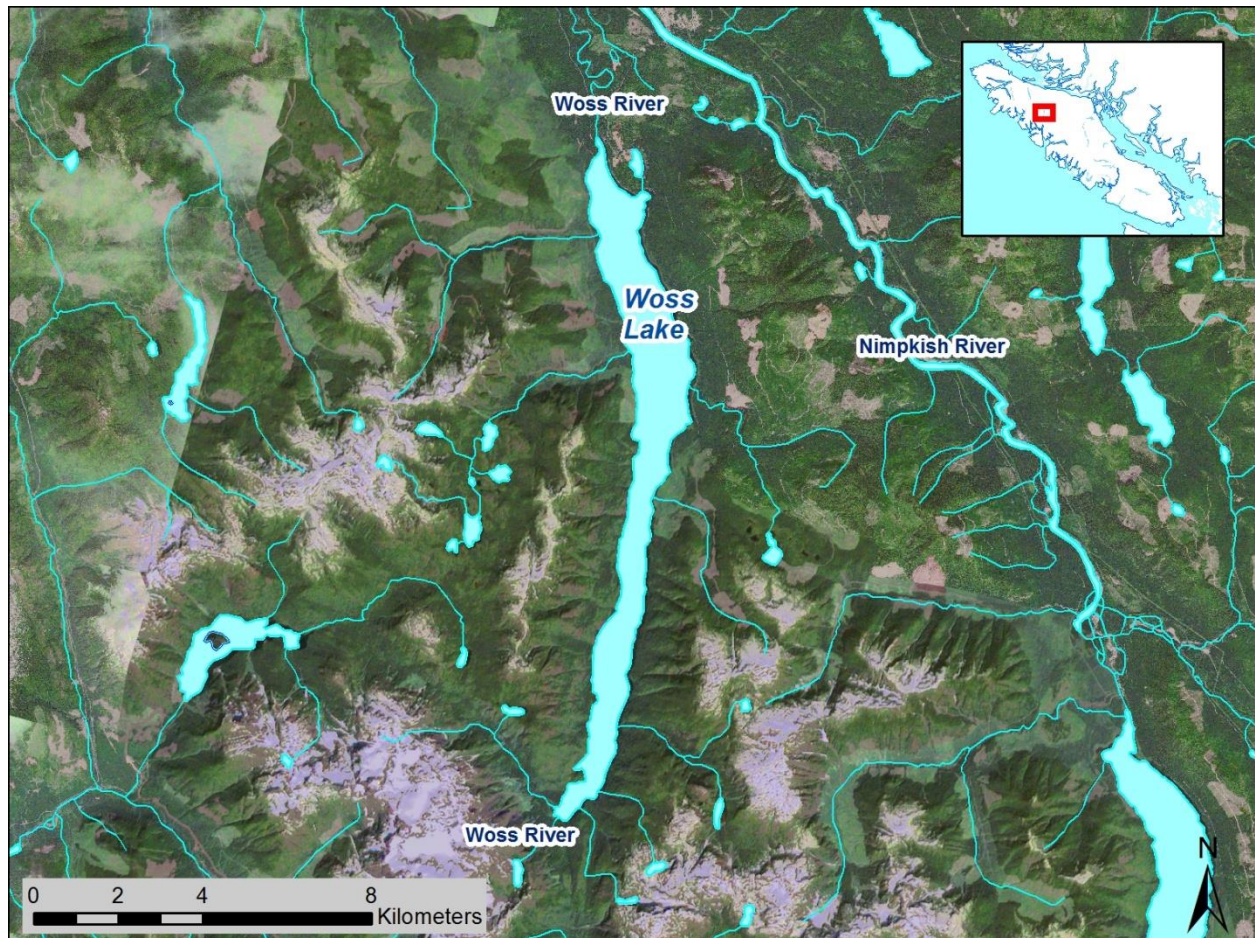


FIGURE 1. Map of Woss Lake and tributaries; a bathymetric profile is provided in Appendix 23 (Source: iMap BC).

¹² Lakes and reservoirs which are relatively deep, do not freeze over during winter, and undergo a single stratification and mixing cycle during the year (usually in the fall).

TABLE 1. Location, size, depth and water quality parameters at Woss Lake (Source: FLNRO files, Nanaimo, FISS, Shortreed et al. 2001).

Planning Unit	Waterbody Identifier	Surface Area (ha)	Perimeter (km)	Max. Depth (m)	Mean Depth (m)	pH	TDS (ppm)	Secchi Depth (m)	Survey Year(s)*
Nimpkish	00594NIMP	1,366	38.1	155	81			8.2	1970, 1986

*Survey years include only those years reported in the Fish Information Summary System (FISS) when the lake was assessed for physical characteristics and chemical parameters. Data for mean depth is from Shortreed et al. 2001.

The Woss Lake Provincial Park was created in 1995 as part of the Vancouver Island Land Use Plan. This park includes the southern portion of Woss Lake, a complete watershed of a major tributary at the south end of the lake, and a pristine old growth forest above the lake.

Tributaries

The Nimpkish River, which runs between Woss and Nimpkish Lakes is the largest river system on Vancouver Island and is the major spawning river in the Woss Lake watershed (Table 2). The Woss River is a short river flowing from Woss Lake into the Nimpkish River, just west of the community of Woss. Stream surveys were conducted on Woss Lake tributaries by MOE in the spring and summer of 1974 and the data is included in the Ministry files in Nanaimo.

TABLE 2. Names, order, length and/drainage area and other information for tributaries to Woss Lake (Source: Ptolemy, 1988; Hansen, 2002; FishFor Contracting Ltd., 2006; FLNRO files, Nanaimo).

Tributary	Length (km) and/or Drainage Area (km ²)	Other Information
Nimpkish River	>100 km long	The largest river on Vancouver Island and the major spawning stream in the watershed; has supported a small sport fishery for steelhead and cutthroat trout and also contains sockeye, coho, pink, chum and Chinook salmon. Previous studies including one by Lirette et al. in the late 1980's (<i>In Ptolemy 1988</i>) found the Nimpkish had the most severely depressed steelhead population on Vancouver Island and the stream was operating well below carrying capacity. The stream was fertilized in the early 2000's. An obstruction at Karmutsen Falls (~30 km upstream of Nimpkish Lake) was removed by blasting a fishway around the falls to allow salmon to migrate to the Schoen and Klaklakoma Lake systems. Various problems have been identified including habitat protection problems as a result of the Nimpkish Iron Mine, snagging of sockeye at Woss Camp and occasional losses of sockeye due to gill fungus (DFO, <i>In Ptolemy, 1988</i>).
Woss River		There is anadromous access and cutthroat are found throughout this river. Dolly Varden and rainbow are also found in the system. Gradients are up to 30% on some tributaries and some tributaries are reported as having no fish above gradient barriers. The stream averages 1.8 m wide and has mostly gravel/fines and gravel/cobble substrate. The stream is frequently confined with high banks. FishFor Contracting Ltd (2006) provides a complete physical assessment of the Woss River in their stream classification summary.
Davie River		Tributary to the Nimpkish River; contains steelhead, cutthroat, Dolly Varden coho and sockeye salmon.

Species Composition

Cutthroat and rainbow trout, Dolly Varden, Chinook, coho, sockeye and kokanee salmon, sculpins and stickleback have been recorded in Woss Lake (FLNRO files, Nanaimo files, Nanaimo). It's also believed the majority of the progeny from sockeye spawners in the watershed rear in Woss and Nimpkish Lakes (Shortreed et al, 2001).

Cutthroat trout are resident year-round in the Nimpkish River, with summer steelhead present from June - September and winter steelhead in the river from January - April. Dolly Varden are found in the Nimpkish River as are fall runs of Chinook and coho salmon. The Woss River contains cutthroat trout and winter steelhead.

Sockeye escapements to the entire Nimpkish River system averaged ~81,000 annually from 1987 until 1997 (Shortreed et al. 2001). In 1992, DFO noted that sockeye escapements the previous year were ~40,000 (Rimmer, 1992) and recently escapements declined to only a few thousand spawners (Rankin, in Shortreed et al, 2001).

Summary of Work and Reports

Truelson and Lyon (1974) conducted a detailed survey of tributaries to Woss Lake and their report can be found in the FLNRO files, Nanaimo. We've also provided a summary of their findings in Appendix 23. Monthly limnological sampling was carried out by DFO at the lake in 1978, 1979, and 1982, and annual hydroacoustic and trawl surveys were conducted for a number of years between the late 1970's, the 1990's and 2000 (Hyatt, in Shortreed et al. 2001).

2.0 Limits to Fish Production

Nutrients

With its favourable physical environment, strong P-limitation, and depauperate plankton community, Woss Lake was a highly favourable candidate for nutrient additions and was fertilized in 1988 and 1989. Fertilization resumed in 2000 and at a presentation to the Nimpkish Resource Management Board in 2008, Hyatt noted that lake treatment had been delivering significant production benefits to populations of sockeye in both Woss and Vernon lakes. He also noted that since 2000 the Woss Lake pelagic fish community had been comprised almost entirely of juvenile sockeye salmon, but that in 2006, trawl catches included large numbers of threespine stickleback. He cautioned that Woss Lake should not be fertilized again until monitoring revealed declines in stickleback.

Stream Habitat

Surveys were performed on Woss Lake tributaries in the spring and summer of 1974 by Truelson and Lyon. These investigators found that overall, streams in this system were short and had low flow and limited spawning area. They also found that although some tributaries had good habitat in the lower reaches, most tributaries that drain into Woss Lake had high gradients throughout their length, cascades or falls that prevented fish access, and many had obstructions which limited useable area. Truelson and Lyon (1974) identified two tributaries on the east side of Woss Lake as warranting protection because of their size, availability of spawning habitat, and potential for a resident trout population.

3.0 Angling Statistics

Angler Effort

Angler effort has averaged ~700 angler days/year at Woss Lake (Figure 2). In 1986 and 1989, angler effort was ~680 angler days but in 1992, angler effort increased to 1,100 angler days. After that, angler effort began to drop and in 2002, angler effort was ~1,000 angler days, in 2006, angler effort dropped to 600 angler days, and in 2011 angler effort dropped to 0.

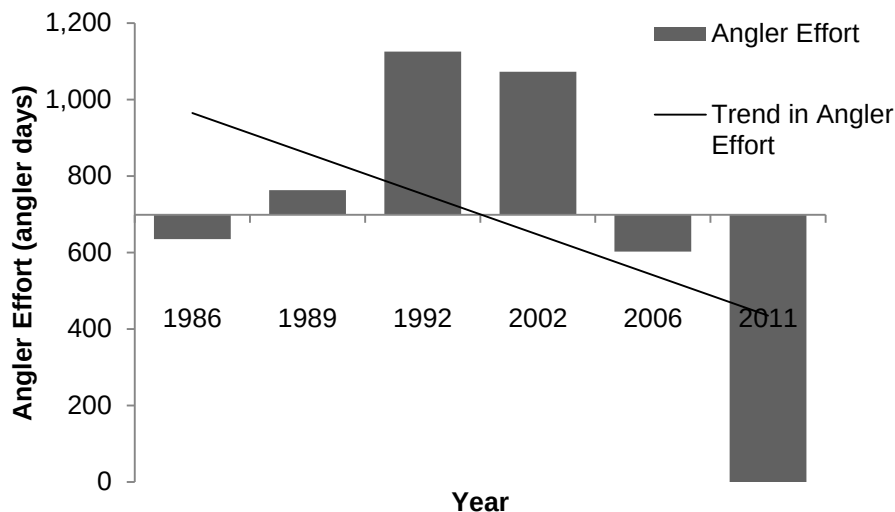


FIGURE 2. Angler effort (angler days) by year compared to average angler effort from 1986-2011 and trend in effort at Woss Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Catch

As with angler effort, total catch built throughout the 1980's with ~800 fish caught in 1986, 1,200 fish caught in 1989 and 1,500 fish caught in 1992 (Figure 3). In 2002, ~2,000 fish were caught by anglers in Woss Lake but in 2006 total catch dropped to ~600 fish which was below the long-term average of ~1,000 fish/year. In 2011, catch was 0.

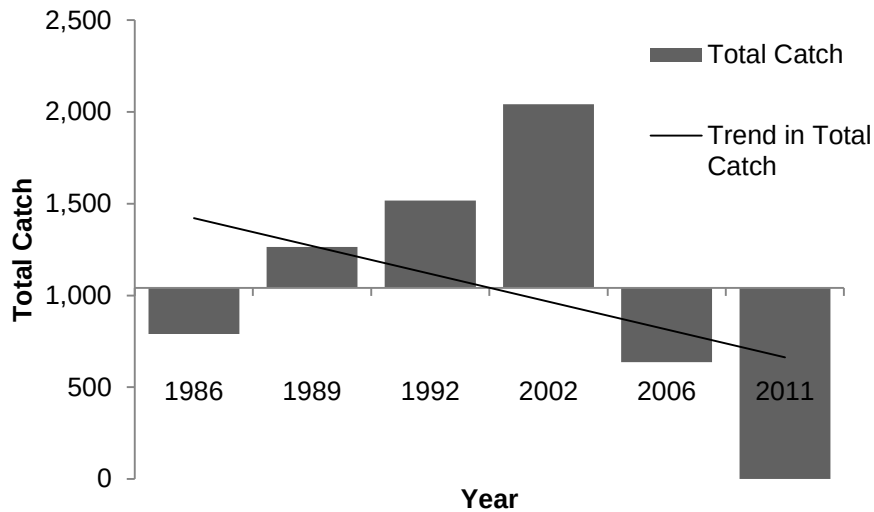


FIGURE 3. Total catch by year compared to average catch from 1986-2011 and trend in catch at Woss Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Sixty-four percent of angler catch at Woss Lake in 2006 was cutthroat trout (409 fish) and ~20% was rainbow trout (125 fish) (Table 3). Anglers also caught 102 Dolly Varden which amounted to 16% of the total catch.

TABLE 3. Catch of rainbow and cutthroat trout at Woss Lake 2006 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	Catch	% of Total
Cutthroat	409	64.3
Rainbow	125	19.7
Dolly Varden	102	16.0
Total	636	

Angler Success

Angler success has averaged 1.2 fish/day over the past 25 years (Figure 4). In 1986, angler success was 1.2 fish/day and in 1989 success rate increased to 1.6 fish/day. Angler success decreased in 1992 to 1.3 fish/day likely in response to the large increase in angler effort (Figure 2). Angler success reached a high of 1.8 fish/day in 2002 when angler effort declined and the catch by remaining anglers increased. However, by 2006, angler success had decreased to 1 fish/day and to 0 in 2011 when no angler effort was recorded.

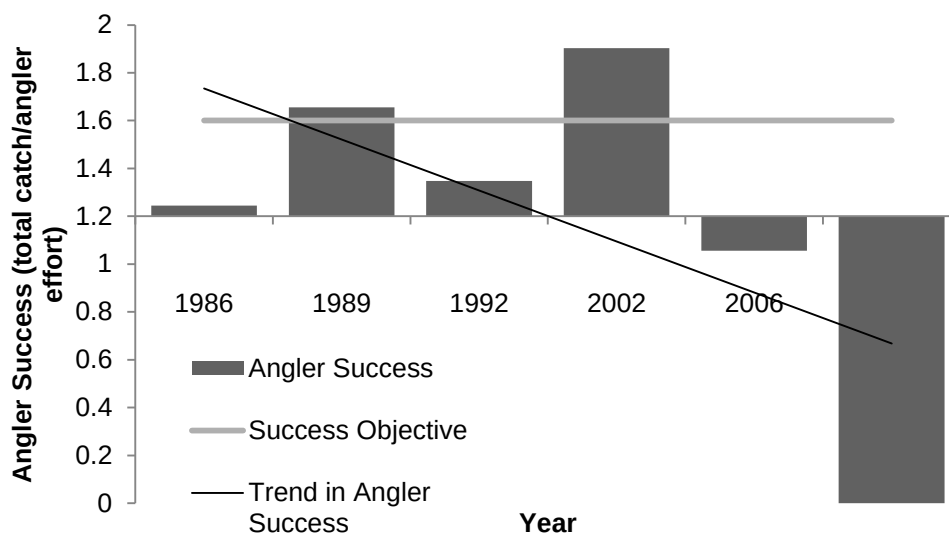


FIGURE 4. Angler success (total catch/total angler effort in angler days) and trend in angler success compared to average angler success and the objective for angler success (1.6 fish/angler day) at Woss Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Fishing Derbies

The Nimpkish Valley Rod and Gun Association (NVR&GA) hosted an annual fishing derby starting in 1970 (Law, 1987), and we've provided a summary of the number of participants and the catch in derbies held in 1984, 1985 and 1986 in Table 4 (Lutz, 1986). In 1984, there were 127 anglers participating in the derby and in the following 2 years there were ~70 participants. On average, 55 fish/year were caught and these ranged from 230 mm to >500 mm.

TABLE 4. Summary of number of anglers, number of fish caught and length range (mm) in Woss Lake fishing derbies in 1984, 1985 and 1986. There is no information on the species breakdown provided in the files (Source: Lutz, 1986).

Year	Number of Participants	Total Fish Caught	Length Range (mm)	Comments
1984	127	54	230 – ~500	most fish 280 – 410 mm
1985	70	66	270 – ~510	most fish 280 – 460 mm
1986	72	47	280 – 470	most fish 280 – 360 mm
1987	75	34	7 fish checked ranged from 345 mm – 495 mm (the winning fish) (Appendix 23).	

Law (1987) attended a Woss Lake Fishing Derby on June 23, 1987 to gather incidental information from derby organizers and check some of the fish caught. There were 75 participants who weighed-in 34 cutthroat trout. The winning fish was 495 mm (Table 4) and all cutthroat checked had sockeye fry in their stomachs (Law, 1987). The average angler day was ~4.5 hours, and the estimated success was ~1 fish/day.

Law spoke with several derby anglers who were concerned about declining trout stocks and some anglers who said that stickleback, which were once abundant in Woss Lake, had disappeared. Several anglers also expressed concern over the stability of several small tributaries and the netting of cutthroat trout during the broodstock capture in Woss Lake. While

local anglers portrayed a decline in the cutthroat population, Law noted it was difficult to determine based on this incidental information whether this unique, large lake cutthroat stock, which is similar in characteristics to Sproat Lake cutthroat, was actually declining.

Harvest

According to the VILQ, anglers harvested ~42% of their cutthroat (170 fish) and 64% of their rainbow trout (80 fish) catches in 2006 at Woss Lake (Table 5). There is no catch or harvest data for 2011.

TABLE 5. Catch, harvest and percent harvest of rainbow and cutthroat trout and Dolly Varden at Woss Lake 2006 (Source: Andrews, 2007, Silvestri 2013 in prep.).

Species	Catch	Harvest	Percent
Cutthroat	409	170	41.6
Rainbow	125	80	64.0
Dolly Varden	102	0	0.0
Total	636	250	39.3

4.0 Stock Status Indicators

Relative Abundance and Catch Indicators

Thirteen fish were captured in gillnets in Woss Lake in 1971. Thirty eight percent of the catch was comprised of cutthroat trout (five fish), 31% were rainbow trout (four fish), 23% were Dolly Varden (three fish) and 8% were kokanee (one fish) (Figure 5). No data regarding fish length, weight, sex or maturity was recorded and there is no information on how many gillnets were set, the number of net sets, the net types, location or soak times.

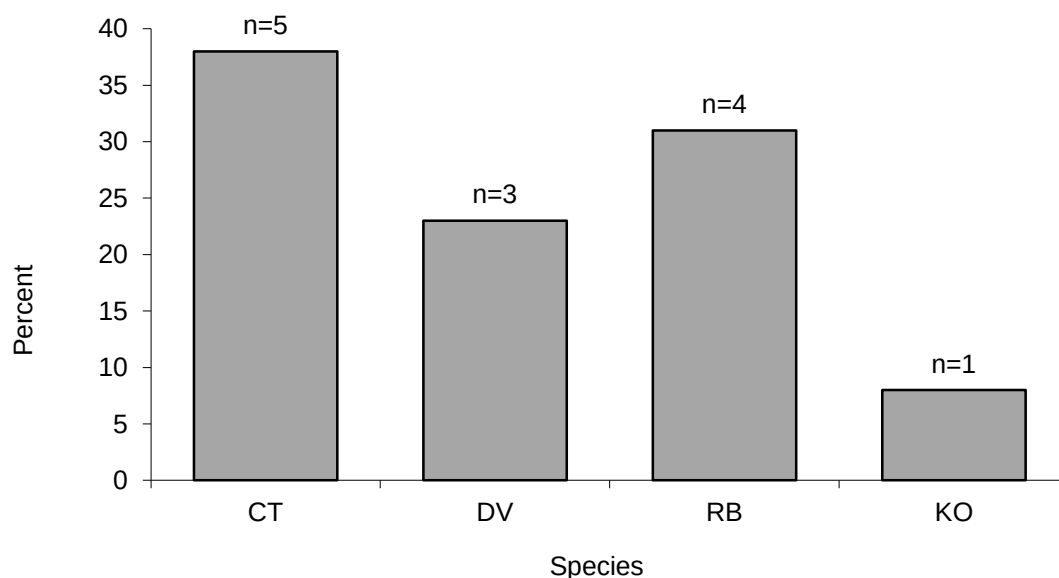


FIGURE 5. Total number and percent of cutthroat trout, rainbow trout, Dolly Varden and kokanee salmon captured in gillnets in Woss Lake in 1971 (N=13) (Source: FLNRO files, Nanaimo).

Data Gaps

We've outlined the age of existing data from Woss Lake in Table 6. Although there have been hydroacoustic surveys, lake limnology and water quality studies at Woss Lake within the last decade, other data including gillnetting is >10 years old. In addition, the gillnetting data on file contains no stock status data. Other data gaps include snorkel surveys of the Nimpkish and Woss Rivers for cutthroat and rainbow trout, and electrofishing surveys to establish densities and locations of juvenile trout. With the exception of the VILQ, there is no fishery data for Woss Lake.

TABLE 6. Summary of data gaps for Woss Lake required for wild stock conservation, fishery evaluation and stock monitoring and potential restoration and enhancement.

Factor	<10 years	>10 years	No data
Gillnetting		X	
Angler Creel Survey			X
VILQ	X		
Snorkel Surveys - Nimpkish (steelhead)	X		
Acoustic Surveys	X		
Electrofishing (streams)			X
Lake/Limnology Inventory	X		
Stream Habitat Inventory-		X	
Level 1 WPP tributary surveys			
Water Quality/Lake Productivity	X		
Instant Angler Counts or Box Creels			X

5.0 Fisheries Objectives and Management Strategies for Woss Lake

Existing Regulations

Woss Lake is covered by the general regional regulations of 4 trout but not more than 1 >50cm. There is no data on how often this goal is achieved. All wild trout and steelhead from streams, and all Dolly Varden caught in the lake or streams must be released.

There is no fishing on the Davie River (a tributary to the Nimpkish River) or tributaries December 1–May 15. All streams are covered by the region-wide, year-long single barbless hook, bait ban regulation.

Maximum Catch and Effort at Current Regulations

We were unable to determine maximum or optimum sustainable angler effort and catch despite the fact there was a close relationship between angler effort and total catch at Woss Lake (Figure 6). It appears as though Woss Lake is under-fished, however, we suspect that isn't the case given the steady increases in angler effort, catch and yield through the 1980's until the early 2000's (Appendix 8), followed by the decline in angler effort and total catch in 2006 and 2011.

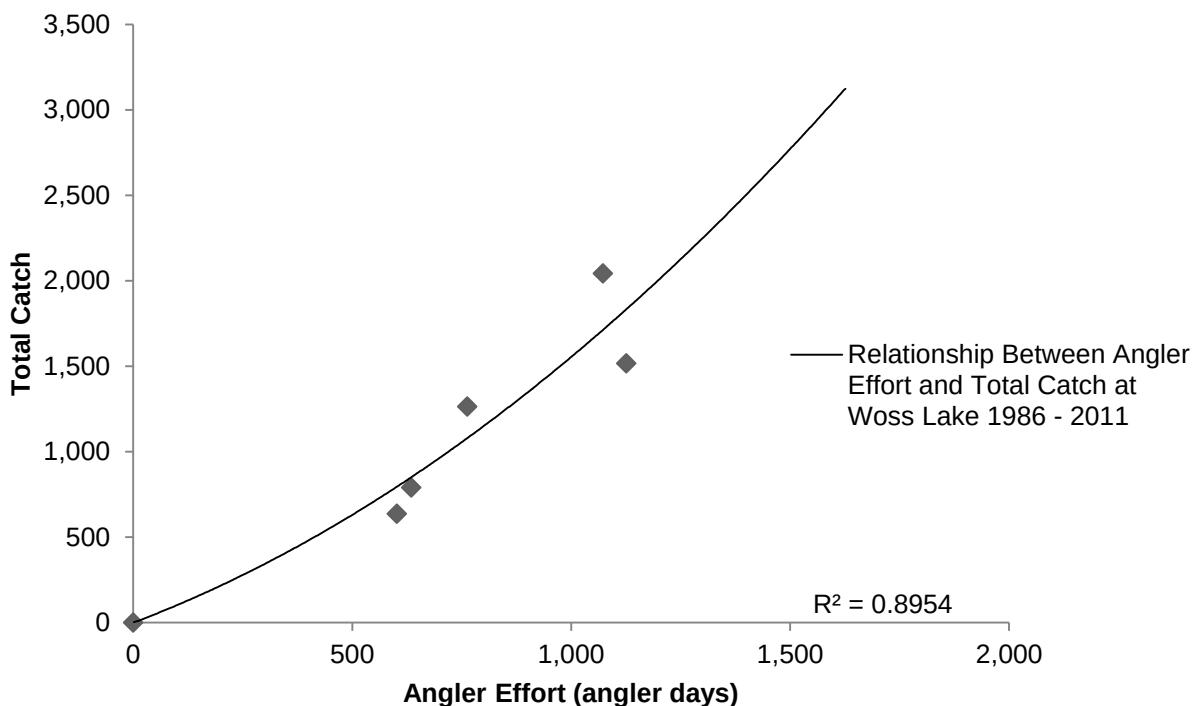


FIGURE 6. Angler effort (angler days) vs. total catch at the current regulations and trend in angler effort and total catch (second order polynomial) at Woss Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Fisheries Objectives and Management Strategies

The average angler success is below our regional target and there has been a downward trend in angler effort, catch and angler success ever since these parameters hit high levels in the late 1990's and early 2000's. Harvest rates at Woss Lake in 2006 were higher (40%) than the average harvest rate at Vancouver Island large lakes (30%), however, what is especially concerning is that no angler effort was recorded at Woss Lake in 2011. In addition, although some large cutthroat (>400 mm) were caught in fishing derbies in the 1980's, anglers at the time suggested that cutthroat trout catches were declining. There was no data then, and there continues to be no data to evaluate if that was, or is the case.

1. Declines in total catch are a concern and there is no information on stock status indicators including mean and maximum length, length-at-age or length-at-maturity. We recommend gillnetting at Woss Lake be done immediately to examine stock status.
2. Conservation regulations may be necessary and slot limits may be required to ensure both immature and large fish are protected (Section 11; Chapter 1). We recommend determining the lengths for these limits following a review of the gillnetting results. We also recommend that regulations focus on both cutthroat and rainbow trout since both comprise the angler creel and the implementation of an out-of-cycle regulation be implemented in 2014 if warranted.
3. Gillnetting should be repeated in 2017 (Table 16; Chapter 1) to monitor stock status indicators. More conservative regulations such as catch-and-release may be required if these netting results and the next VILQ indicate stock declines.

4. Determine if the annual Woss Lake derby still occurs and if so establish a partnership with the PAF&GA to monitor derby catch and angler success.
5. Implement a public awareness program focused on regulations and information regarding fish stocks and fish identification to assist Woss Lake anglers.

Operational Management Plan for Woss Lake

We've outlined an operational management plan for Woss Lake in Table 7. It's important that gillnetting be conducted immediately to establish stock status and implementation of an out-of-cycle regulation may be required in 2014. In addition to gillnetting, we've suggested snorkel and electrofishing surveys to gather baseline data on spawning and juvenile fish, and monitoring the Woss Lake derby. We've also recommended habitat assessment and enhancement projects as well as a signage program to provide information to anglers regarding Woss Lake fish stocks and regulations. Finally, we've recommended discussing future fertilization projects with DFO as this enhancement technique may benefit Woss Lake fish stocks.

TABLE 7. Operational management plan for Woss Lake.

Activity	Objective	Tentative Schedule
Stock Assessment	Conduct gillnetting assessment to determine stock status.	2013; 2017
	Conduct snorkel surveys for spawning cutthroat and rainbow in Nimpkish and Woss Rivers in June.	2017
	Conduct an electrofishing survey in the Nimpkish and Woss River to gather baseline data on juvenile fish populations.	
Regulations	Develop conservation regulations based on initial gillnetting results; more restrictive regulations may be required after the next netting and/or VILQ Consult with the PAF&GA and VIFFRAC about proposed changes.	Possibly in 2014
Fisheries Assessments	There are no angler creel surveys on Woss Lake, consequently, no data regarding effort and catch; this survey can be done with box angler creels.	2014/15
	Partner with PAF&GA to monitor annual derbies and collect stock status, catch and effort data.	2014/15
Public Awareness	Erect signs at Woss Lake to advise anglers of regulations changes.	2014/15
Habitat - Assessment	Level 1 WRP is suggested on key tributaries; develop a restoration plan based on assessment results.	2017+
	Conduct Level 2 WRP for priority streams (see also Truelson and Lyon, 197); develop and implement plans.	2018+
Habitat - Enhancement	Fertilization by DFO was stopped because of increases in stickleback. Review stock status and, depending on results, consider fertilizing if cutthroat stocks are declining. Discuss with DFO and develop a joint plan in partnership with the Alert Bay Band and/or Nimpkish First Nations.	2017+
VILQ	Evaluate changes in fisheries statistics every three years; review in conjunction with results of gillnetting assessments to determine if more restrictive regulations are required.	Ongoing

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Appendix 1

The Vancouver Island Lakes Questionnaire

The Vancouver Island Lakes Questionnaire (VILQ) was set up as a tool to determine what lakes anglers fished, provide an estimate of how many fish anglers caught, and their success (catch per angler day). The VILQ provides a course filter for the evaluation of angler catch and success through time so management planning can focus on those lakes where these factors are declining. Because the VILQ provides data regarding angler effort, it allows fisheries managers in Region 1 to set management priorities and develop management actions for the highest use lakes.

The VILQ provides useful trend information on angler catch, angling effort and angler success rates that can be used in setting lake priorities. The data is also comparable since the same sampling procedure has been in place since Ministry statisticians designed this survey in the late 1980's. Because of the inherent bias in the survey including inconsistency when the survey takes place, reliance on angler's memories and a positive catch bias, precision around the estimates of the true value decreases. We recognize there is a positive catch bias when anglers are asked to recall how many fish they caught in a particular lake a year after they fished that lake. Our assumption is that the bias will be the same for each year of the survey and, therefore, the catch and angler success data is comparable and, trend information derived from the data is also comparable.

The VILQ was originally designed to run every three years however budget constraints and other priorities prohibited this sampling regime over the 24 year span since it was introduced. Currently there are five years of survey data which provide trend information for the large lakes in the region.

Appendix 2

The Large Lakes Kokanee Model

In the 1980's MOE convened a Large Lakes Committee to develop a coordinated management strategy for use in managing provincial large lakes (Ministry of Environment, 1985). The committee's first task was to determine a means of calculating the potential production of large lakes assuming that, in most instances, the sport fish species of interest were rainbow trout and kokanee, and recognizing that, again in most cases, little, if any hard data existed. The resulting Large Lakes Kokanee Model was developed on data from some of BC's more productive lakes in the Interior of the province and relied on TDS and mean depth to calculate a morphoedaphic index (MEI) for the lake (Russell et al., 1990). The MEI would then be used to predict kokanee catch yield for the lake which, in turn, would be used to estimate the number of predators (i.e. rainbow trout) that could be supported (Russell et al., 1990). Once a manager determined theoretical estimates of kokanee yield and predaceous rainbows, he/she would determine which of four potential large lake management strategies to use:

- Type I Large Lake – few, if any kokanee; few, if any, predaceous trout.
- Type II Large Lake – abundance of kokanee; no predaceous trout.
- Type III Large Lake – few kokanee; numerous predaceous trout.
- Type IV Large Lake – few if any kokanee; no predaceous trout.

Whether the Large Lakes Model is appropriate for predicting the productivity of Vancouver Island large lakes has been a long standing question in this region. Previous investigators including Russell et al., (1990) and Griffith (1989) tested this model on Comox and Cowichan Lakes respectively, and both suggest the model has limitations for use in this region. Ptolemy (1990) also reviewed the use of the model at Cowichan Lake and pointed out that juvenile coho and stickleback form part of the prey population at this lake and the combined population size of these species is likely significant. As a result, potential production of large piscivorous fish at this, and likely other coastal large lakes depends on the availability of prey other than kokanee which is not considered by the Large Lakes Kokanee Model. In addition, large, predaceous cutthroat trout co-occur with rainbow trout in coastal large lakes. This species, in particular, forms a large portion of the predator biomass in many Island large lakes which is also not considered in the model. Griffith (1989) points out that there may be a much more complex association between the kokanee and stickleback prey and rainbow and cutthroat trout predators than can be accounted for by the model. Finally, in contrast to the Interior where the kokanee model was developed, on Vancouver Island, kokanee rarely exceed 30 cm and incidental observations suggest there are exceedingly large, stunted populations of this species in Island large lakes. Predictions of kokanee abundance made by the model likely cannot account for kokanee stock structure in Region 1 lakes.

Whether the Large Lakes Model developed by MOE is appropriate for predicting the productivity of Vancouver Island large lakes has been a long standing question in this region. Previous investigators including Russell et al (1990) and Griffith (1989) tested this model on Comox and Cowichan Lakes respectively and both authors, as well as Ptolemy (1990) suggest the model has limitations for use in this region because the model may not account for the much more complex association between prey and predators species at Island large lakes than found in the Interior of province where the model was developed.

We were unable to run the Large Lakes Model on lakes which do not contain kokanee/sockeye, or for which TDS was not available. Of the ten lakes on which we were able to run the model, the difference between the predictions based on a medium yield of kokanee and angler catch varied by up to 400%. We found no correlation ($R^2 = 0.034$) between the potential yield of predaceous fish predicted by the model, and the actual yield of these species.

We present the results of our predictions of the number of predaceous fish in Island large lakes using the Large Lakes Kokanee model in Table 1 and Table 2. In short, we were unable to run the model on five lakes which do not contain kokanee/sockeye, and on Nitinat Lake for which TDS is not available. Of the ten lakes on which we were able to use the model, the difference between the predictions based on a medium yield of kokanee and angler catch varied by up to 400%. We found no correlation ($R^2 = 0.034$) between the potential yield of predators predicted by the model, and the actual yield of these species.

TABLE 1. Predicted number of predators at low, medium and high yields of kokanee/sockeye at Vancouver Island large lakes. Note: we could not estimate predator production for lakes with no kokanee/sockeye. For lakes with kokanee/sockeye, the model under-estimated the number of predators by between 5% and 400% on 4 lakes, and overestimated by 5% to 90% on remaining lakes (i.e. anglers reported catching up to 90% more predators than the model predicted the lake could produce (Source: FLNRO files, Nanaimo).

Lake	Sockeye	Kokanee	MEI (ppm/ft)	Number Predators Supported		
				Low	Medium	High
Alice	x		0.451113072	236	490	944
Buttle	No kokanee/ sockeye		0.197735924	No prediction possible		
Lower Campbell			0.708842814			
Upper Campbell			1.390958768			
Comox		x	0.109289617	282	563	1095
Cowichan		x	0.320570979	1110	2127	3976
Elsie	x		1.243201243	313	594	1320
Great Central	x	x	0.048875855	682	1213	2425
Henderson	x		0.196813496	207	437	806
Huaskin	No kokanee/sockeye		0.04669188	No prediction possible		
Kennedy	x	x	0.167464115	868	1737	3377
Nimpkish		x	0.042225534	490	871	1742
Nitinat	x		No TDS			
Sproat	x	x	0.145819093	506	1013	1969
Victoria	No kokanee/sockeye		0.244943663	No prediction possible		
Woss	x	x	0.079254079	271	482	965

TABLE 2. Number of predators predicted at medium kokanee/sockeye yields compared to the catch of predaceous fish (cutthroat trout and Dolly Varden char) in 2006 and the percent difference between the two. Note: catch data is from the 2006 Vancouver Island Lakes Questionnaire (Source: Aitzhanova, et al. 2003; Andrews, 2007).

Lake	Number of Predators Predicted with Medium Kokanee Yields	Cutthroat and Dolly Varden Catch 2006	Percent Difference Between Medium Prediction and Catch
Alice	490	466	-5.2
Comox	563	5875	90.4
Cowichan	2127	7091	70.0
Elsie	594	466	-27.5
Great Central	1213	4091	70.4
Kennedy	1737	966	-79.8
Nimpkish	871	170	-411.0
Sproat	1013	3091	67.2
Woss	482	511	5.7

Appendix 3

MEI and Predicted Yield Based on MEI at Vancouver Island Large Lakes

TABLE 1. TDS (ppm), average depth (ft) MEI (T/D), surface area (acres), average annual catch, harvest rate, harvest (catch*harvest rate), estimated yield (pounds/acre/year) and predicted yield based on MEI* at Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) (Source: FLNRO files, Nanaimo).

Lake Name	TDS (ppm)	Mean Depth (ft)	MEI	Surface Area (acres)	Predicted Yield based on MEI (pounds/acre/yr)*
Alice	46	101.97	0.45111	3,007.41	1.34
Buttle	40	202.29	0.19774	7,641.48	0.89
Lower Campbell	40	56.43	0.70884	6,650.86	1.68
Upper Campbell	56	40.26	1.39096	7,353.09	2.36
Comox	22	201.3	0.10929	5,183.95	0.66
Cowichan	53	165.33	0.32057	15,319.26	1.13
Elsie	32	25.74	1.2432	2,733.09	2.23
Great Central	20	409.2	0.04888	12,555.56	0.44
Henderson	63	320.1	0.19681	3,814.81	0.89
Huaskin	10	214.17	0.04669	5,234.57	0.43
Kennedy	21	125.4	0.16746	15,987.65	0.82
Nimpkish	17	402.6	0.04223	9,019.75	0.41
Sproat	32	219.45	0.14582	9,320.99	0.76
Victoria	35	142.89	0.24494	3,891.11	0.99
Woss	17	214.5	0.07925	3,372.84	0.56
Total				111,086.42	15.61
Minimum	10	25.74	0.04223	2,733.09	0.41
Maximum	63	409.2	1.39096	15,987.65	2.36
Average	33.6	189.442	0.35959	7,405.76	1.04

*Ryder's (1965) simplified regression: $Y \sim 2\sqrt{X}$ where Y = fish yield and X = MEI

Appendix 4

Characteristics of fish in Vancouver Island Large Lakes

Length Frequency Distributions of Cutthroat and Rainbow Trout Caught by Anglers by Decade
1950 - 2000

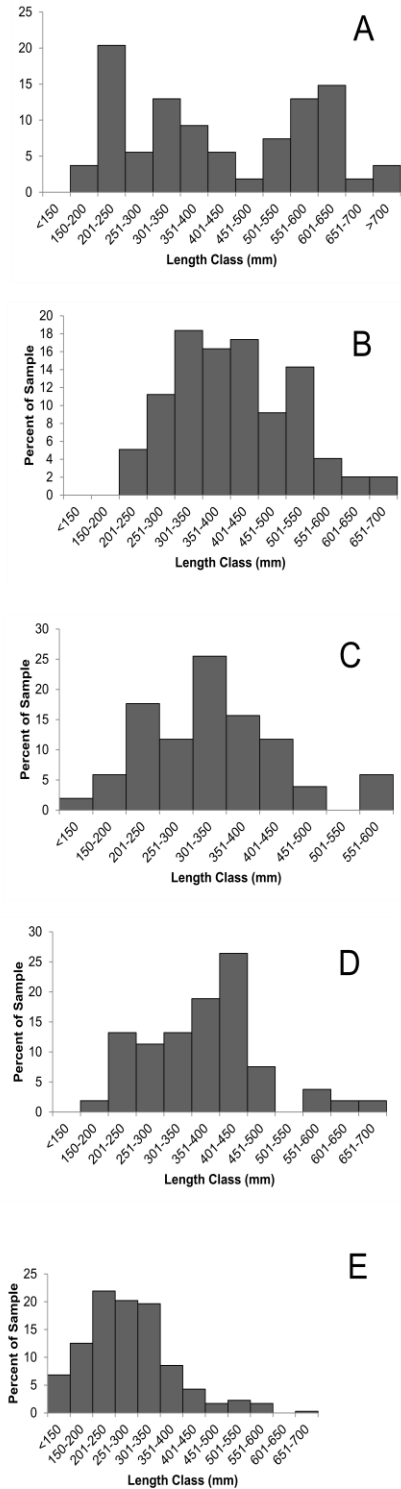


FIGURE 1. Length frequency distributions of cutthroat trout captured by anglers in (A) the 1950's (N=54), (B) the 1970's (N=98), the 1980's (N=51), the 1990's (N=53) and the 2000's (N=351) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss (Source: FLNRO files, Nanaimo).

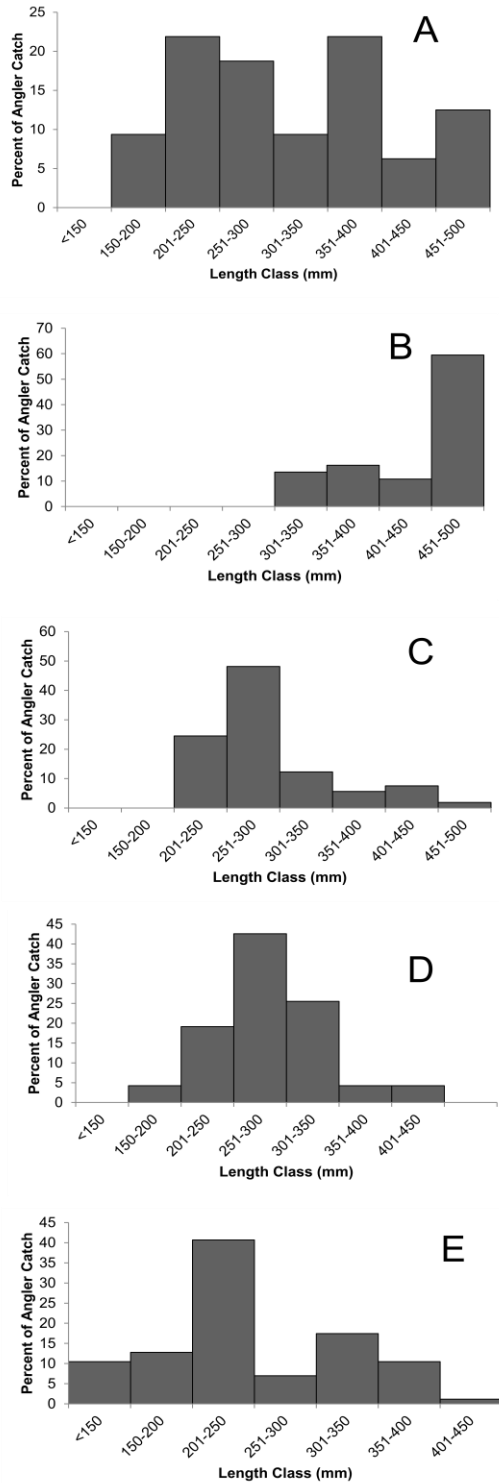


FIGURE 2. Length frequency distributions of rainbow trout captured by anglers in (A) the 1950's (N=32), (B) the 1970's (N=37), the 1980's (N=106), the 1990's (N=47) and the 2000's (N=86) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss. Note: we removed rainbow >500 mm as these are likely steelhead (Source: FLNRO files, Nanaimo).

Length vs. Weight Relationships for Cutthroat and Rainbow trout in Vancouver Island Large Lakes

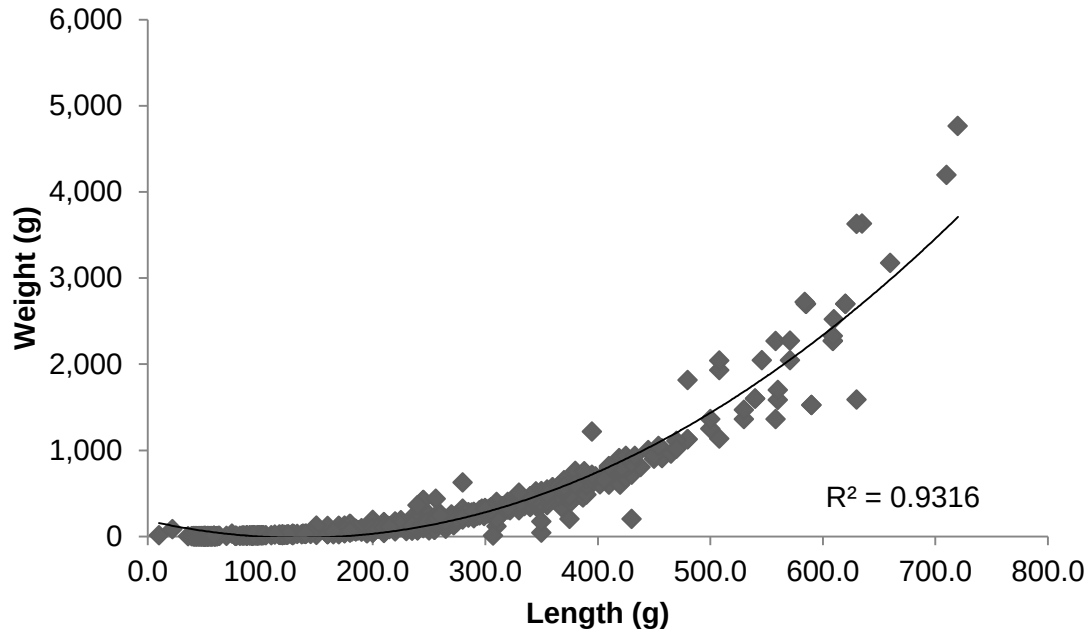


FIGURE 3. Length vs. weight relationship for cutthroat trout captured on Vancouver Island by angling, gillnetting, net trap and electrofishing 1951 – 2011 (N=878) (Source: FLNRO files, Nanaimo).

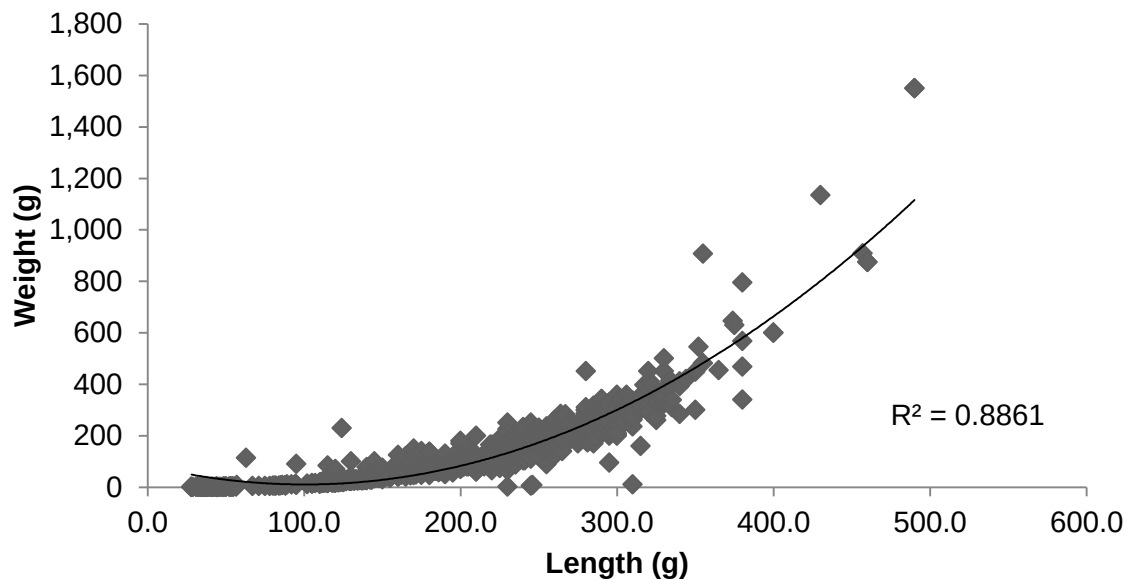


FIGURE 4. Length vs. weight relationship for rainbow trout captured on Vancouver Island by angling, gillnetting, net trap and electrofishing 1951 – 2013 (N=930); rainbow >500 mm have been removed as these are defined as steelhead (Source: FLNRO files, Nanaimo).

Appendix 5

Procedure and Results of Prioritization of Vancouver Island Large Lakes

We prioritized large lakes by assigning points for total angler effort, total catch and average angler success as determined from VILQ data between 1986 and 2011. We added the total number of angler days to determine the total angler effort at each lake for the six survey periods. The lake with the highest angler effort received a ranking of one, which reflected the popularity of the lake and resulting angling pressure placed on the stocks. The lake with the second highest angler effort and catch received a two, and so on.

We then added angler catch for each lake for the six survey periods to determine total catch at each lake. We then assigned the same ranking scheme for catch at each lake so that the lake with the highest catch received a one; the lake with the second highest catch received a two and so on.

We divided the total catch by the total angler effort for each survey then calculated the average angler success over the entire survey period. We then reversed our ranking criteria for this parameter to reflect possible angler impacts and low stock sizes. For example, we gave the lake with the lowest angler success a rank of one; the lake with the second lowest success received a two and so on.

We added the ranks by each lake for all three factors to determine a total score for each lake (Table 1). The lake with the lowest total score was ranked as the highest priority; the lake with the 2nd lowest score was the 2nd highest priority through to the lake with the highest total score which became the lowest priority.

TABLE 1. Priority ranking of Vancouver Island Large Lakes. To determine priority, we assigned points for total catch, total angler effort and average angler success at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Large Lake by Priority	Total Catch	Points	Total Angler Effort	Points	Average Angler Success		Total Points	Regional Priority
Cowichan	81,591	16	99,014	16	1.01	16	48	1
Comox	38,069	12	38,678	15	1.22	13	40	2
Sproat	35,810	11	36,135	14	1.18	15	40	3
Upper Campbell	63,240	15	32,295	13	2.24	7	35	4
Great Central	22,506	10	17,639	10	1.55	10	30	5
Lower Campbell	50,129	13	27,414	12	2.61	3	28	6
Buttle	54,124	14	21,490	11	3.00	1	26	7
Alice	12,519	7	7,634	8	1.43	11	26	8
Woss	6,249	5	4,199	5	1.20	14	24	9
Victoria	19,419	9	9,363	9	2.50	4	22	10
Elsie	14,086	8	7,443	7	2.29	5	20	11
Kennedy	7,268	6	4,710	6	2.19	8	20	12
Nimpkish	2,004	4	1,259	4	1.33	12	20	13
Nitinat	1,525	3	1,065	3	1.60	9	15	14
Huaskin	68	1	20	1	2.27	6	8	15
Henderson	125	2	35	2	2.98	2	6	16

Appendix 6

Data Files Reviewed and Compiled for Completion of Large Lakes Plan

We reviewed each large lakes file in the Fisheries and Water Sections of the Ministry office in Nanaimo and conducted Fish Inventory Data Queries (FIDQ), Ecocat, Ministry of Forests and BC Hydro web site searches to ensure we had all data collected on large lakes in the Vancouver Island region (Table 1). In many cases, we had to enter raw data into Excel files before we could conduct any analyses. We also contacted researchers listed in reference sections of lake reports to gather any additional data and information. Finally, we conducted a search at the PBS Library for DFO publications and technical reports conducted on large lakes in the region and entered that data into Excel files so we could perform our analyses.

TABLE 1. Sampling type, year, dates of sampling, data and information available and source for data used in the assessment of stock status for Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) (Source: FLNRO files, Nanaimo).

Lake	Sampling Type	Year	Dates	Data/Information	Source
Alice	Gillnetting	1969	August	no lengths & weights; just sample size	Alice Lake file
		1980	September	length, weight, sex, maturity	Alice Lake file
Buttle	Angling/Gillnetting	1951	June	length, weight, sex, maturity, age	Ecocat Lake Summary of Buttle Lake (unknown author) and McMyynn and Larkin
	Angling/Gillnetting	1954	August	cutthroat with length; rainbow has weight some sex and age	Ecocat Lake Summary (unknown author)
	Gillnetting	1960	July 30-31	no length/weight data; just numbers	
	Gillnetting	1960	Sept 12-13	no length/weight data; just numbers	
	Gillnetting	1960	October 22	just numbers no length/weight	
	Gillnetting	1967	June - August	numbers, mean length, range and mean weight, range; no raw data Ecocat - Clarke 1980	
	Unknown	1967	Oct/Dec	numbers, mean length, range and mean weight, range; no raw data in Buttle file	
	Unknown	1968	April	numbers, mean length, range and mean weight, range; no raw data in Buttle file	
	Gillnetting	1969	June-August	numbers, mean length, range and mean weight, range; Burns in Ecocat - notes	

Lake	Sampling Type	Year	Dates	Data/Information	Source
	Gillnetting	1969	October 21-23	length/weight, sex, maturity, Ecocat, Burns in Ecocat - notes	
	Gillnetting	1979	May	lengths; data sheets in Buttle file	
	Tagging	1982	Varies - April-June	lengths; Hatfield Consultants - raw data in Buttle file; some Upper Campbell tributaries	
	Gillnetting	1984	June 19	length data; Buttle Lake file - raw data	
	Unknown	1985	June 3	length, weight, sex	Unknown; data sheets Buttle file
	Gillnetting	1985	June 4	numbers, lengths, weight, sex	water quality monitoring file Buttle Lake
	Gillnetting	1986	June 12	numbers, lengths, weight, sex	water quality monitoring file Buttle Lake
	Gillnetting	1987	October 14	numbers, some length, weight, sex, some maturity	water quality monitoring file Buttle Lake
	Gillnetting	1988	June	numbers, some length, weight, sex, some maturity	water quality monitoring file Buttle Lake
	Gillnetting	1989	June	numbers, some length, weight, sex	water quality monitoring file Buttle Lake
	Gillnetting	1990	June 12	numbers, some length, weight, sex	water quality monitoring file Buttle Lake
	Angling	1991	August/September	length and some weight data	Buttle lake file - no source
	Gillnetting	1991	June 18	length, weight, sex	water quality monitoring file Buttle Lake
	Angling	1992	June 3	Thelwood creek - length, sex, maturity	Buttle lake file - no source
	Gillnetting	1992	June 16	length, weight, maturity, sex	water quality monitoring file Buttle Lake
	Gillnetting	1993	June 8	length, weight, maturity, sex	Hansen, 1993; Ecocat - Netting in S. Buttle
	Gillnetting	1994	June 21	length, weight, maturity, sex	Hansen, 1994; Ecocat - Netting in S. Buttle
	Gillnetting	1995	June	length, weight, sex	Buttle lake file - no source
	Gillnetting	1996	June	length, weight, sex	water quality monitoring file Buttle Lake
	Gillnetting	1997	June	length, weight, sex	water quality monitoring file Buttle Lake

Lake	Sampling Type	Year	Dates	Data/Information	Source
					Lake
	Gillnetting	1998	June	length, weight, sex	water quality monitoring file Buttle Lake
	Gillnetting	1999	July	length, weight, sex	Buttle lake file - no source
	Electrofishing	1999	September	Ralph, Henshaw, Thelwood; length, weight	Hallum, Knight 2000 in Buttle file
	Minnow Trap	1999	September	Ralph, Henshaw, Thelwood; length, weight, some ageing	Hallum, Knight 2000 in Buttle file
	Minnow Trap	1999	November	Ralph, Henshaw, Thelwood; length, weight, some ageing	Hallum, Knight 2000 in Buttle file
	Gillnetting	2001	May	length, weight, sex	Buttle lake file - no source
Comox	Gillnetting	1948	October	length, sex, maturity	FISS
	Gillnetting	1951	June & August	length, weight, sex, maturity	FISS
	Gillnetting	1953	May, June, July	length, weight, sex, ageing	FISS
	Electrofishing	1989	August	Comox Creek & U. Puntledge; just numbers and ages	Comox Lake file; Russell et al., 1990
	Unknown	1993	November	U. Puntledge, Cruikshank, length, weight	Comox Lake File - DFO?
	Gillnetting	2009	August	length, weight, sex, maturity, age	Comox Lake File
	Gillnetting	2010	August	length, weight, sex, maturity, age	Comox Lake File
	Electrofishing	2011	September 6-7	Rees & Comox Creeks length, weight	Comox Lake File
	Minnow Trap	2011	August	U. Puntledge numbers	Comox Lake File
	Hydroacoustic	2009	July	kokanee estimates	Comox Lake File
Cowichan	Angler creel surveys	2009	All Year	numbers, lengths, weight	Comox Lake File
	Angler creel surveys	2010	All Year	numbers, lengths, weight	Comox Lake File
	Unknown	1950	June	Honeymoon Bay; DV sampling, lengths	FISS
	Angle	1953	March	Cowichan Lake and River; rainbow; length, weight, some sex	FISS
	Unknown	1953	November	Cutthroat length, weight	FISS
	Gillnet	1984	December	Bear Lake channel; 1 cutthroat caught	Cowichan Lake file

Lake	Sampling Type	Year	Dates	Data/Information	Source
	Trawl-mid-water	1984	November	kokanee numbers only	Rutherford, 1987 (DFO) in Cowichan file
	Trawl-mid-water	1985	October	kokanee numbers only	Rutherford, 1987 (DFO) in Cowichan file
	Trawl-mid-water	1986	October	kokanee numbers only	Rutherford, 1987 (DFO) in Cowichan file
	Trawl-mid-water	1987	March	kokanee numbers only	Rutherford, 1987 (DFO) in Cowichan file
	Trawl-mid-water	1987	August	kokanee numbers only	Rutherford, 1987 (DFO) in Cowichan file
	Gillnetting	1989	July 24-25	sinking near Nixon, Robertson and vertical in lake; counts and some lengths; soak time	Griffith, 1989 in Cowichan file
	Electrofishing	1989	July-August	tributaries; length data; ageing	Griffith, 1989 in Cowichan file
	Angler creel survey & Derby	1989	July-October	length data and some sex data; ageing	Griffith, 1989 in Cowichan file
	Electrofishing	1990	August	tributaries; length and age	Stewart, 1990 Appendix G
	Angler creel survey & Derby	1990	August-October	lengths and ageing; age at length entry	Stewart, 1990 Appendix F
	Net Traps	1996	November	lengths and weights	Cowichan Education Centre in Cowichan file
	Net Traps	1998	April-June	lengths	Cowichan Education Centre in Cowichan file
	Minnow Trap	2005	September-October	Gracie creek; Cottonwood creek; lengths	Cowichan file
	Gillnet	2009	August	Nixon and Shaw lengths, weights, maturity, sex, ageing	Cowichan file
	Angler creel survey	2009	All Year	lengths and weights	Cowichan file
	Angler creel survey	2010	All Year	lengths and weights	Cowichan file
	Angler creel survey	2011	All Year	lengths and weights	Cowichan file
	Gillnet	2011	August	Nixon and Shaw lengths, weights, maturity, sex, ageing	Cowichan file
Elsie	Electrofishing	2012	August 27-29	Nixon and Shaw lengths, weights, maturity, sex, ageing	Cowichan file
	Gillnetting	1962	June 11	floating net; sample numbers	Triton Environmental, 1994 in Elsie Lake file

Lake	Sampling Type	Year	Dates	Data/Information	Source
Great Central	Gillnetting	1963	April 2	sample numbers	Triton Environmental, 1994 in Elsie Lake file
	Gillnetting	1968	June 4	floating net; sample numbers	Triton Environmental, 1994 in Elsie Lake file
	Gillnetting	1969	August	sample numbers	Ecocat - Harding, Reconnaissance Survey
	Gillnetting	1969	November 4	sinking and floating nets; length, weight, sex	FISS and Ecocat - Burns, 1969 notes on Elsie
	Gillnetting	1994	May 26	length, some weights, sex, maturity and age	Triton Environmental, 1994 in Elsie Lake file
	Gillnetting	1996	October 11	length, weight, sex, maturity, age	Klohn Crippen, 1999 Reconnaissance on Elsie
	Electrofishing	1996	October 11	length, some weights, ageing	Klohn Crippen, 1999 Reconnaissance on Elsie
	Electrofishing & Minnow Trap	2001	June 21, 26; July 26	lengths	BC Hydro file; Ecocat BC Hydro - Wickman
	Gillnetting	2002	August 7-9	lengths, weight, ageing	cited in Burt and Robert, 2003 found on on-line BC Hydro search; data sent electronically from author
	Electrofishing	2002	September 15-19	Ramsay Creek; length, weight, sex, maturity, ageing	cited in Burt and Robert, 2003 found on on-line BC Hydro search; data sent electronically from author
Great Central	Angling	2002		Elsie Lake; length and ages	cited in Burt and Robert, 2003 found on on-line BC Hydro search; data sent electronically from author
	Electrofishing	2005		tributaries; not confirmed cutthroat; no raw data just report graphs	Lewis and Ganshorn, 2005-found on on-line BC Hydro search
	Gillnetting	1978	June & July	lengths	field data sheets in GC file
Henderso n	Angling	1970	May-August	lengths	in Narver, 1975 - in GC file; no raw data for ageing-summaries only
	Gillnetting	1977	May	lengths	data in file
Huaskin	Minnow Trap	1996	August/Sep tember	length ranges and sample size	data in file
	Gillnetting	1992	August	length, weight, sex,	MoE; data in Huaskin

Lake	Sampling Type	Year	Dates	Data/Information	Source
Kennedy	Hydroacoustic	1987	February-November	maturity sockeye and kokanee; stickleback trapping and zooplankton summaries no data	File no fish data for Kennedy
	Trawl-mid-water	1985	April	sockeye and kokanee; stickleback trapping and zooplankton summaries no data	no fish data for Kennedy
	Trawl-mid-water	1984		sockeye and kokanee; stickleback trapping and zooplankton summaries no data	no fish data for Kennedy
Lower Campbell	Unknown	1951	September	length, weight, sex, maturity, age	MoE; in Lower Campbell file
	Unknown	1953	July	length, weight, sex, maturity	MoE; in Lower Campbell file
	Unknown	1957	April	length, weight, sex, maturity, age	MoE; in Lower Campbell file
	Gillnetting	1960	April	Loveland - sample numbers only	MoE; in Lower Campbell file
	Gillnetting	1961	March, April, July	Loveland & Fry - sample numbers only	MoE; in Lower Campbell file
	Gillnetting	1962	April	Loveland & Fry - sample numbers only	MoE; in Lower Campbell file
	Electrofishing	1996	December	tributaries surveys, sample numbers and size ranges, ageing	Lough and Associates, 2000
	Electrofishing	1997	March	tributaries surveys, sample numbers and size ranges, ageing	Lough and Associates, 2000
	Electrofishing	1998	August- October	tributaries surveys, sample numbers and size ranges, ageing	Lough and Hay, 2000 Reconnaissance Inventory of Lower Campbell
	Dip netting	1998		lengths	FISS and Lough and Hay, 2000 Reconnaissance Inventory of Lower Campbell
	Gillnetting	1978		length, weight, sex	MoE; in Lower Campbell file
	Gillnetting	2004		length, weight, sex, maturity	Michalski; in Lower Campbell file
	Angler creel survey	2004 & 2005	All Year	length data from anglers	Michalski; must be added to All Fish data and Appendix
Nimpkish	Box Creel	Jul-05	All Year	box creel and aerial counts of anglers	MoE; Must be added to All Fish Data and Appendix
	Hydroacoustic	1987	March, May, July- September	sockeye, stickleback - no fish data	in files

Lake	Sampling Type	Year	Dates	Data/Information	Source
	Minnow Trap	1989		stickleback trapping - no fish data	in files
Nitinat	Gillnet	1961	June	marine species only and summaries only	in files
Sproat	Gillnet	1951	August	length, weight, sex, ageing	FISS
	Angling	1951	April	length, weight, sex, some maturity	FISS
	Seine	1951	August	length, weight, sex, maturity	FISS
	Angling	1952	August	length, weight, sex, maturity	FISS
	Gillnetting	1952	March-September	length, weight, sex, maturity, some ageing	FISS
	Gillnetting	1953	April-July	length, weight, sex, ageing	FISS
	Gillnetting	1977	July	length	in Sproat file
	Angling	1972	April-May	lengths and ageing	Lough, 1990 report in Sproat Lake file
	Seine	1980	May 8	Taylor River; length, ageing	Lough, 1991 - Cutthroat Life History Characteristics from Scale Analysis
	Seine	1987	May 21	Taylor River; length, ageing	Lough, 1991 - Cutthroat Life History Characteristics from Scale Analysis
Upper Campbell	Angling	1989	May 6	Sproat Lake; length, ageing	Lough, 1991 - Cutthroat Life History Characteristics from Scale Analysis
	Seine	1989	May 19	Taylor River; length, ageing	Lough, 1991 - Cutthroat Life History Characteristics from Scale Analysis
	Electrofishing	1989	October 5	Taylor River juvenile sampling; length, ages	Lough, 1991 - Cutthroat Life History Characteristics from Scale Analysis
	Gillnetting	2012	September	2 cutthroat caught in netting experiment	raw data in file
	Angling	1951	June	length, weight, sex, maturity	MoE in the file
	Gillnetting	1980	June	length, weight, sex, maturity	FISS
	Electrofishing	1978	September-October	Elk River; length, weight, ageing	Tredger, 1979; need to add to All Fish Data
	Gillnetting	2010	September	sinking and floating nets; length, weight, sex, maturity	MoE and Lough (ageing) in file
	Angler creel survey	2010	All Year	box creel and aerial counts of anglers	MoE
Victoria	Gillnet	1992	April	length, weight, sex, maturity	MoE; in files

Lake	Sampling Type	Year	Dates	Data/Information	Source
	Gillnet	1993	May	length, weight, sex, maturity	MoE; in files
	Gillnet	1994	June	length, weight, sex, maturity	MoE; in files
	Gillnet	1995	July	length, weight, sex, maturity	MoE; in files
	Gillnet	1996	August	length, weight, sex, maturity	MoE; in files
	Minnow Trap	2002	June	Green River; lengths only	MoE; in files
Woss	Minnow Trap	1987	May-July	stickleback trapping - no fish data	in files
	Hydroacoustic	1987	May	zooplankton	in files
	Angling-Derby	1984		sample size and length ranges	in files
	Angling-Derby	1985		sample size and length ranges	in files
	Angling-Derby	1987	June	sample size and length ranges	in files
	Gillnet	1971	June	numbers of species caught	in files

Appendix 7

Indicators Used to Assess Stock Status

We relied heavily on fish length and, where available, age-at-length to highlight concerns with stocks and identify management recommendations. We based our approach on Ricker's (1945) observation that there is a marked decrease in the relative number of the oldest and largest fish when enough years of fishing have elapsed to spread those effects through the stock.

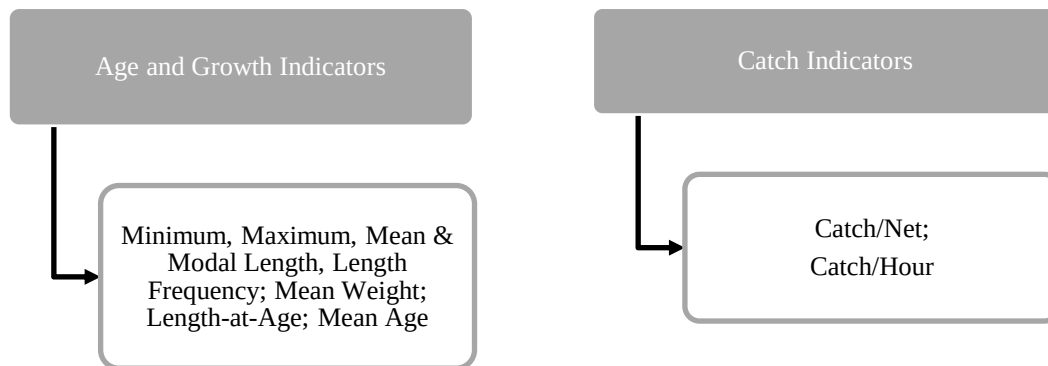


FIGURE 1. Stock status indicators used to monitor age and growth status; sampling is done using gillnets. We use a decline in any two of these parameters by 10% to initiate more specific management actions such as regulatory measures, creel and habitat surveys.

In addition to age and growth indicators, we used relative abundance (catch per unit gear) where possible to make judgements regarding stock status. Unfortunately, there was no information regarding the number of nets used or the set times with many data sets. In these cases we use the catch data to comment on overall changes only.

Appendix 8

Yield and Predicted Yield at Vancouver Island Large Lakes

TABLE 1. Yield (pounds/acre) based on 2011 catch and harvest rates and mean fish weights vs. predicted yield based on Ryder's simplified regression using MEI at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss). Mean fish size is calculated from mean weight of fish sampled in gillnets at individual large lakes (Source: FLNRO files, Nanaimo).

Year	2011							
	Catch	Harvest Rate	Harvest	Mean Fish Weight	Pounds of Fish	Surface Area (acres)	Yield (lb/acre)	Predicted Yield (lb/acre)
Alice	56	25	14	0.5	7.0	3007.41	0.002	1.343
Buttle	6,752	25	1,699	1	1,698.5	7641.48	0.222	0.889
Comox	8,757	35	3,091	0.5	1,545.4	5183.95	0.298	0.661
Cowichan	15,273	20	3,007	1	3,007.2	15319.3	0.196	1.132
Elsie	2,450	21	515	0.5	257.6	2733.09	0.094	2.230
Great Central	5,597	14	807	1	807.5	12555.6	0.064	0.442
Henderson	0	0	0	0.5	0.0	3814.81	0.000	0.887
Huaskin	0	0	0	0.5	0.0	5234.57	0.000	0.432
Kennedy	3,063	1	42	0.5	20.9	15987.7	0.001	0.818
Lower Campbell	9,258	37	3,383	1	3,383.1	6650.86	0.509	1.684
Nimpkish	0	0	0	0.5	0.0	9019.75	0.000	0.411
Nitinat	125	45	56	0.5	27.8	2748	0.010	
Sproat	6,516	15	961	0.5	480.3	9320.99	0.052	0.764
Upper Campbell	8,548	31	2,659	1	2,659.2	7353.09	0.362	2.359
Victoria	1,866	27	501	0.5	250.6	3891.11	0.064	0.990
Woss	0	0	0	0.5	0.0	3372.84	0.000	0.563

TABLE 2. Yield (pounds/acre) at maximum catch and harvest rate of 40% and mean fish weights vs. predicted yield based on Ryder's simplified regression using MEI at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss). Mean fish size is calculated from mean weight of fish sampled in gillnets at individual large lake (Source: FLNRO files, Nanaimo).

Year	At Maximum		Harvest Rate	Harvest	Mean Fish Weight	Pounds of Fish	Surface Area (acres)	Yield (lb/acre)	Predicted Yield (lb/acre)
	Year	Catch							
Alice	1986	3,700	40	1,480	0.5	740.1	3007.41	0.246	1.343
Buttle	1986	4330.85	40	1,732	1	1,732.3	7641.48	0.227	0.889
Comox	2002	9,563	40	3,825	0.5	1,912.6	5183.95	0.369	0.661
Cowichan	1992	20,113	40	8,045	1	8,045.2	15319.3	0.525	1.132
Elsie	1989	4,955	40	1,982	0.5	991.0	2733.09	0.363	2.230
Great Central	1989	6,632	40	2,653	1	2,652.8	12555.6	0.211	0.442
Henderson	2002	125	40	50	0.5	25.0	3814.81	0.007	0.887
Huaskin	2002	63	40	25	0.5	12.6	5234.57	0.002	0.432
Kennedy	1986	1,945	40	778	0.5	389.0	15987.7	0.024	0.818
Lower Campbell	2002	14,656	40	5,862	1	5,862.4	6650.86	0.881	1.684
Nimpkish	1986	930	40	372	0.5	186.0	9019.75	0.021	0.411
Nitinat	1989	590	40	236	0.5	118.0	2748	0.043	
Sproat	1989	8,898	40	3,559	0.5	1,779.6	9320.99	0.191	0.764
Upper Campbell	2002	16,920	40	6,768	1	6,768.0	7353.09	0.920	2.359
Victoria	1986	6,334	40	2,534	0.5	1,266.8	3891.11	0.326	0.990
Woss	2002	2,042	40	817	0.5	408.4	3372.84	0.121	0.563

Appendix 9. Alice Lake

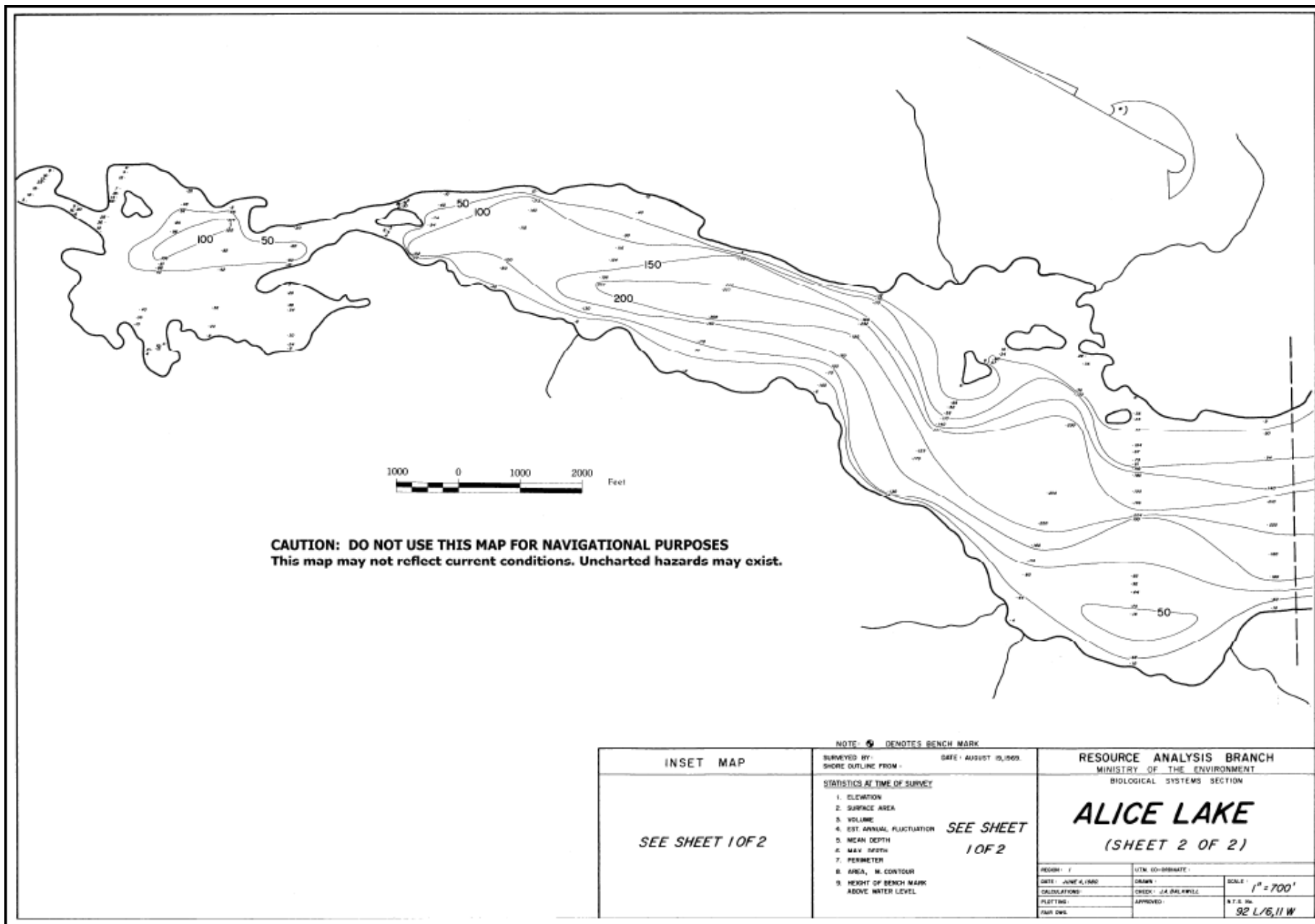


FIGURE 1(CONTINUED). Bathymetric map of Alice Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Appendix 10. Buttle Lake

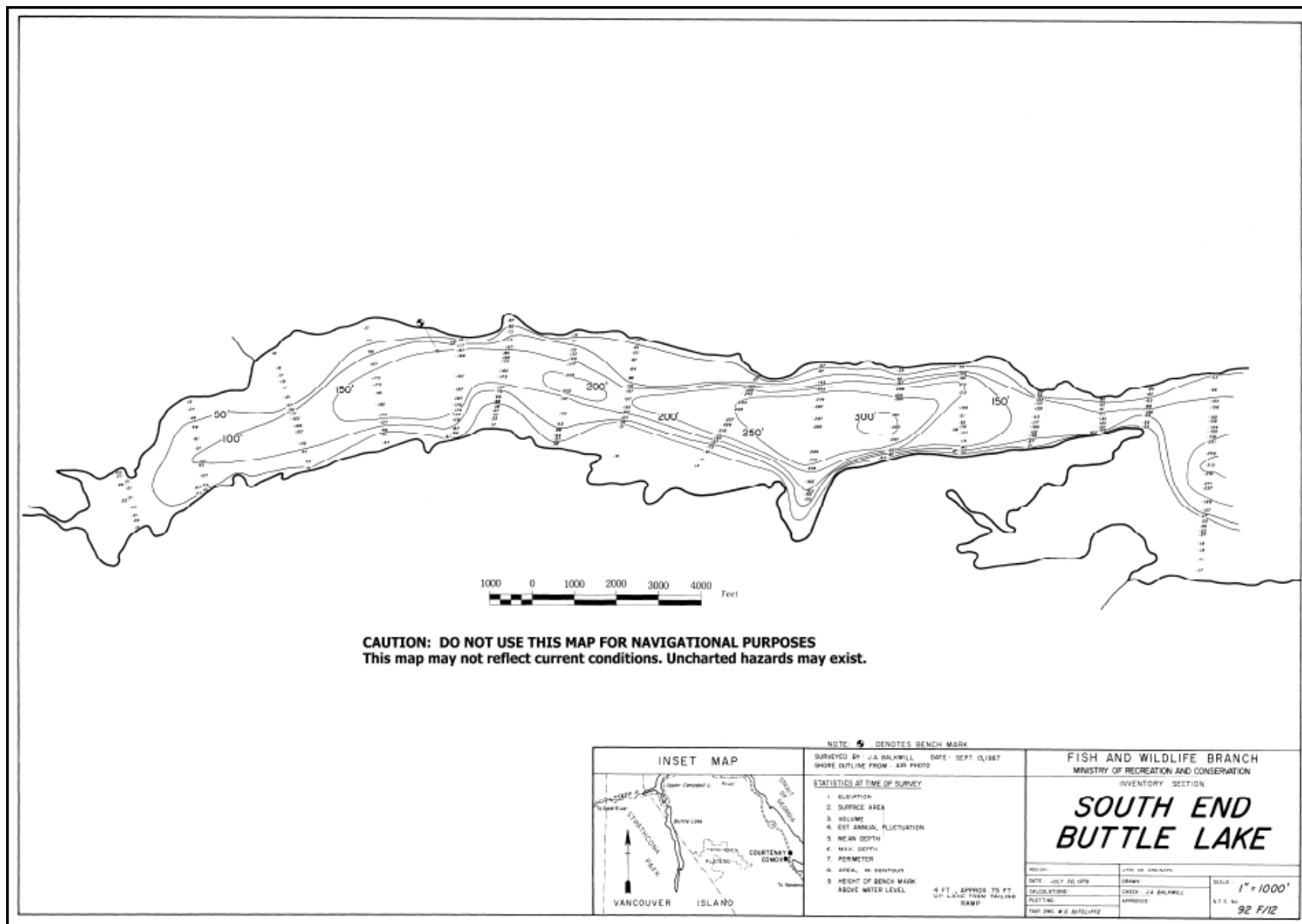


FIGURE 1. Bathymetric map of Buttle Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

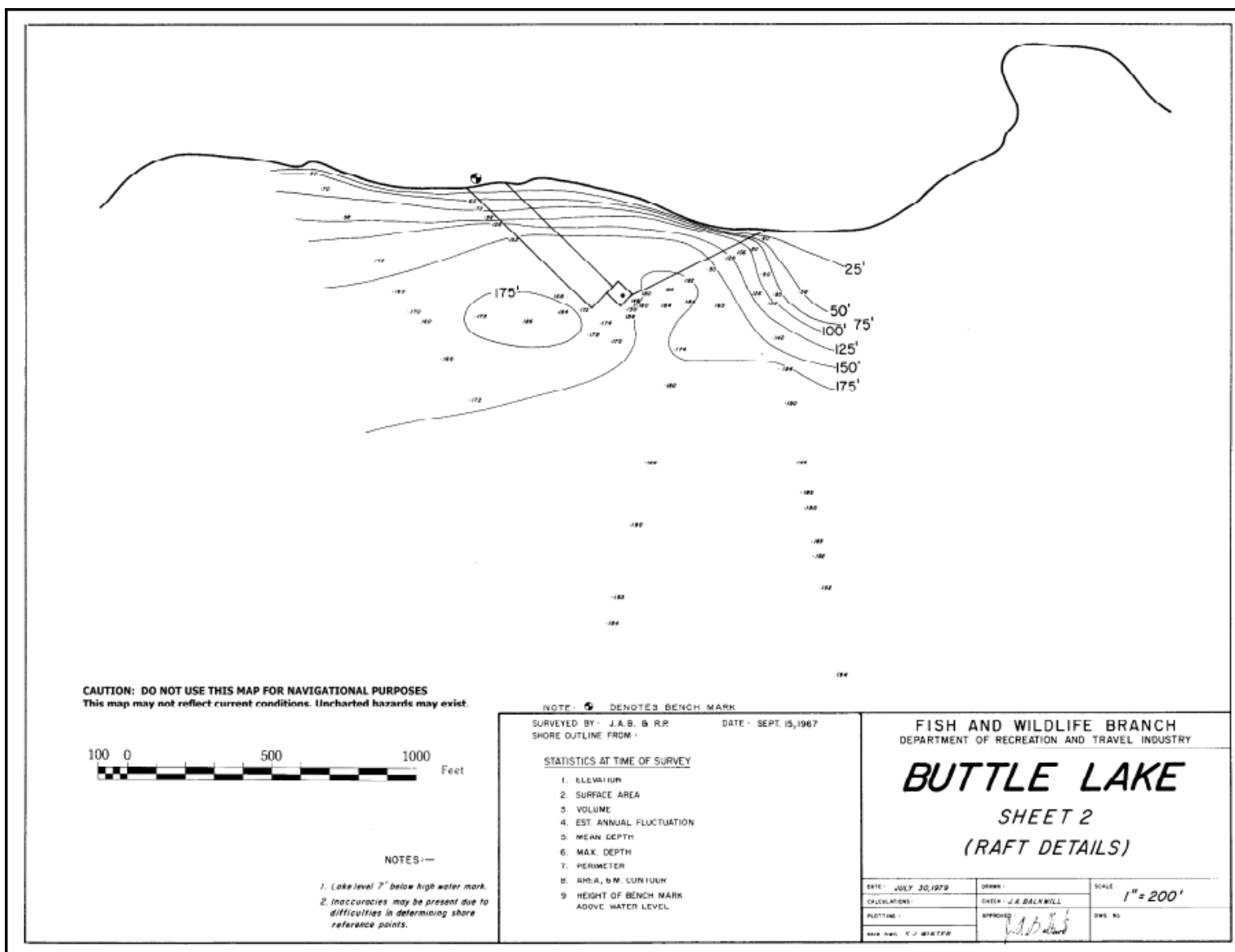


FIGURE 1 (CONTINUED). Bathymetric map of Buttle Lake (Source: FLNRO, Fish Inventory Data Queries; bathymetric (depth) maps).

Angling Data

TABLE 1. Total number, and minimum, maximum and mean length (mm) of cutthroat trout, Dolly Varden and rainbow trout caught by anglers in the 1980's and 1990's in Buttle Lake (Source: FLNRO files, Nanaimo).

Species	Year	n	Length (mm)		
			Minimum	Maximum	Mean
Cutthroat	1980	46	245	621	330.8
	1990	4	220	320	260.0
Rainbow	1980	72	233	451	269.8
	1990	26	50	350	273.0
Dolly Varden	1980	49	227	425	289.9

Stock Status Indicators

Cutthroat Trout

Length and Weight Data

The total number of cutthroat trout captured in gillnets in Buttle Lake has ranged from 1 to 59 with catches averaging ~12 fish/sample (Table 2). Fork lengths have ranged from 190 mm to 633 mm, and have averaged 307 mm.

TABLE 2. Total numbers, and minimum, maximum and mean fork length of cutthroat trout captured in gillnets in Buttle Lake in 1951, 1954, 1967, 1968, 1969, 1979, 1984, 1985, 1987, 1989, 1991, 1993, 1994, 2001 (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1951	26			357.0	
1960	13				
1963	10				
1967	3			408.0	215 – 610
1969	59	240	355	293 - 295	240 – 355
1979	43	190	430	286.7 - 301	
1984	4	275	490	382.5	
1985	3	250	295	275.0	205.7
1986	1	285	285	285.0	230.0
1987	3	330	395	358.3	490.0
1989	3	290	340	320.0	372.0
1990	1	375	375	375.0	578.5
1991	1	316	316	316.0	342.0
1992	1	275	275	275.0	216.5
1993	1	334	334	334.0	410.2
1994	4	228	375	302.3	331.4
1996	1	300	300	300.0	291.7
1997	1	297	297	297.0	321.5
1998	1	436	436	436.0	
1999	2	316	410	363.0	523.0

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
2001	6	330	390	364.2	478.3
Total	187	190	490	312.2	358.8

Length Frequency Distributions

Length frequency distribution of cutthroat trout captured in gillnets in 1951, 1969, 1979 and 1982 are presented in Figure 2. Fish >300 mm were captured in every sample, and a small percentage of the sample in 1982 included fish >600 mm.

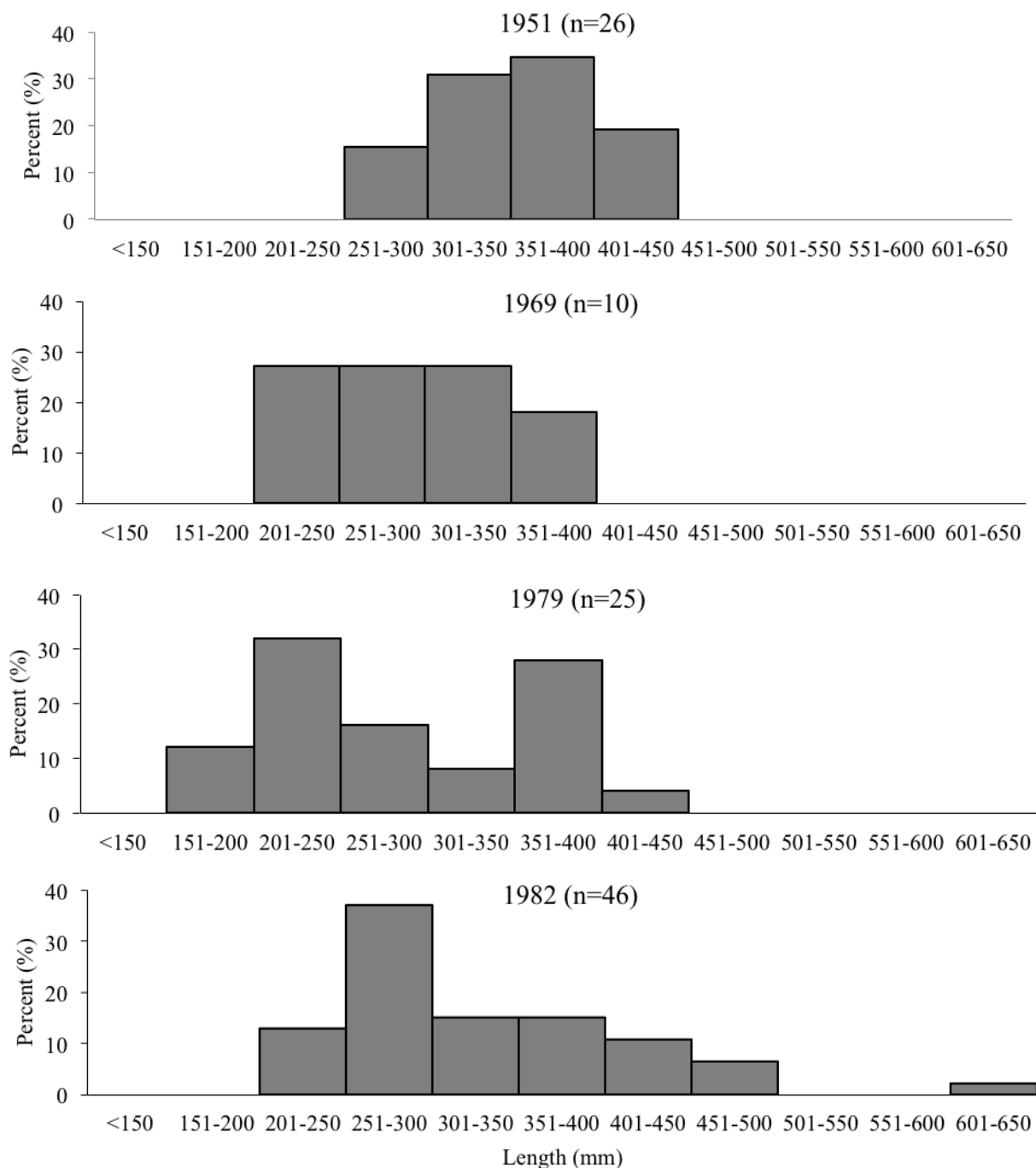


FIGURE 2. Length frequency of cutthroat trout captured in gillnets in Buttle Lake 1951 (N=26); 1969 (N=10); 1979 (N=25) and 1982 (N=46) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

The length-weight relationship of cutthroat trout in Buttle Lake is presented in Figure 3. At ~300 mm, cutthroat in Buttle Lake are ~ 300 g, while larger fish (>450 mm) weigh ~900 g or <2 lb.

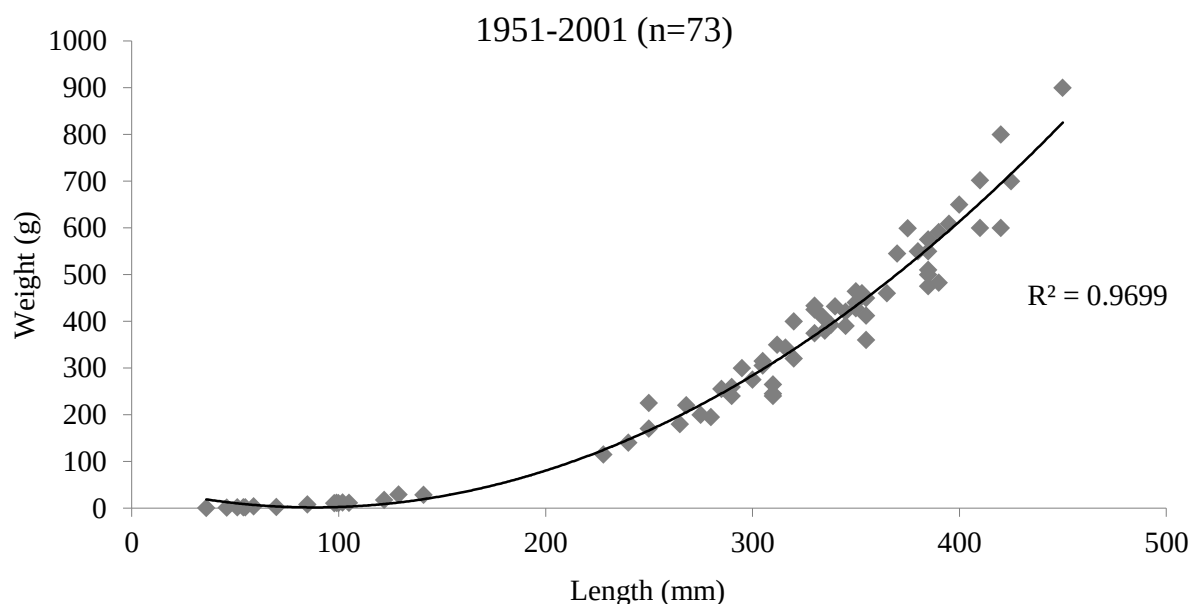


FIGURE 3. Length-weight relationship for cutthroat trout captured in gillnets in Buttle Lake in 1951, 1969, 1987, 1989, 1991, 1993, 1994, 1999 and 2001 (N=73) (Source: FLNRO files, Nanaimo).

Maturity

Ten female and 12 male cutthroat trout captured in Buttle Lake have been examined for maturity and the results are presented in Table 3. Immature cutthroat ranged from 228 mm to 400 mm and at 354 mm, immature females were slightly larger than immature males. Mature fish ranged from 310 mm to 425 mm and averaged 380 mm for females, and 391 mm for males.

TABLE 3. Range of lengths and mean sizes of male and female cutthroat trout captured in gillnets in Buttle Lake in 1951 (Source: FLNRO files, Nanaimo).

Factor	Female cutthroat N=10		Male cutthroat N=12	
	Immature (n=4)	Mature (n=6)	Immature (n=6)	Mature (n=6)
Range	228-400	310-450	265-385	320-425
Mean	354	380	304	391

The results of surveys by Hatfield Consultants Ltd (1982) suggest that cutthroat trout spawning in the Upper Campbell Lake-Buttle Lake area occurs largely over the last week in March and first week in April. Researchers from this study captured small (29 mm) cutthroat trout in Henshaw Creek in June. Based on this sampling, researchers determined that with the low

water temperatures and a possible incubation time of seven weeks and alevin in-gravel growth period of two weeks, spawning occurs probably just before mid-April (Hatfield, 1982).

Snorkel Survey Summaries

Numbers of cutthroat have been recorded during annual rainbow trout snorkel surveys conducted since 1991 in tributaries to Buttle Lake (Figure 4). Counts of cutthroat trout in all tributaries combined reached highs of 200 in 1991, ~350 in 1994, and ~450 in 2001. Between 2004 and 2012, however, counts of cutthroat trout were <50 fish in all tributaries (Pellet, 2011; snorkel summary reports).

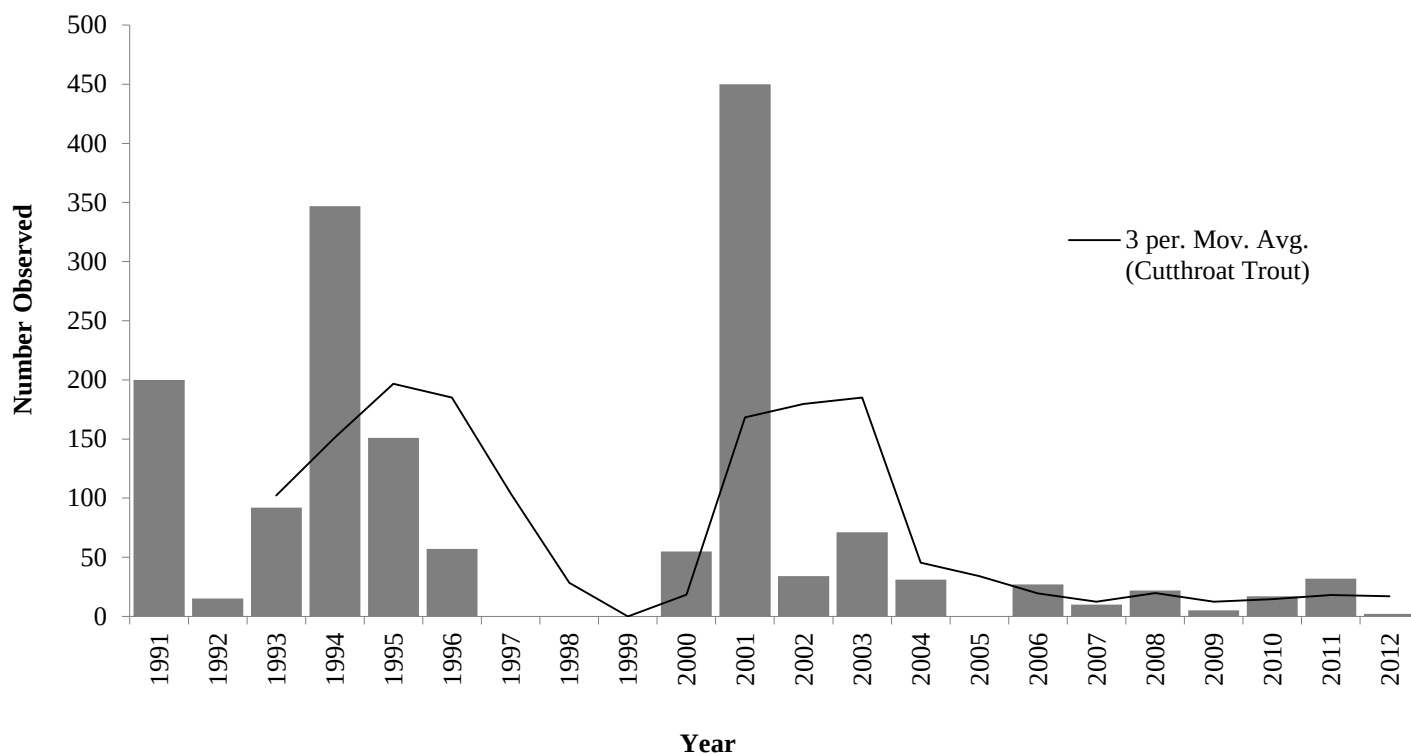


FIGURE 4. Total number of cutthroat trout observed in snorkel surveys of the tributaries to Buttle Lake (Thelwood Creek (n=1556), Ralph River (n=25), Phillips Creek (n=21), Wolf River (n=13), and Henshaw Creek (n=1), June 1991 – 2012 (N=1616). Trend line represents 3-year moving average. Note: no swims were conducted 1997-1999 (Source: Kevin Pellett, BCCF; FLNRO files, Nanaimo).

Cutthroat trout numbers have declined or remained stable at relatively low levels over the survey period. Very few adult spawners have been observed in recent years although survey timing in June has focused on peak rainbow trout spawning activity. As a result, counts for cutthroat trout do not represent spawners and nearly all cutthroat observed are post-spawn (kelts). Thelwood Creek has the largest population of adfluvial cutthroat trout based on late season snorkel counts, which have varied widely from a peak of 441 in 2001, to a low of 4 in 2009. A total of 32 cutthroat trout were observed in Thelwood Creek in 2011 (Table 4) (Pellet, 2011; snorkel summary reports).

TABLE 4. Total number of cutthroat trout observed in snorkel surveys of Thelwood Creek (n= 1,556), Ralph River (n=25), Phillips Creek (n=21), Wolf River (n= 15), and Henshaw Creek (n=1), June 1991 – 2012 (N=1,616) (Source: Kevin Pellett, BCCF; FLNRO files, Nanaimo).

Year	Thelwood	Ralph	Phillips	Wolf	Henshaw
1991	200				
1992	15				
1993	88	4			
1994	347				
1995	141	2	6	2	
1996	53	1	2	1	
1997					
1998					
1999					
2000	53	2			
2001	441		6	3	
2002	34				
2003	64	2	5		
2004	20	10	1		
2005					
2006	25	2			
2007	10				
2008	12	2	1	6	1
2009	4			1	
2010	17				
2011	32				
2012				2	
Total	1556	25	21	15	1

Rainbow Trout

Length and Weight Data

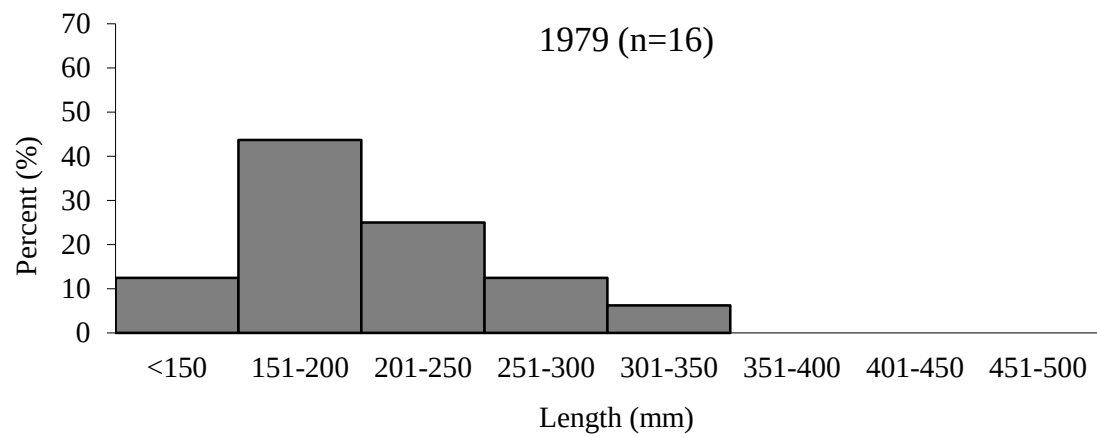
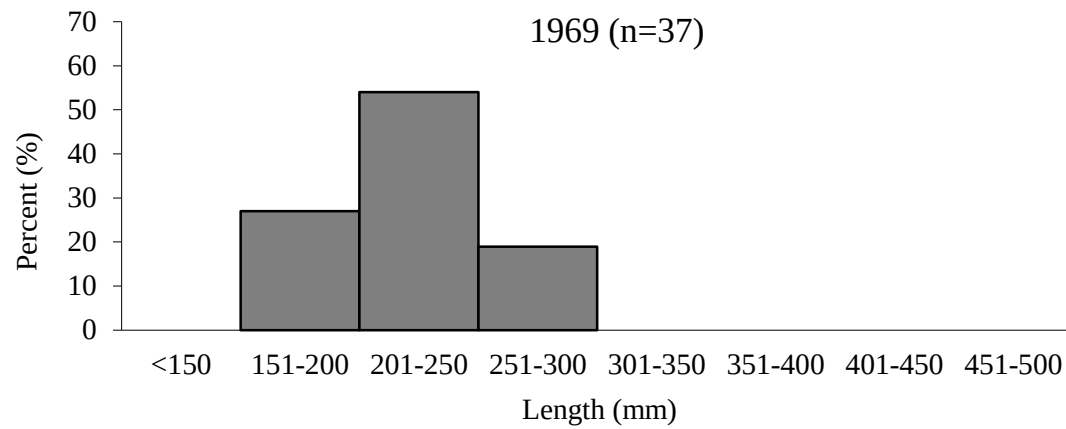
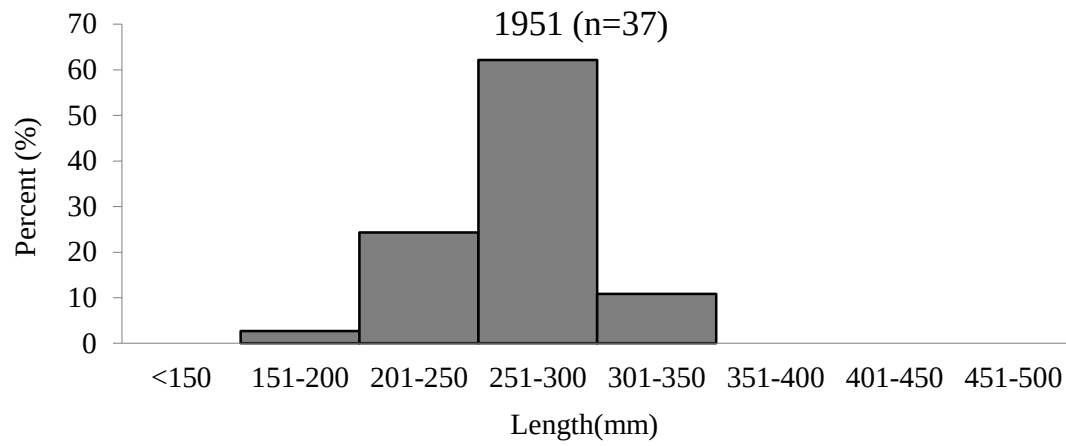
A total of 533 rainbow trout have been captured in gillnets in Buttle Lake since 1951 (Table 5). The largest sample was in 1969 when 117 were caught. Catches of this species have averaged ~26 fish/sample and fish size has ranged from 50 mm to ~500 mm.

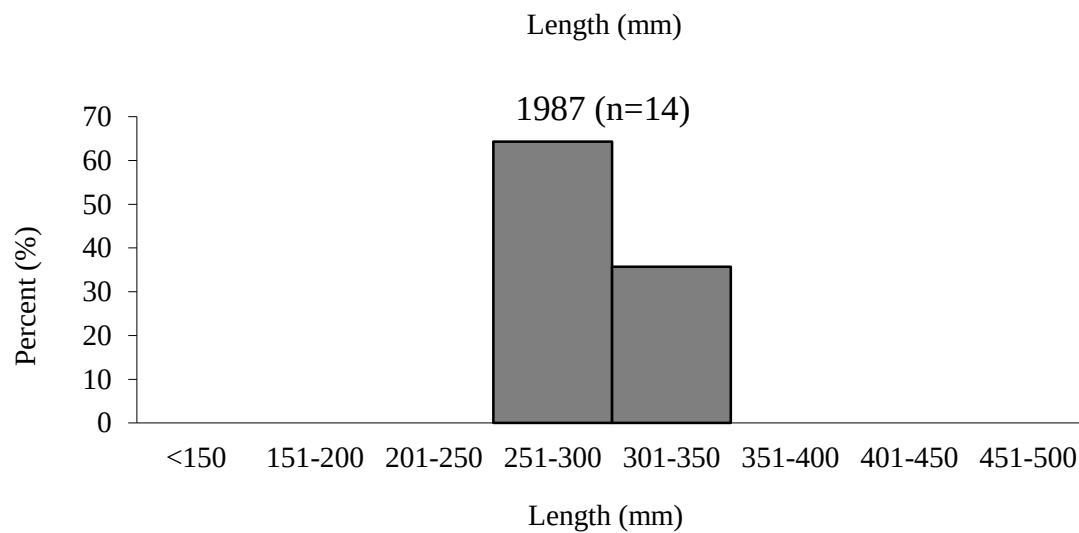
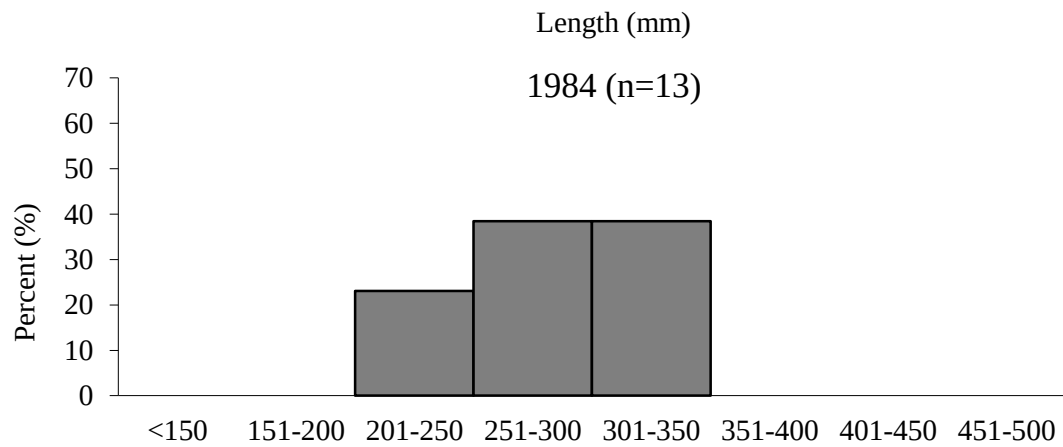
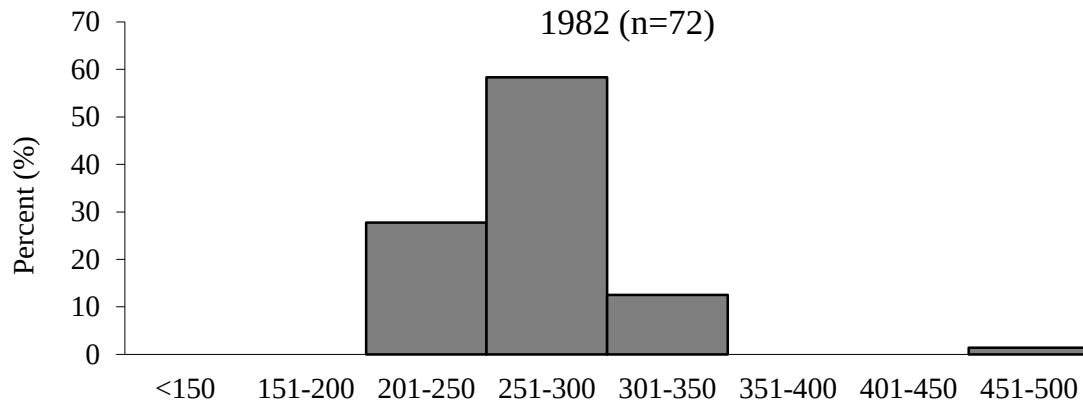
TABLE 5. Total number and minimum, maximum and mean fork length of rainbow trout captured in Buttle Lake in 1951, 1967, 1968, 1969, 1979, 1984, 1985, 1987, 1988, 1989, 1993, 1994, 1995, and 2001 (Source: FLNRO files, Nanaimo).

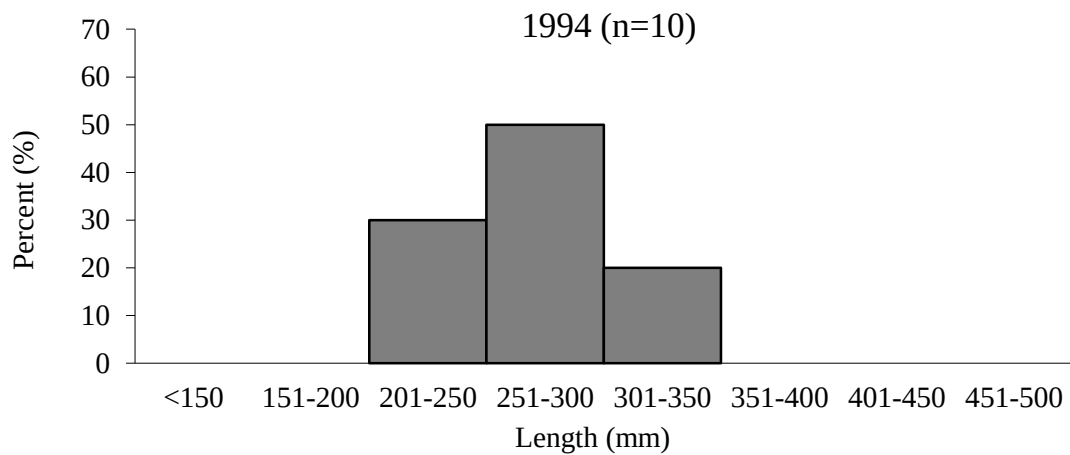
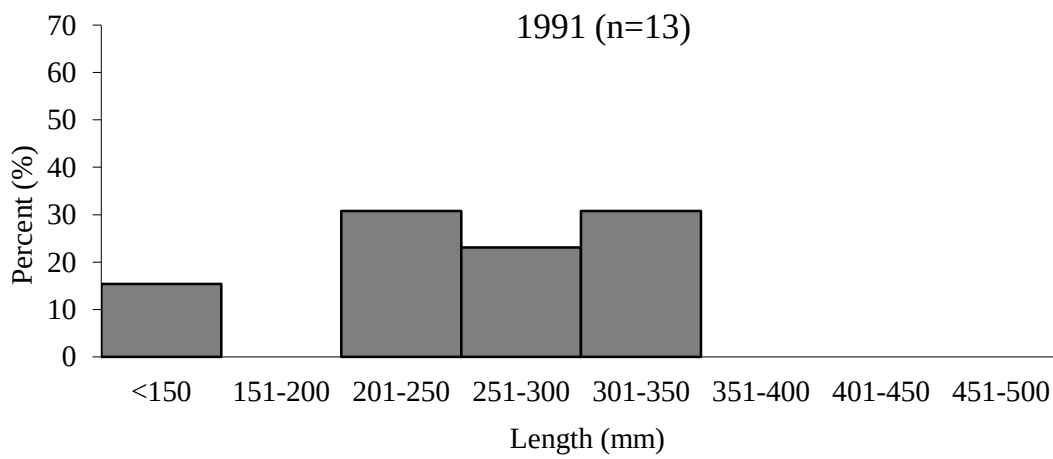
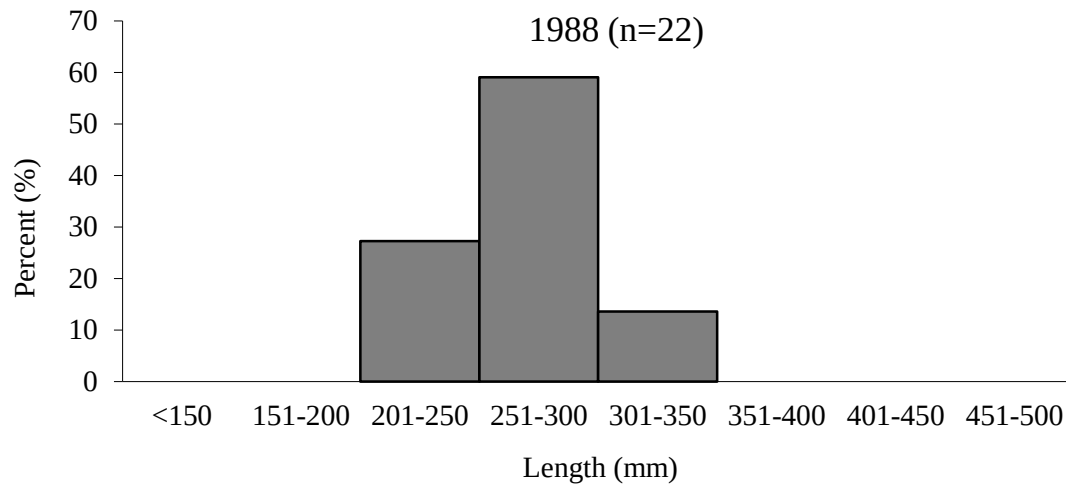
Year	N	Length (mm)		Mean	Weight (g)
		Minimum	Maximum		Mean
1951	37			266	
1960	66				
1963	152				
1967	99			212.0	110 - 380
1969	154	165	290	219 - 221.2	152.3 - 280
1979	39	150	310	215.3 – 247	
1984	13	225	330	284.2	
1985	17	240	335	273.5	221.6
1986	11	220	355	270.2	231.5
1987	14	260	350	299.6	277.4
1988	22	222	335	266.9	234.0
1989	8	200	310	267.5	216.5
1990	34	215	320	251.2	185.0
1991	11	253	324	286.5	249.9
1992	9	150	335	262.2	204.3
1993	8	195	292	263.5	204.5
1994	10	224	329	274.9	228.3
1995	15	204	268	240.0	156.1
1996	4	224	334	268.3	226.1
1997	6	247	306	284.3	284.4
1998	3	222	272	248.0	117.2
1999	3	230	246	240.3	157.0
2001	26	165	380	272.9	242.6
Total	761	150	380	258.4	210.1

Length Frequency Distributions

Length frequency distributions of rainbow trout captured in Buttle Lake are presented in Figure 5. Over the past 5 decades, the mode of rainbow trout has remained relatively stable at 251 mm –300 mm. In 1951, 60% of the rainbow captured fell within this length class, while in 2001, 35% were within this class. Although fish >300 mm have been sampled in most years, fish >350 mm were only caught in 1982 and 2001.







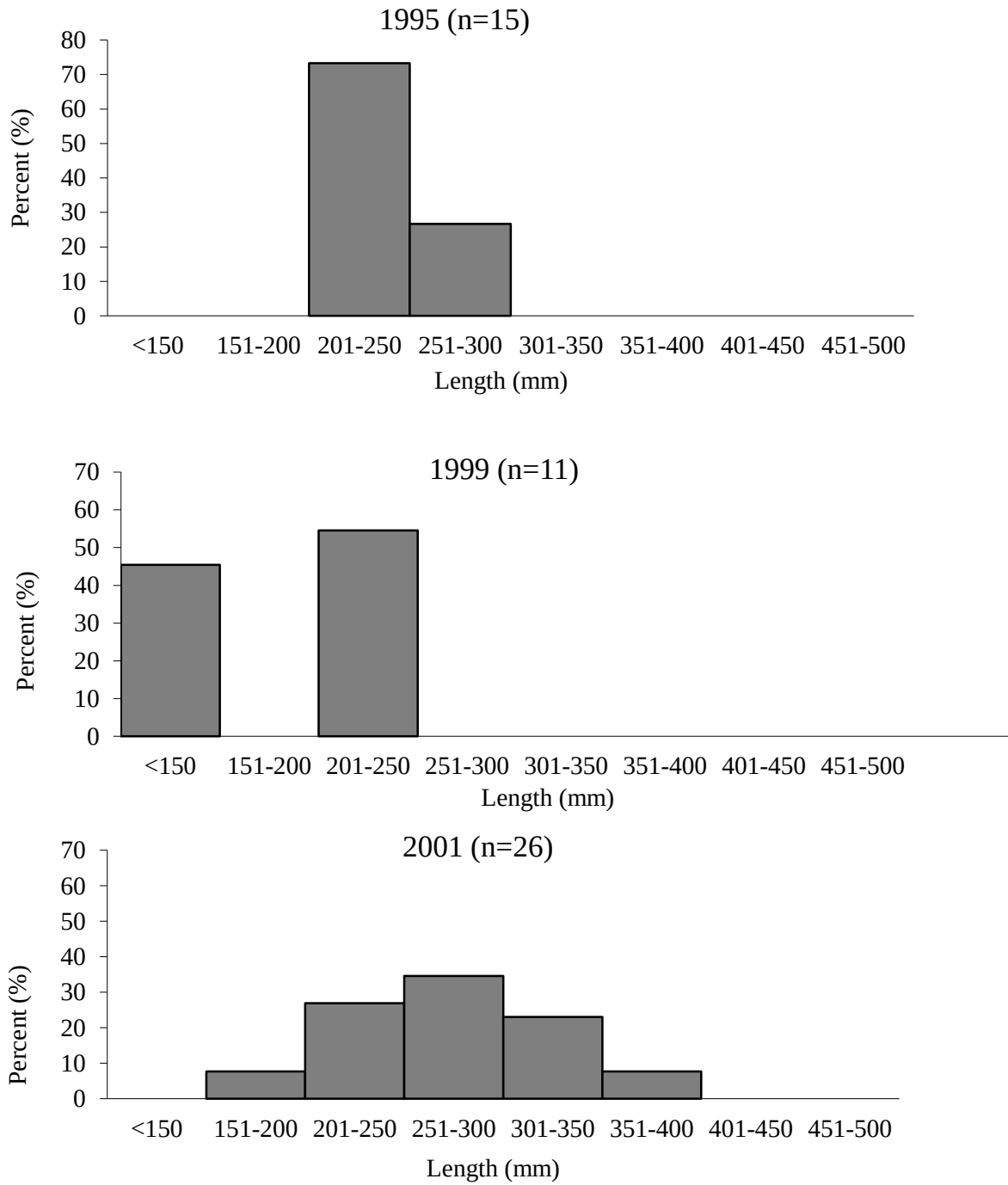


FIGURE 5. Length frequency of rainbow trout captured in gillnets in Buttle Lake in 1951 (N=37); 1969 (N=37); 1979 (N=16); 1982 (N=72); 1984 (N=13); 1987 (N=14); 1988 (N=22); 1991 (N=13); 1994 (N=10); 1995 (N=15); 1999 (N=11); 2001 (N=26) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

We've presented the length-weight relationship for Buttle Lake rainbow trout in Figure 6. The smallest rainbow captured were ~50 mm and 50 g, however, most fish were >200 mm and 100 g. Fish > 300 mm ranged from 200 - <400 g (<1/2 pound).

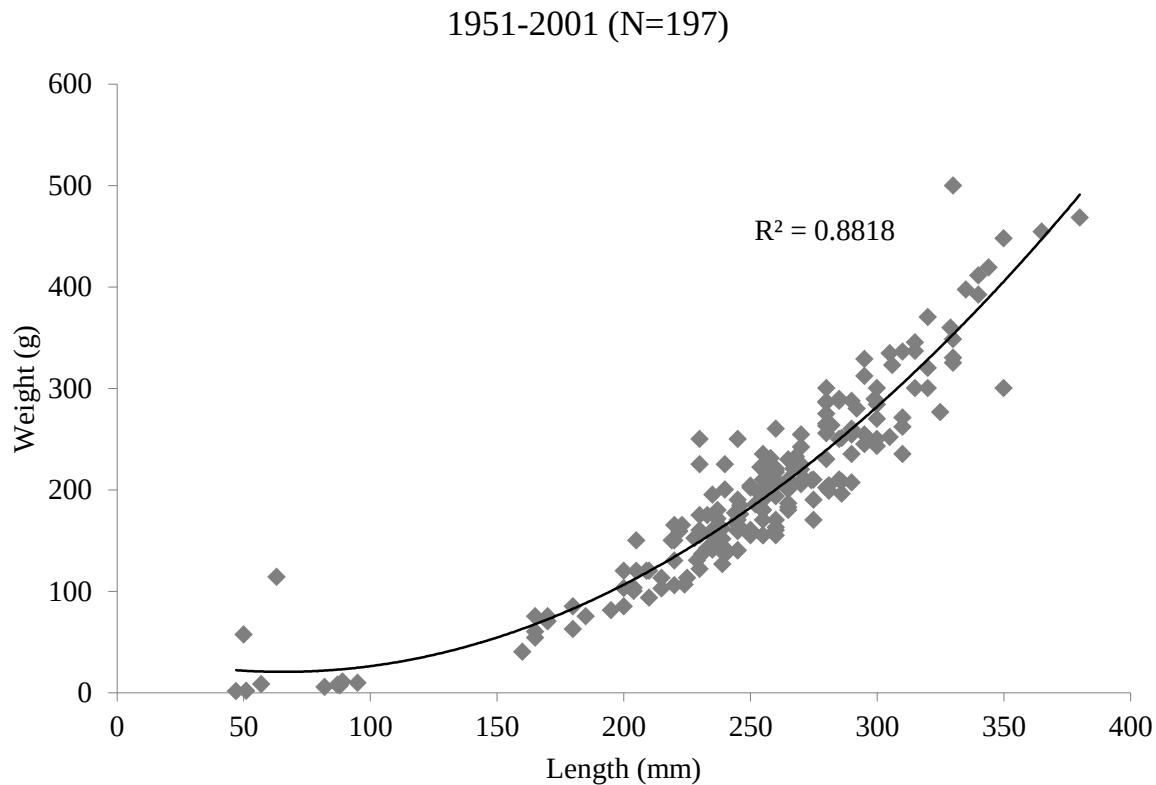


FIGURE 6. Length-weight relationship for rainbow trout captured in gillnets in Buttle Lake in 1951, 1969, 1987, 1988, 1989, 1991, 1993, 1994, 1995, 1999 and 2001 (N=197) (Source: FLNRO files, Nanaimo).

Rainbow Trout

Thirteen female and 28 male rainbow trout captured in gillnets in Buttle Lake were examined for maturity (Table 6). Immature fish ranged from 160 mm to 330 mm and averaged 225 mm for females, and 271 mm for males. Mature fish ranged from 230 mm to 320 mm, and at 274 mm mature males were larger than mature females, which averaged 264 mm.

TABLE 6. Range of lengths and mean sizes of male and female rainbow trout captured in gillnets in Buttle Lake in 1951, 1988 and 1989 (Source: FLNRO files, Nanaimo).

Factor	Female (N=13)		Male (N=28)	
	Immature (n=3)	Mature (n=10)	Immature (n=13)	Mature (n=15)
Range	160-260	230-305	230-330	235-320
Mean	225	264	271	274

Fifty-three rainbow trout were seined from Buttle Lake tributaries for the purposes of conducting genetic sampling (Table 7) (Figure 7) (Pellett, 2010). These fish were likely all mature given this sampling was conducted during rainbow trout spawning. The sample consisted of 30 females with a mean length of 292 mm, and 23 males averaging 316 mm (BCCF Snorkel Survey Report, June 2010) (Table 7). From Thelwood Creek, a total of 52 rainbow trout were sampled consisting of 10 females averaging 301 mm, and 42 males averaging 319 mm in length.

TABLE 7. Range of lengths, mean length, mean weight and condition factor of male and female rainbow trout sampled in Ralph River and Thelwood Creek, June 10, 2010. Note: only Ralph River was sampled for weight (Source: Pellet, 2010).

Factor	Ralph River (N=53)		Thelwood Creek (N=52)	
	Female (n=30)	Male (n=23)	Female (n=10)	Male (n=42)
Length Range (mm)	265-319	286-354	288-338	279-347
Mean Length (mm)	292	316	301	319
Mean Weight (g)	263	305		
Condition Factor (k)	1.07	0.96		

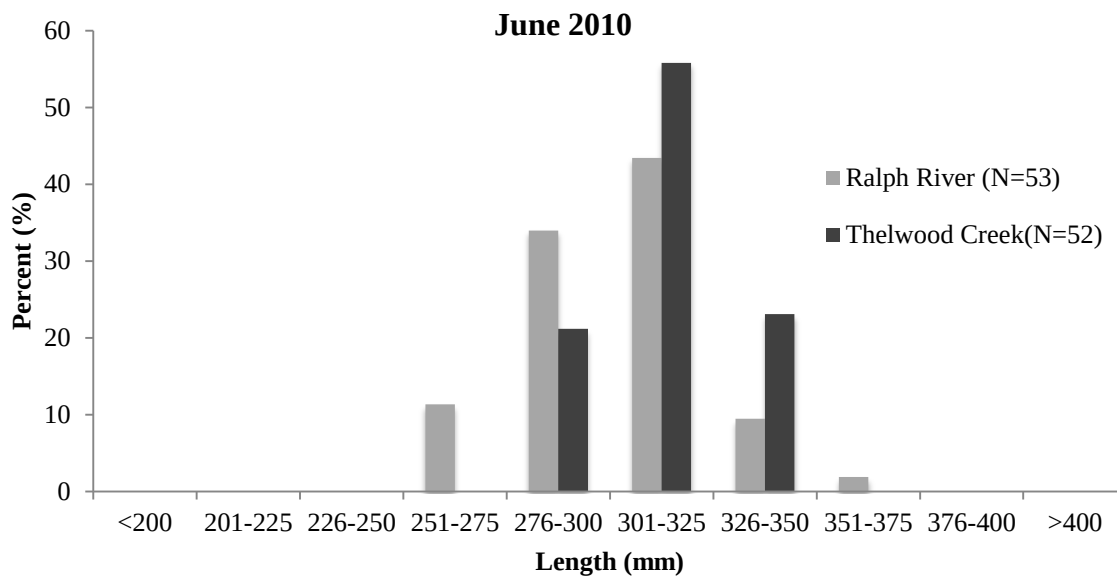


FIGURE 7. Length frequency of rainbow trout sampled in Ralph River (N=53) and Thelwood Creek N=52), June 10, 2010 (Source: FLNRO files, Nanaimo).

Dolly Varden

Length and Weight Data

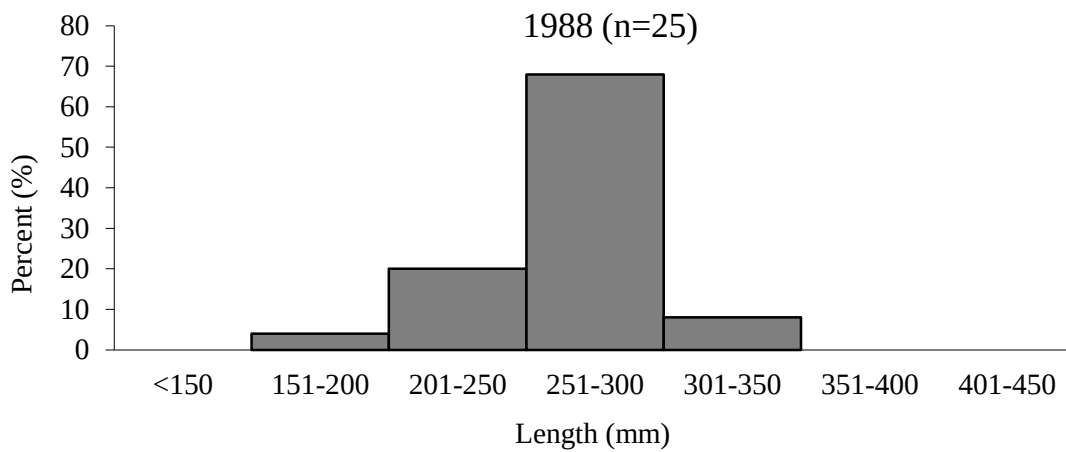
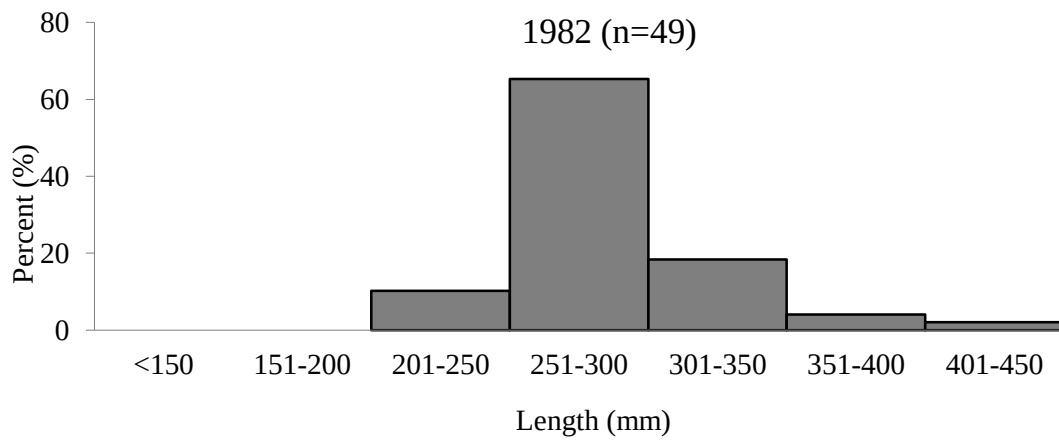
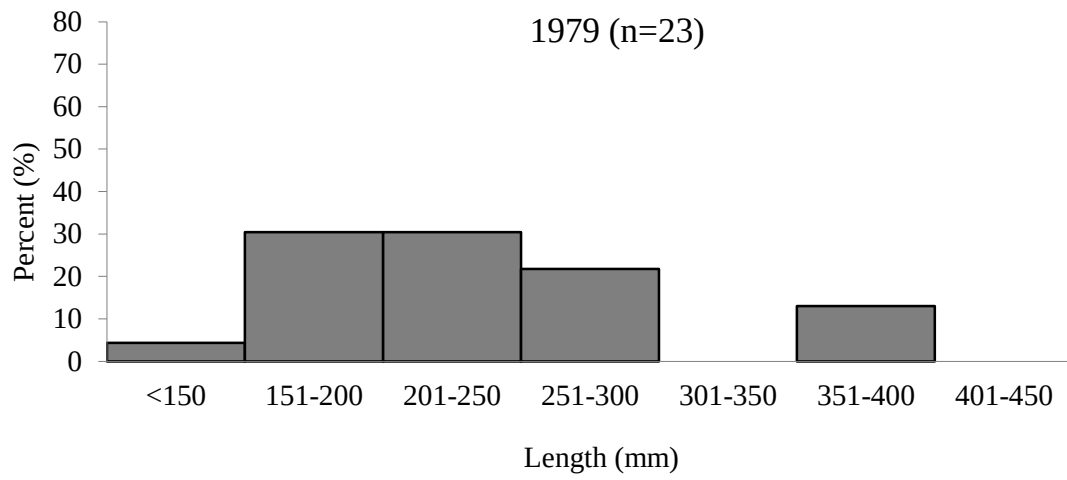
The total number of Dolly Varden captured in gillnets in Buttle Lake has ranged from 2 in 1985 and 1987, to 27 in 1988 with catches averaging 14 fish/sample over the 17 year sample period (Table 8). Fork lengths have ranged from 140 mm to 390 mm, and have averaged 274 mm.

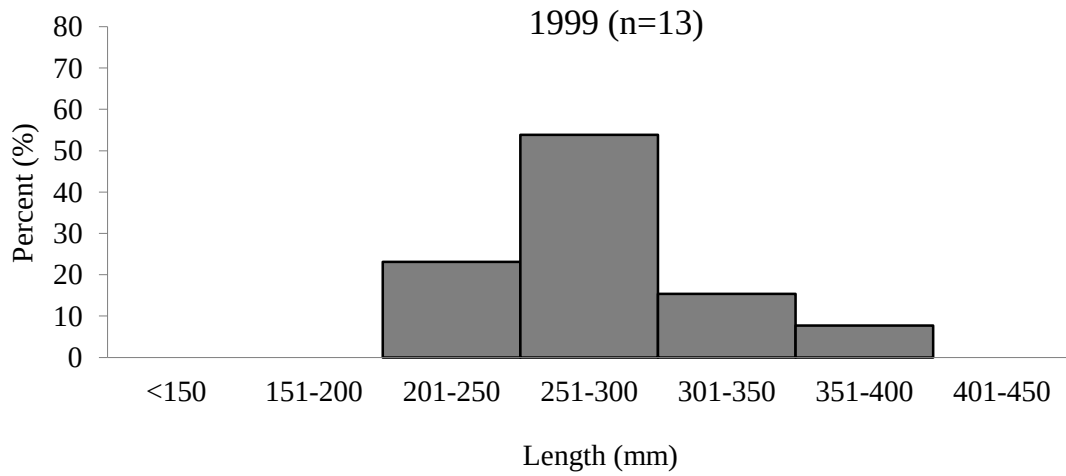
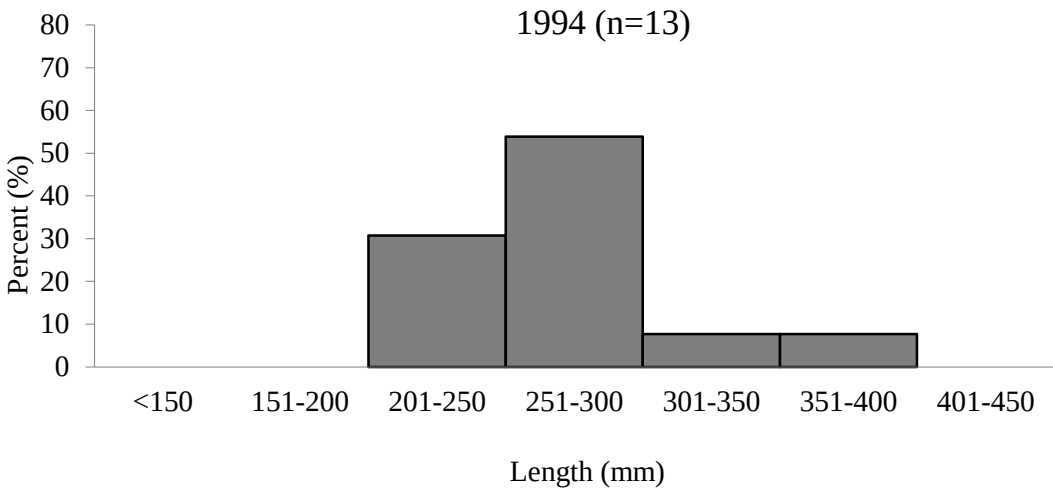
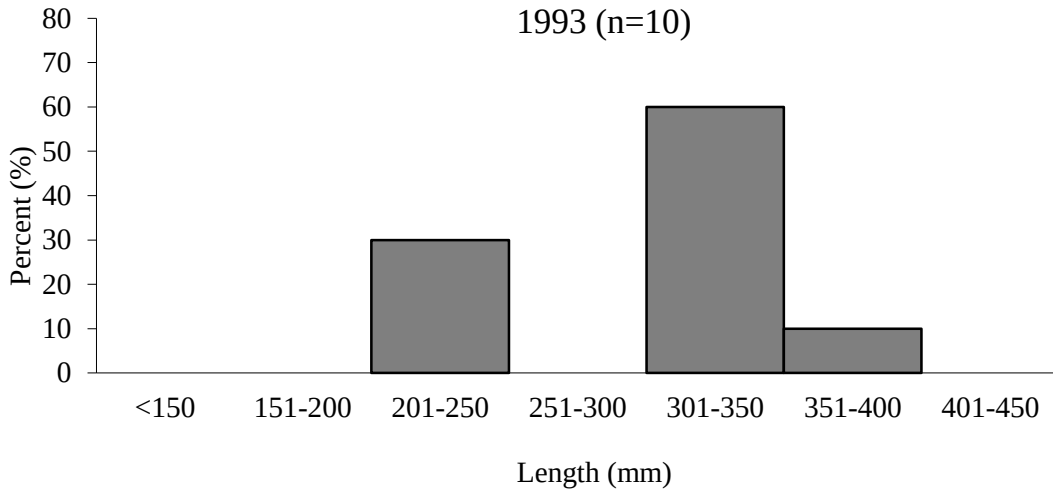
TABLE 8. Total number, minimum, maximum and mean fork length of Dolly Varden captured in Buttle Lake in 1951, 1967, 1968, 1969, 1979, 1984, 1985, 1987, 1989, 1993, 1994, and 2001 (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)		Mean	Weight (g)
		Minimum	Maximum		Mean
1951	3			222.0	
1960	14				
1963	5				
1967	13			253.0	105 - 310
1969	9	195	245	220.0	127.5
1979	23	140	390	236.8	
1984	8	210	295	239.4	
1985	4	240	370	281.3	200.0
1986	12	235	390	284.2	294.7
1987	2	370	380	375.0	544.3
1988	27	174	337	269.9	245.0
1989	7	230	325	263.6	198.1
1990	1	330	330	330.0	407.5
1991	9	234	445	333.2	414.3
1992	15	190	350	297.3	372.1
1993	10	214	374	301.8	378.3
1994	13	216	367	267.3	230.1
1996	8	215	367	284.4	334.6
1997	9	234	344	280.3	290.4
1998	9	216	343	268.4	205.7
1999	13	245	361	280.7	273.1
2001	15	175	335	279.3	267.8
Total	229	140	445	275.7	288.2

Length Frequency Distributions

Length frequency distributions of Dolly Varden captured in gillnets from 1979 until 2001 are presented in Figure 8. Although almost 60% of the Dolly Varden captured in 1993 were 300 mm - 350 mm in length. In general, the highest percentage of fish has been in the 250 mm - 300 mm length class and fish >400 mm were only captured in 1982.





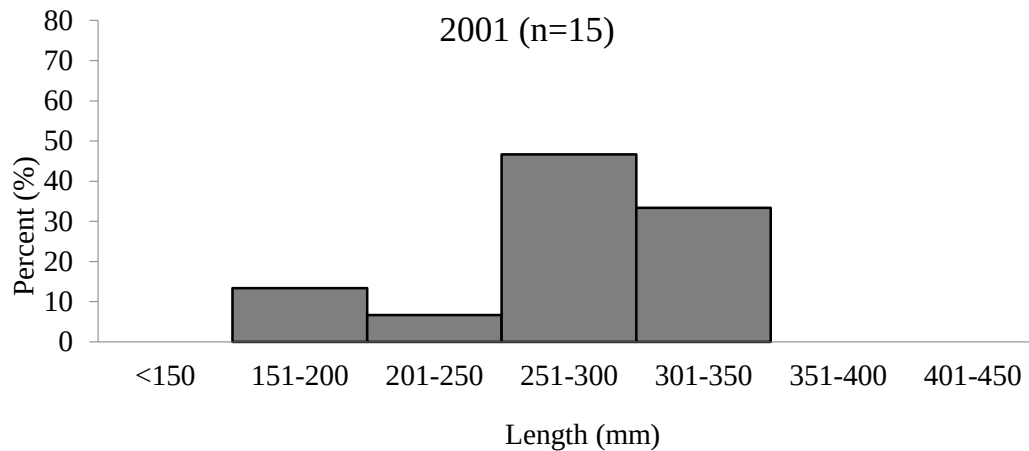


FIGURE 8. Length frequency of Dolly Varden captured in gillnets in Buttle Lake 1979 (N=23), 1982 (N=49), 1988 (N=25), 1993 (N=10), 1994 (N=13), 1999 (N=13) and 2001 (N=15) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

The length-weight relationship of Buttle Lake Dolly Varden is presented in Figure 9. At ~300 mm, Dolly Varden are just over 300 g, while larger fish (>400 mm) are between 600 - 700 g.

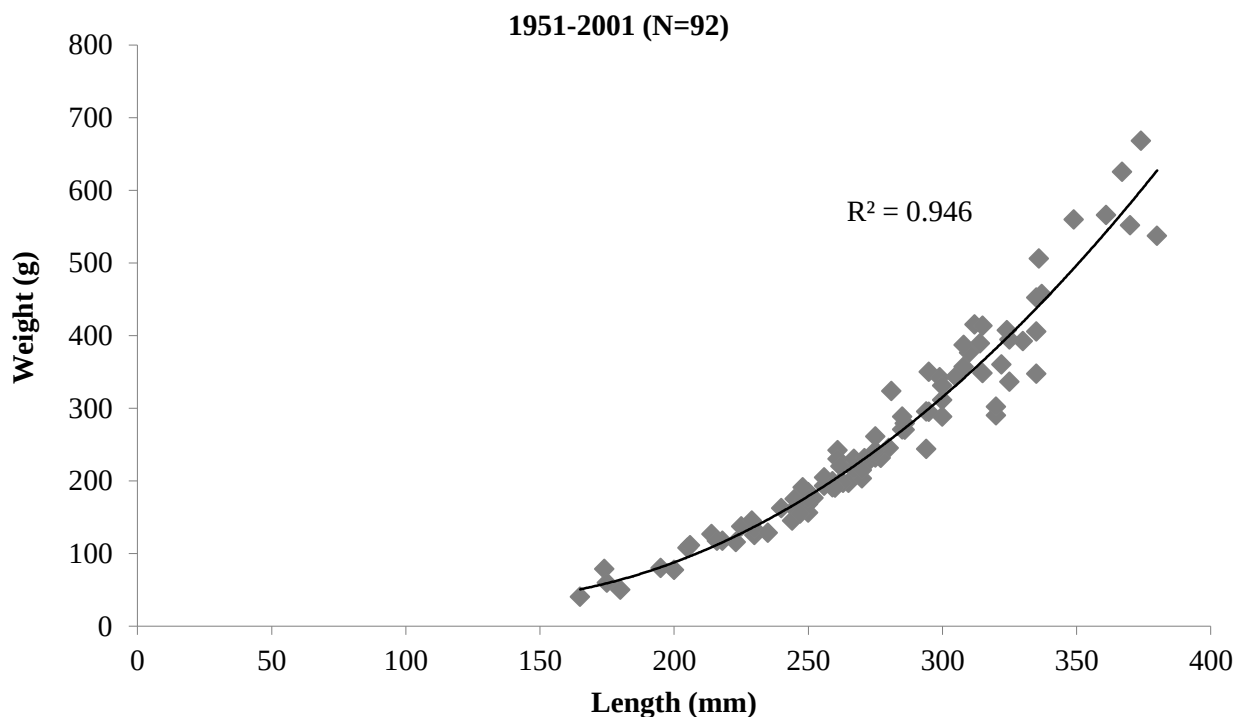


FIGURE 9. Length-weight relationship for Dolly Varden captured in gillnets in Buttle Lake in 1951, 1969, 1987, 1988, 1989, 1993, 1994, 1999 and 2001 (N=92) (Source: FLNRO files, Nanaimo).

Ten female and two male Dolly Varden have been examined form maturity and a summary of the findings is presented in Table 9. Immature females ranged from 165 mm – 250 mm and

averaged 213 mm while mature females ranged from 275 mm – 370 mm and averaged ~320 mm. The two mature males sampled averaged 350 mm.

TABLE 9. Range of lengths and mean sizes of male and female Dolly Varden captured in gillnets in Buttle Lake in 1951, 1987, 1988 and 1989 (Source: FLNRO files, Nanaimo).

Factor	Females (N=10)		Males (N=2)	
	Immature (n=5)	Mature (n=5)	Immature (n=0)	Mature (n=2)
Range	165-250	275-370	---	320-380
Mean	213	319	---	350

Snorkel Survey Summaries

The total number of Dolly Varden trout observed in all tributaries to Buttle Lake during June snorkel surveys is presented in Figure 10. Annual counts have ranged from as high as 235 fish in 1991, to only four fish in 1993, with an average of 55 fish/year. In 2010, a total of 162 Dolly Varden were observed in the tributaries to Buttle Lake.

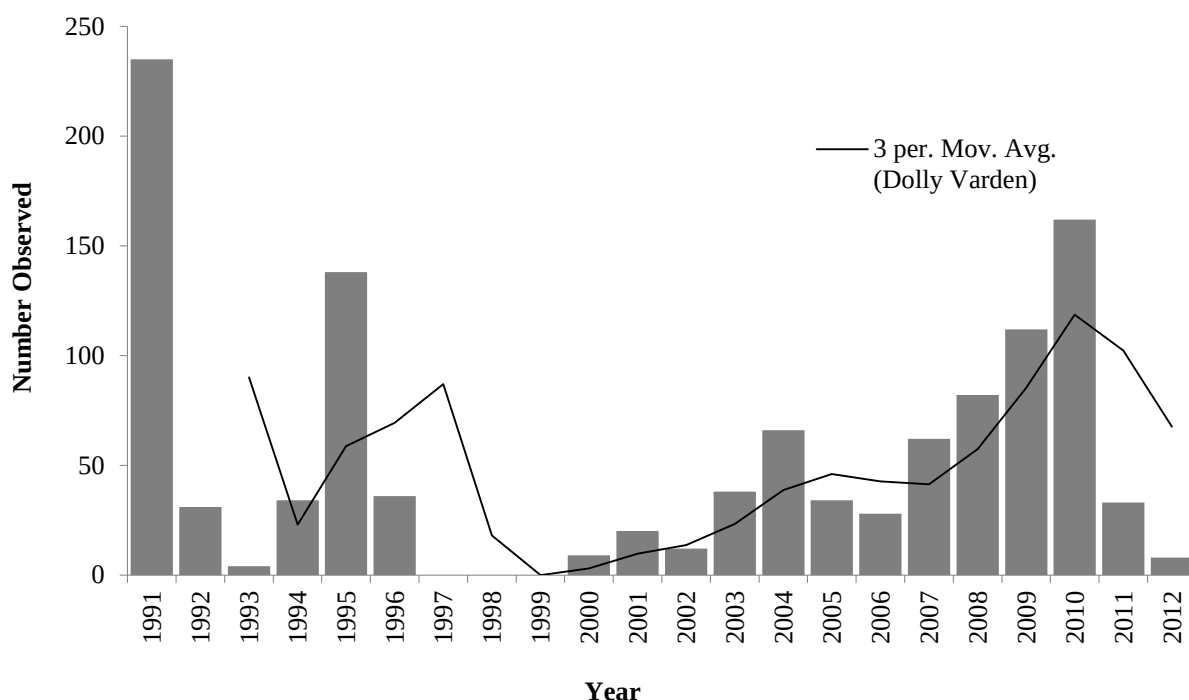


FIGURE 10. Total number of Dolly Varden observed in snorkel surveys of the tributaries to Buttle Lake (Thelwood Creek (n=353), Ralph River (n=194), Wolf River (n=430), Phillips Creek (n=165), and Henshaw Creek (n=2), June 1991 – 2012 (N=1144). Trend line represents 3-year moving average. Note: no swims were conducted 1997-1999 (Source: Kevin Pellett, BCCF; FLNRO files, Nanaimo).

Wolf River and Thelwood Creek are important streams for monitoring this Dolly Varden stocks. Since 1991, 395 and 351 Dolly Varden were counted in Wolf River and Thelwood Creek respectively (Table 10). Ralph River and Phillips Creek are also important streams with total counts of 194 and 161 of this species between 1991 and 2012. Only 2 Dolly Varden have been counted in Henshaw Creek over the course of these annual swims. Lough et al. (2003) described Dolly Varden spawning in Thelwood and Phillips Creeks to peak near the end of October with a rapid migration of kelts back to the lake.

TABLE 10. Total number of Dolly Varden observed in snorkel surveys of Wolf River (n= 430), Thelwood Creek (n= 353), Ralph River (n=194), Phillips Creek (n=165) and Henshaw Creek (n=2), June 1991 – 2012 (N=1144). Note: No swims were conducted 1997-1999 (Source: Kevin Pellett, BCCF; FLNRO files, Nanaimo).

Year	Wolf	Thelwood	Ralph	Phillips	Henshaw
1991		225	10		
1992		1	10	20	
1993			4		
1994		30	4		
1995	30	28	30	50	
1996	12	2	12	10	
1997					
1998					
1999					
2000			8	1	
2001	4			16	
2002		8	3	1	
2003	30	3		5	
2004	41	6	17		2
2005	23			11	
2006		24	4		
2007		6	56		
2008	75	4		3	
2009	90	9	9	4	
2010	90	5	27	40	
2011	30	2		21	
2012	5			3	
Total	430	353	194	165	2

Fisheries Objectives and Management Strategies

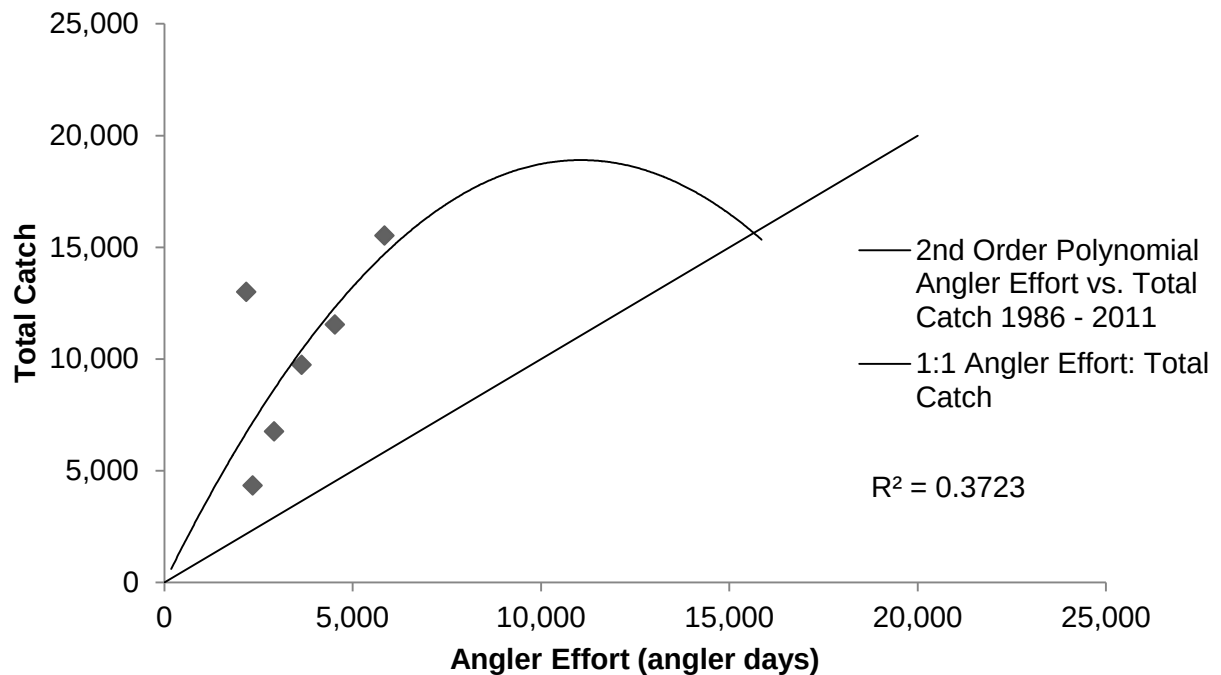


FIGURE 11. Angler effort (angler days) vs. total catch and maximum angler effort and catch at the current regulations at Buttle Lakes 1986 – 2011. The point at which the 2nd degree polynomial curve diverges furthest from the 1:1 equilibrium line is where the optimum angler effort produces the highest sustained catch. In this case, 10,000 angler days would result in an optimal catch of ~18,000 fish and a success rate of 1.8 fish/day. However, we chose not to use this relationship to determine optimum and maximum levels at Buttle Lake because of the low R^2 value (0.3723) (Source: Aitzhanova, et al. 2003; Andrews, 2007, Silvestri, 2013 in prep.).

Appendix 11. Comox Lake

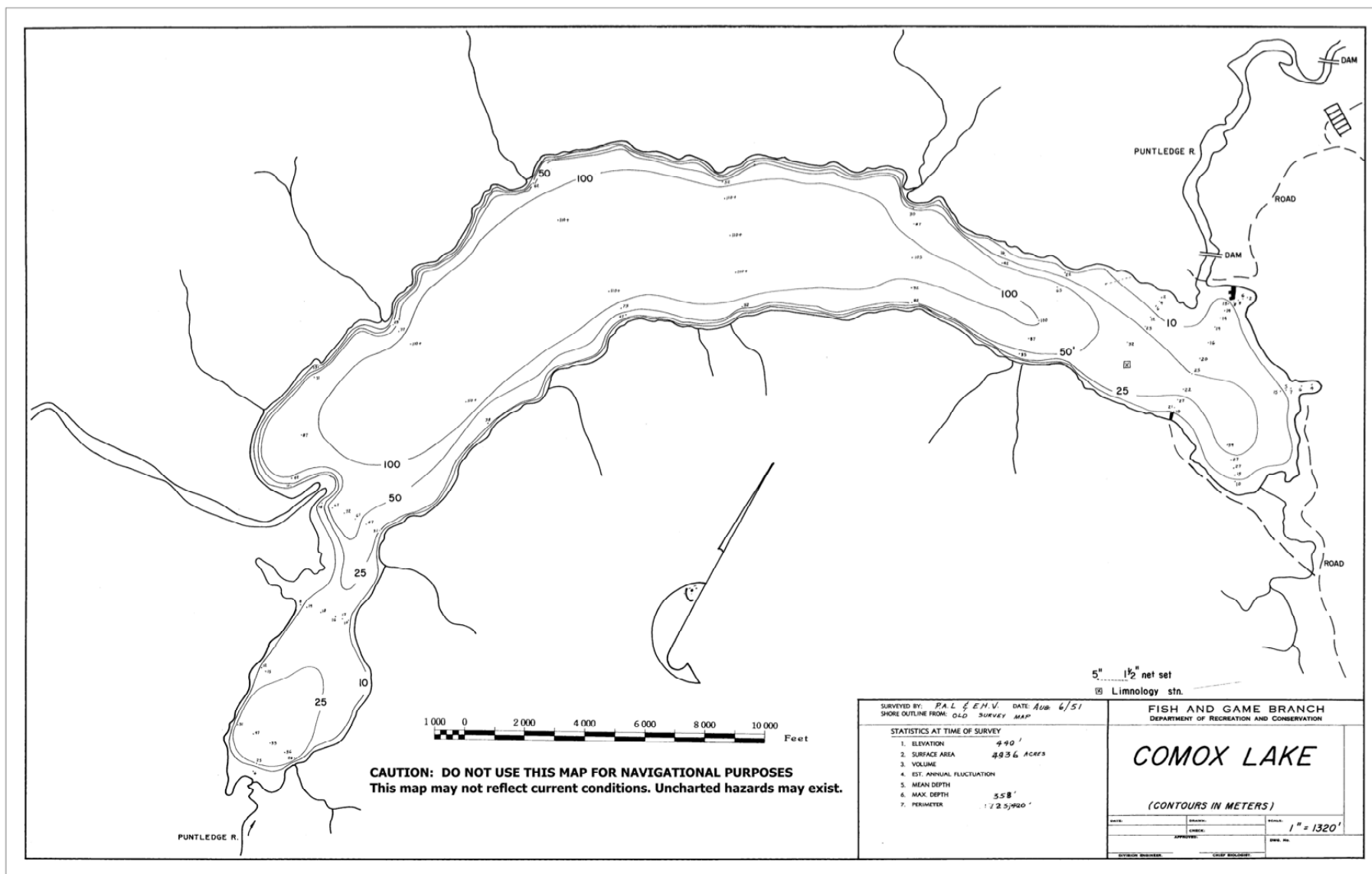


FIGURE 1. Bathymetric map of Comox Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Angling Data

Size of Angler-Harvested Fish – Courtenay Fish and Game Association Study at Comox Lake 2009 – 2010

Cutthroat harvested by anglers ranged from 150 mm (~ 6") to 445 mm (17.5") in 2009 and from 250 mm (9.8") to (17.7") in 2010 (Table 1). The mean size of cutthroat harvested by anglers throughout the study period was 278.8 mm (10.9") while the mean size of rainbow harvested was 320 mm (12.6").

TABLE 1. Total number, minimum, maximum and mean size of cutthroat, rainbow and trout harvested by anglers at Comox Lake April, 2009 – September, 2010. Only catch by Fish and Game Club members that occurred on instant count days included (Source: angler interviews conducting following instantaneous counts conducted by Courtenay Fish and Game Club April, 2009 – October, 2010 and Angler Logs kept by Courtenay Fish and Game Club May – October, 2009).

Species	Length (mm) 2009				2010				Total			
	N	Min.	Max.	Ave.	N	Min.	Max.	Ave.	N	Min.	Max.	Ave.
Cutthroat	61	150.0	445.0	267.2	15	250.0	450.0	326.1	76	150.0	450.0	278.8
Rainbow	-----	-----	-----	-----	1	320.0	320.0	320.0	1	320.0	320.0	320.0
Trout	4	150.0	230.0	210.0	-----	-----	-----	-----	4	150.0	230.0	210.0
Total	65	150.0	445.0	263.7	16	250.0	450.0	325.8	81	150.0	450.0	275.9

Stock Status Indicators

Cutthroat Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of cutthroat trout captured in gillnets in Comox Lake from 1948 to 2010 is shown in Table 2. Minimum fork length has varied from 380 mm in 1953 to 130-140 mm in recent surveys in 2009 and 2010, while maximum fork length has varied from 355 mm in 1948, to 560 mm in 1953. Mean fork length of cutthroat captured in gillnets has stayed somewhat consistent at ~260 mm with the exception of 1953 when the mean size was close to 500 mm. Note, however, that only eight cutthroat were captured that year.

TABLE 2. Total numbers and minimum, maximum and mean fork length of cutthroat trout captured by gillnet in Comox Lake in October 1948, August 1951, June 1953, August 2009 and August 2010 (Source: FISS, Province of BC files, Nanaimo; Courtenay Fish and Game Protective Association).

Year	N	Length (mm)				Weight (g)
		Minimum	Maximum	Mean	Mode	Mean
1948	34	208	355	276.5	280	-----
1951	32	165	375	267.9	255	201.4
1953	8	380	560	495.8	500	1,231.9
2009	19	130	425	225.6	210	156.7
2010	9	140	365	267.2	265	227.4

Length Frequency Distributions

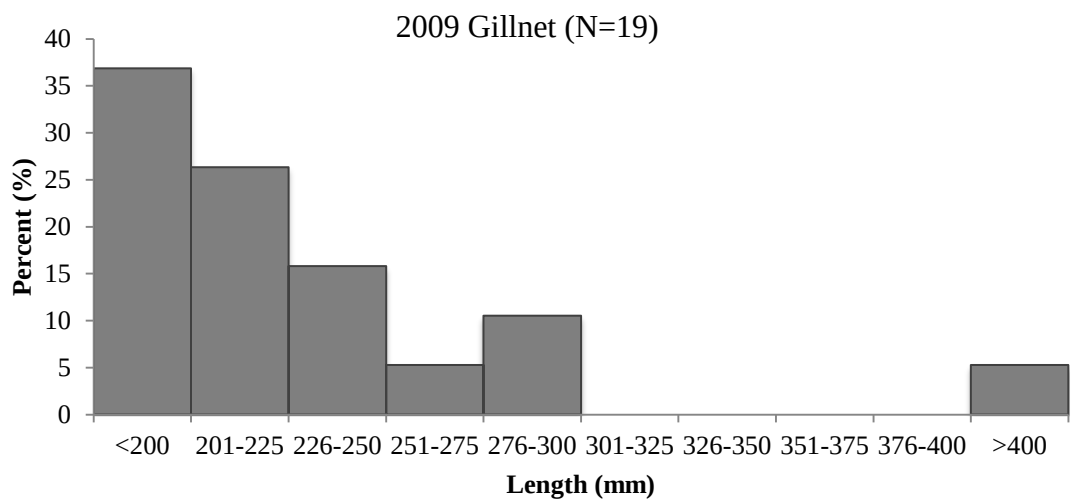
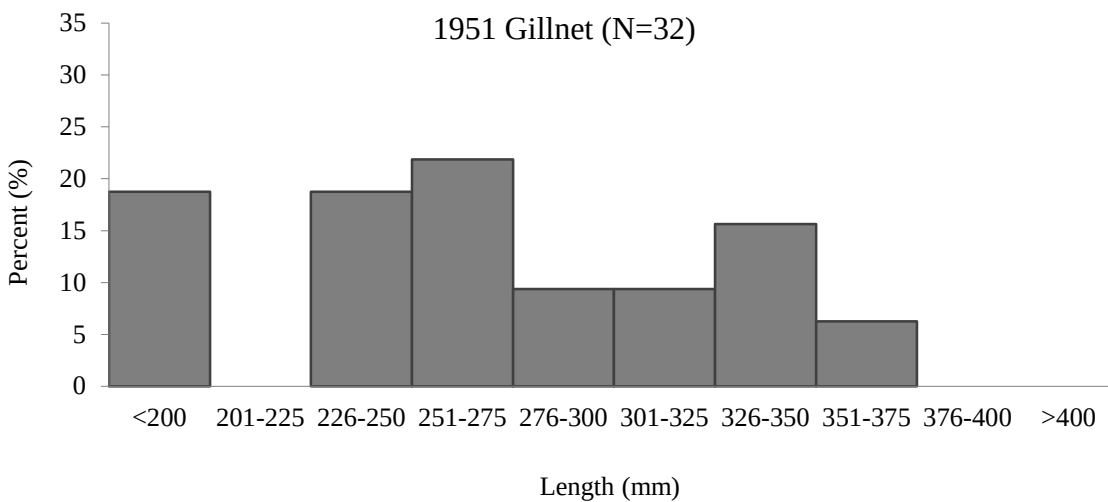
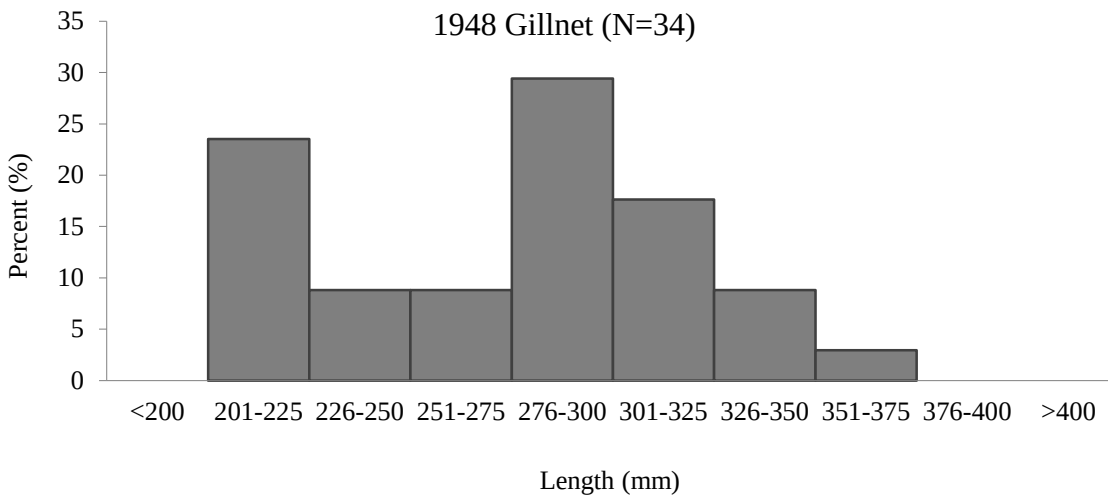


FIGURE 2. Length frequency of cutthroat trout captured in gillnets in 1948 (N=34), 1951(N=32) and 2009 (N=19) (Source: FLNRO files, Nanaimo; Courtenay Fish and Game Protective Association, 2011).

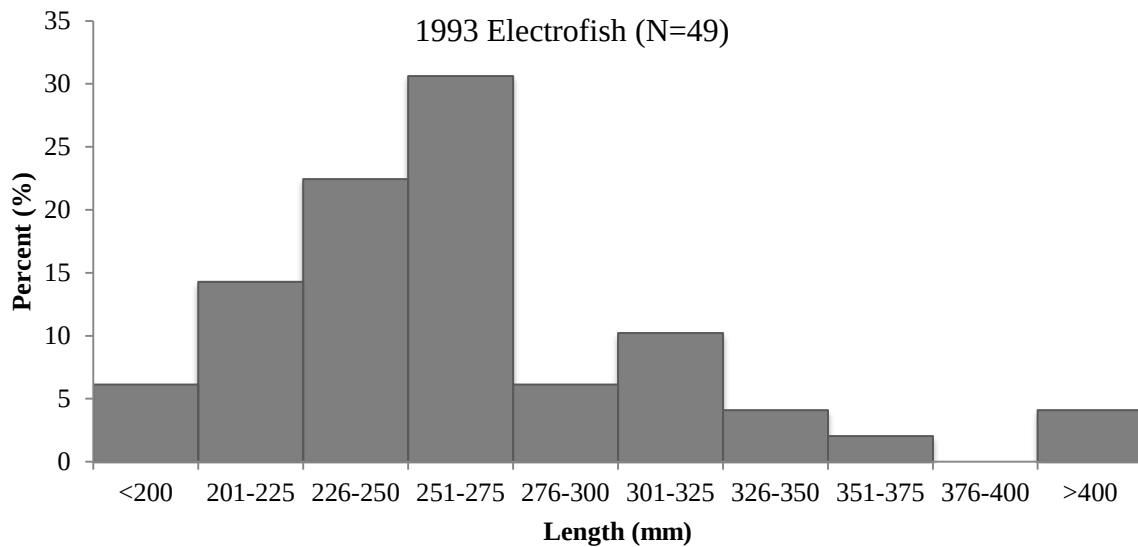


FIGURE 3. Length frequency of cutthroat trout captured in the Cruikshank and Upper Puntledge Rivers by electrofishing in 1993 (N=49) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

We've presented a length-weight relationship for cutthroat trout captured in gillnets in Comox Lake and by electrofishing Comox Lake tributaries in Figure 4. Although some cutthroat sampled have been >500 mm and >1400 g, most cutthroat have been ~300 mm and 300 g.

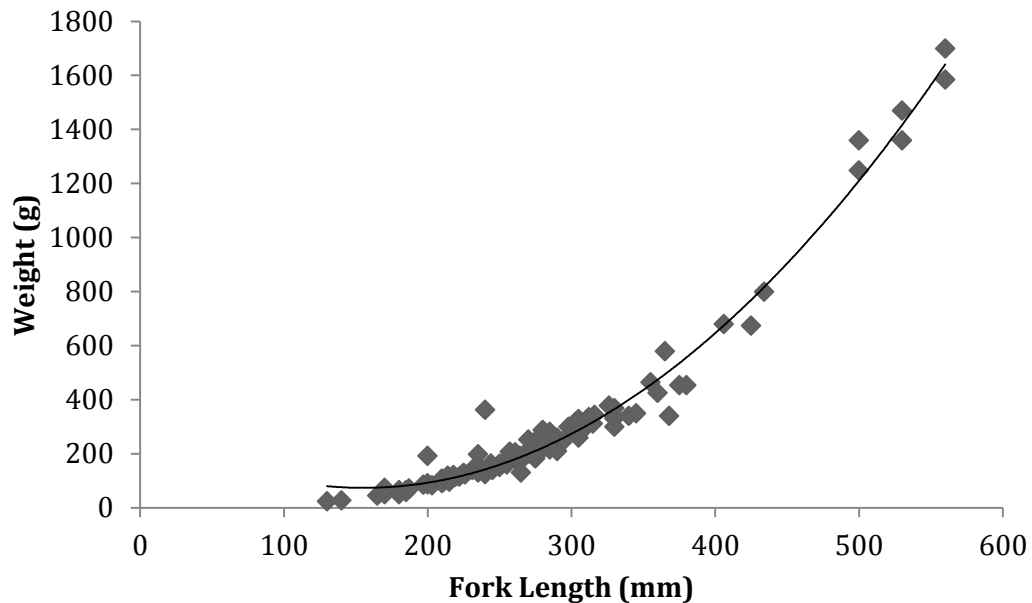


FIGURE 4. Length-weight relationship for cutthroat trout captured in gillnets in Comox Lake and by electrofishing in Comox Lake tributaries 1951- 2010 (N=116) (Source: FLNRO files, Nanaimo).

Maturity

The age-at-maturity for 23 cutthroat trout sampled in 2009 and 2010 is presented in Table 3. All but one fish was immature. The 22 immature cutthroat trout sampled were on average ~2 years of age while the only maturing cutthroat sampled was 4 years.

TABLE 3. Total number, mean age and minimum, maximum and mean fork length (mm) of cutthroat trout sampled in gillnets and by anglers in 2009 and 2010 in Comox Lake (Source: FLNRO files, Nanaimo; Lough, 2009; Lough 2010).

Maturity	N	Mean Age
Immature	22	2.1
Maturing	1	4.0

The mean size of immature cutthroat trout has ranged from ~258 mm to 261 mm in 1948 and 1951, to 225 mm in 2009 and 2010 (Table 4). Mature cutthroat trout were only recorded in the 1948 samples and these fish averaged 300 mm in length.

TABLE 4. Mean lengths (mm) of immature and mature cutthroat trout sampled in gillnets in 1948, 1951, 2009 and 2010 in Comox Lake (Source: FLNRO files, Nanaimo; Lough, 2009; Lough 2010).

1948 (N=20)		1951 (N=30)	2009 and 2010 (N=23)
Immature (n=9)	Mature (n=11)	Immature	Immature
258 mm	300 mm	261	225

The size distribution of mature female cutthroat trout varied between 255 mm and 425 mm, while mature male cutthroat trout varied between 280 mm and 315 mm (Table 5). The size distribution of immature female cutthroat trout ranged from 185 mm – 340 mm while immature male cutthroat trout varied between 165 mm and 355 mm. The mean length of immature female cutthroat trout was 265 mm while the mean length of immature males was 258 mm. At a mean length of 318 mm, mature female cutthroat trout tended to be larger than the mature males, which had a mean length of 297 mm.

TABLE 5. Male vs. female cutthroat numbers and size captured in gillnets in Comox Lake in 1948, 1951, 2009 and 2010. Small sample size is due to data omissions on maturity and sex (Source: FLNRO files, Nanaimo).

Factor	Female cutthroat N=44		Male cutthroat N=37	
	Immature (n=19)	Mature (n=11)	Immature (n=26)	Mature (n=5)
Range	185-340	255-425	165-355	280-315
Mean	265	318	258	297

Rainbow Trout

Population Data

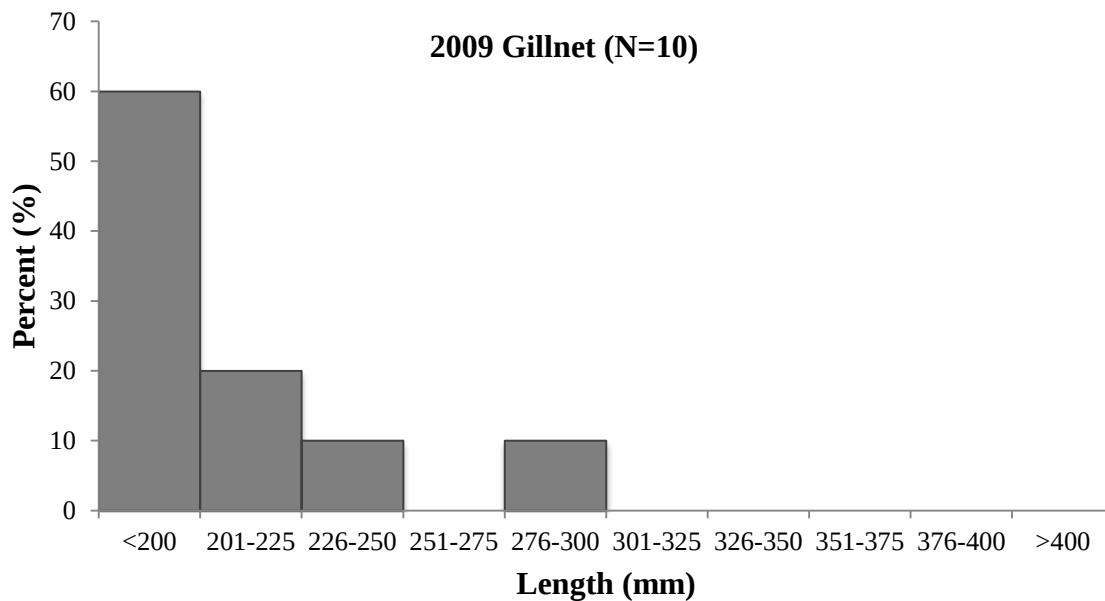
Three rainbow trout ranging in length from 230 mm – 250 mm were sampled by gillnet in Comox Lake in 1948 (Table 6). In 1951, another three rainbow were sampled by gillnet ranging in length between 155 mm – 267 mm. Fork length of the two rainbow trout sampled in 1953 ranged between 290 mm – 330 mm. In 2009, a total of ten rainbow trout were sampled by gillnet ranging in length between 127 mm – 300 mm, while in 2010, a total of 19 rainbow trout were sampled by gillnet ranging in length between 110 mm – 375 mm.

TABLE 6. Total numbers and minimum, maximum and mean fork length of rainbow trout captured by gillnet in Comox Lake in October 1948, August 1951, June 1953, August 2009 and August 2010 (Source: FISS, FLNRO files, Nanaimo; Courtenay Fish and Game Protective Association).

Year	N	Length (mm)		Mean	Mode	Weight (g)
		Minimum	Maximum			Mean
1948	3	230	250	243.3	250	
1951	3	155	267	219	-----	161
1953	2	290	330	310	-----	284
2009	10	127	300	196	-----	102.6
2010	19	110	375	202.1	130	126.8

Length Frequency Distributions

Percent length frequency of rainbow trout sampled in 2009 and 2010 is shown in Figure 5. 1948, 1951 and 1953 sample years were not shown due to small sample size. In both years, the highest percentage of rainbow captured (~60%) were <200 mm.



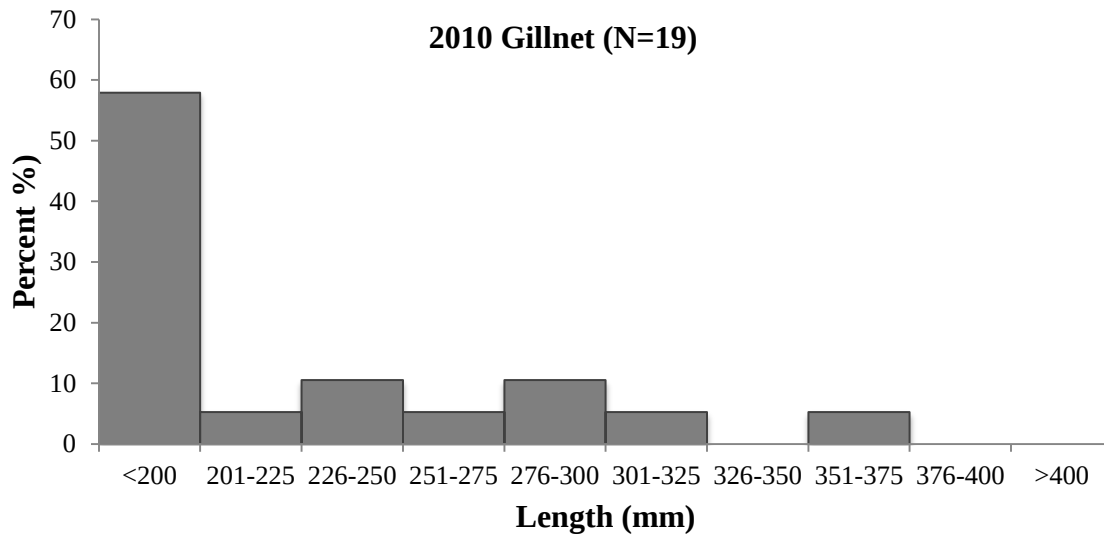


FIGURE 5. Length frequency of rainbow trout captured in gillnets in Comox Lake, 2009 (N=10) and 2010 (N=19) (Source: Courtenay Fish and Game Protective Association, 2011).

Length-Weight Relationship

The length and weight relationship for rainbow trout captured in gillnets in Comox Lake in 1951, 1953, 2009 and 2010 is shown in Figure 6. Length ranged between 110 mm - 375 mm while weight ranged between 14 g – 630 g.

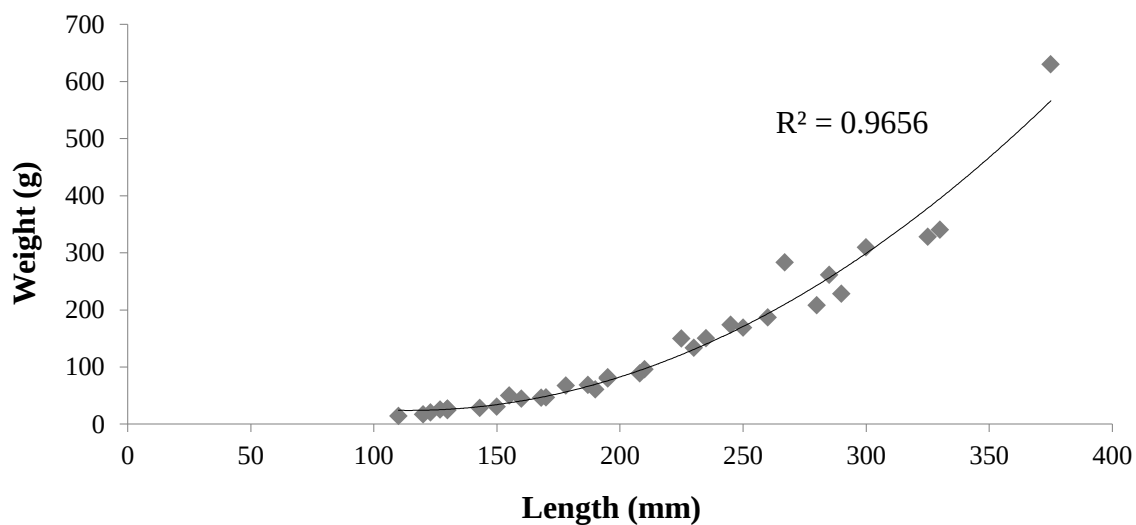


FIGURE 6. Length-weight relationship for rainbow trout captured in gillnets in Comox Lake 1951, 1953, 2009, and 2010 (N=34) (Source: FLNRO files, Nanaimo).

Maturity

The size distribution of maturing female rainbow trout ranged between 285 mm and 375 mm, while maturing male rainbow trout averaged 300 mm (Table 7). Immature female rainbow trout averaged 280 mm while immature male rainbow trout varied between 155 mm and 260 mm.

TABLE 7. Male vs. female rainbow numbers and size captured in gillnets in Comox Lake in 1948, 1951, 1953, 2009 and 2010. Small sample size is due to data omissions on maturity and sex (Source: FLNRO files, Nanaimo).

Factor	Female rainbow N=5		Male rainbow N=13	
	Immature (n=1)	Maturing (n=2)	Immature (n=8)	Maturing (n=1)
Range	280	285-375	155-260	300
Mean	280	330	219	300

Dolly Varden

Population Data

Forty-seven Dolly Varden ranging in length from 195 mm – 380 mm were captured in Comox Lake in 1948 while in 1993, 60 Dolly Varden were captured by electrofishing. These fish ranged in size from 112 mm – 392 mm (Table 8). In 2009, a single Dolly Varden measuring 187 mm was captured by gillnet and in 2010, eight Dolly Varden were captured by gillnet ranging between 150 mm – 340 mm. There was a decline in Dolly Varden mean length from 254 mm in 1948, to 246 mm in 1993. This may be the result of different sampling methodologies. Also, sampling in both years was done in October/November so some mature fish would have been in the streams and missed in the assessment.

TABLE 8. Total numbers and minimum, maximum and mean fork length of Dolly Varden captured by gillnet in Comox Lake in October 1948, August 1951, June 1953, August 2009 and August 2010 (Source: FISS, FLNRO files, Nanaimo; Courtenay Fish and Game Protective Association).

Year	N	Length (mm)		Mean	Mode	Weight (g)
		Minimum	Maximum			Mean
1948	47	195	380	254.4	210	
2009	1	187	187	187	-----	64.2
2010	9	120	340	232.2	250	182.6

Length Frequency Distributions

The length frequency distributions of Dolly Varden sampled by gillnet in Comox Lake in 1948, and 2010, and by electrofishing in the Cruikshank and Upper Puntledge Rivers in 1993 is shown in Figures 7 and Figure 8. Only 1 Dolly Varden was captured in the 2009 gillnet sample so was not included in these figures.

Approximately 20% of Dolly Varden in length classes between 201 mm – 275 mm in 1948 while in 1993 and 2010 the highest percentage of Dolly Varden captured were 226 mm – 250 mm. Fish up to 400 mm were captured in 1948 and 1993. However, the largest Dolly Varden captured in 2010 was <350 mm.

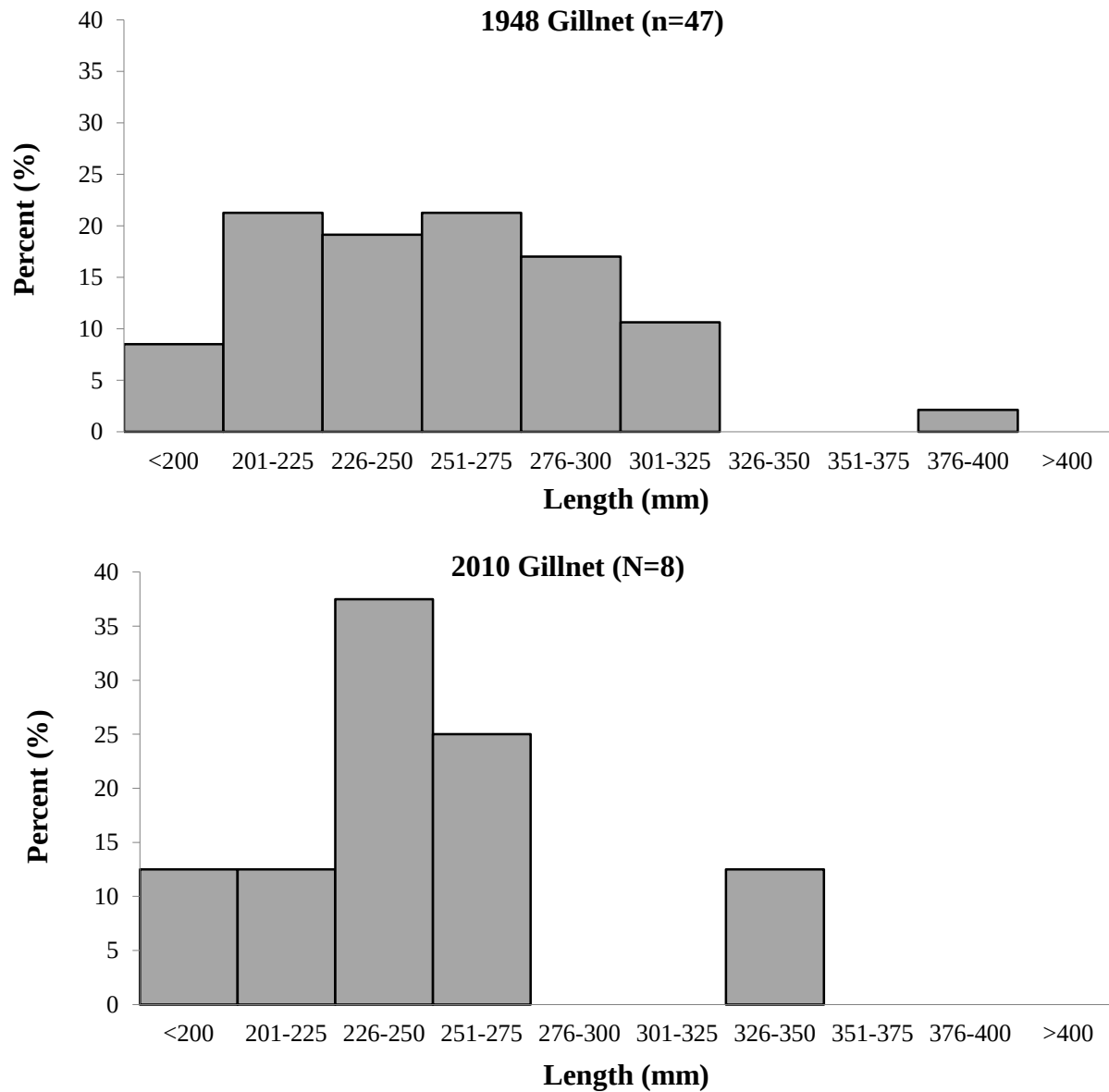


FIGURE 7. Percent length frequency analysis of Dolly Varden captured in gillnets in Comox Lake 1948 (N=47) and 2010 (N=8) (Source: FLNRO files Nanaimo; Courtenay Fish and Game Protective Association, 2011).

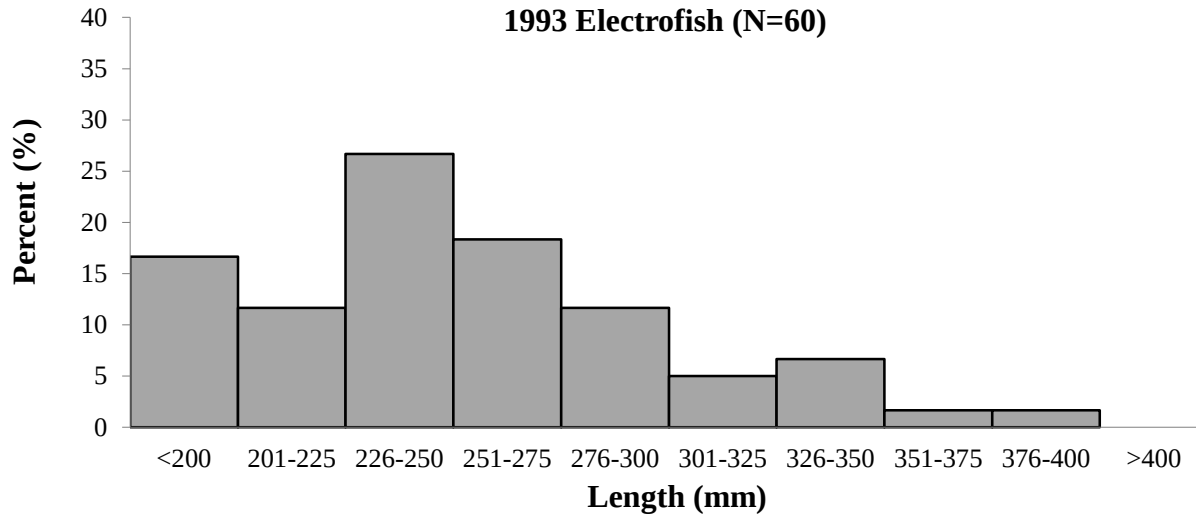


FIGURE 8. Percent length frequency analysis of Dolly Varden electrofished in the Cruikshank and Upper Puntledge Rivers, 1993 (N=60) (Source: FLNRO files, Nanaimo).

Length Weight Relationship

The length-weight relationship of immature and mature Dolly Varden captured by electrofishing in 1993 and gillnetting in 2009 and 2010 is shown in Figure 9. The smallest fish captured was 112 mm and 14 g while the largest was 392 mm and 750 g.

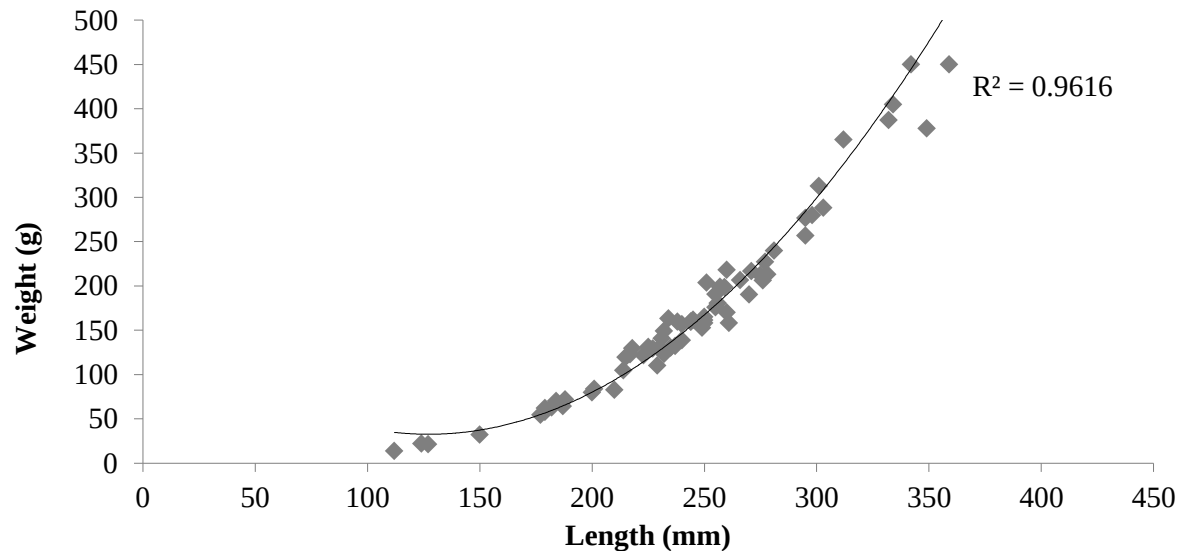


FIGURE 9. Length weight relationship of Dolly Varden caught by electrofishing in the Cruikshank and Upper Puntledge Rivers, 1993, and by gillnetting in Comox Lake, 2009 and 2010 (N=69) (Source: FLNRO files, Nanaimo)

Maturity

The size distribution of mature female Dolly Varden varied between 285 mm and 375 mm, while mature male Dolly Varden varied between 265 mm and 340 mm (Table 9). Immature female Dolly Varden varied between 200 mm and 290 mm while immature male Dolly Varden varied between 210 mm and 308 mm.

TABLE 9. Male vs. female Dolly Varden numbers and size captured in gillnets in Comox Lake in 1948, 2009 and 2010 (Source: FLNRO files, Nanaimo).

Factor	Female Dolly Varden N=35		Male Dolly Varden N=18	
	Immature (n=22)	Mature (n=5)	Immature (n=6)	Mature (n=7)
Range	200-290	285-375	210-308	265-340
Mean	238	293	246	291

Kokanee Salmon

Population Data

Larkin and Vernon (1948) sampled 78 kokanee in Comox Lake 1948 ranging from 200 mm – 251 mm (Table 10). In 1993, DFO electrofished only 13 kokanee ranging from 162 mm – 198 mm. The mean size differed by almost 40 mm between the two years. No kokanee were captured in the 2009 and 2010 gillnet sampling.

TABLE 10. Total numbers and minimum, maximum and mean fork length of kokanee salmon captured by gillnet in Comox Lake in October 1948, No kokanee were captured in other sampling years (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)		
		Minimum	Maximum	Mean
1948	48	210	251	234.3

Length Frequency Distributions

The percent length frequency distributions of kokanee captured by gillnet in Comox Lake in 1948 and by electrofishing in the Cruikshank and Upper Puntledge Rivers in 1993 are shown in Figure 10. A total of 48 kokanee ranging between 210 mm and 251 mm were sampled in October 1948. The 13 kokanee sampled in 1993 were smaller and ranged from 162 mm - 198 mm. The 1948 sampling shows three modes indicating 1, 2 and 3 year old kokanee at 200, 225 and 235 mm respectively, while the 1993 sampling shows one mode at 190 mm indicating age 1 kokanee. The largest kokanee captured in 1948 was 251 mm, and in 1993 was 198 mm. Kokanee caught in 1993 were much smaller in size than those caught in 1948 and there was only one age class indicating that fish had already spawned. In 1993, kokanee were sampled in November when most mature fish would have already spawned.

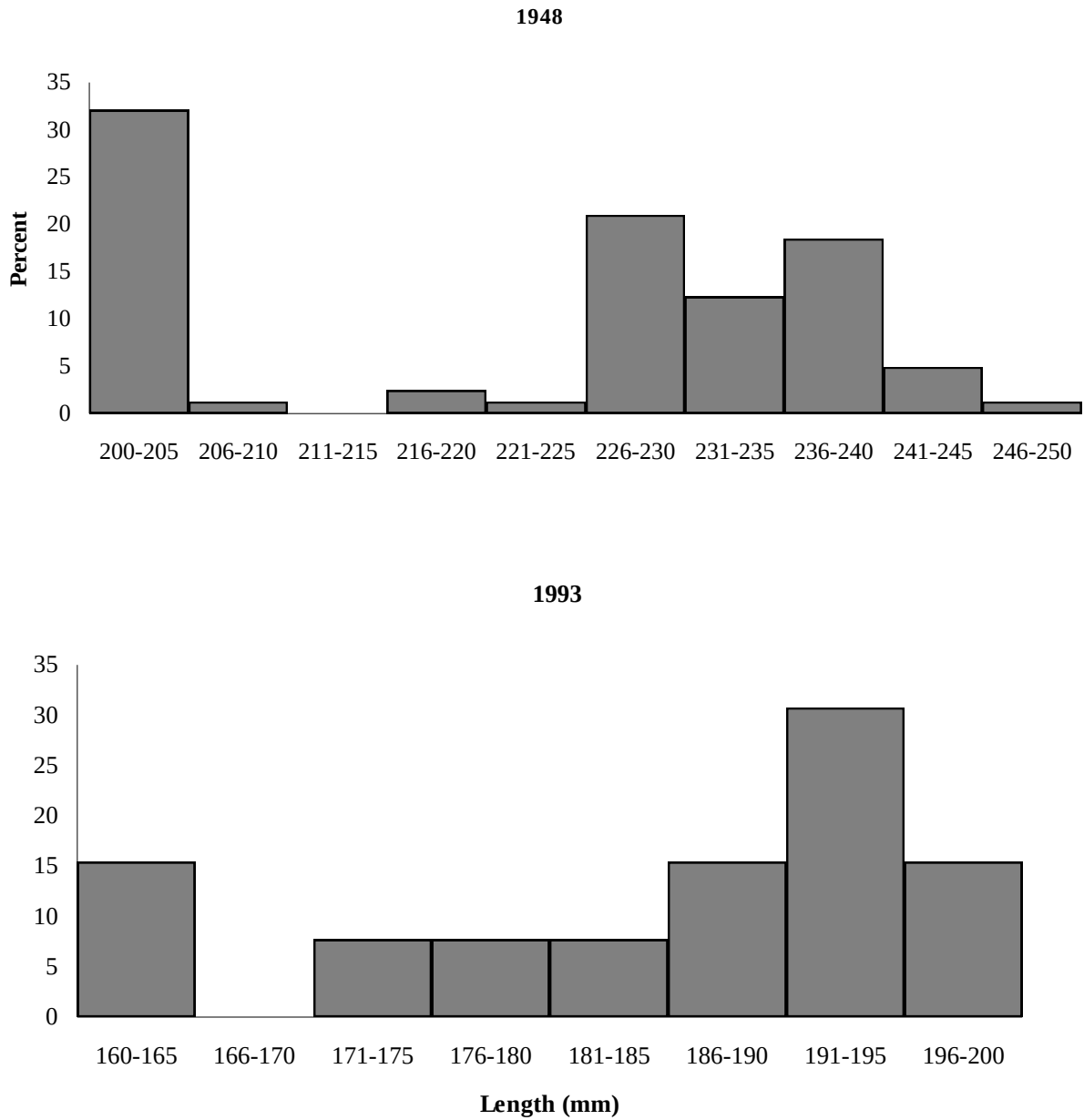


FIGURE 10. Percent length frequency analysis of kokanee captured in Comox Lake 1948 (N=77) and 1993 (N=13). Note that no fish >200 mm were sampled in 1993 (Source: FLNRO files, Nanaimo).

Appendix 12. Cowichan Lake

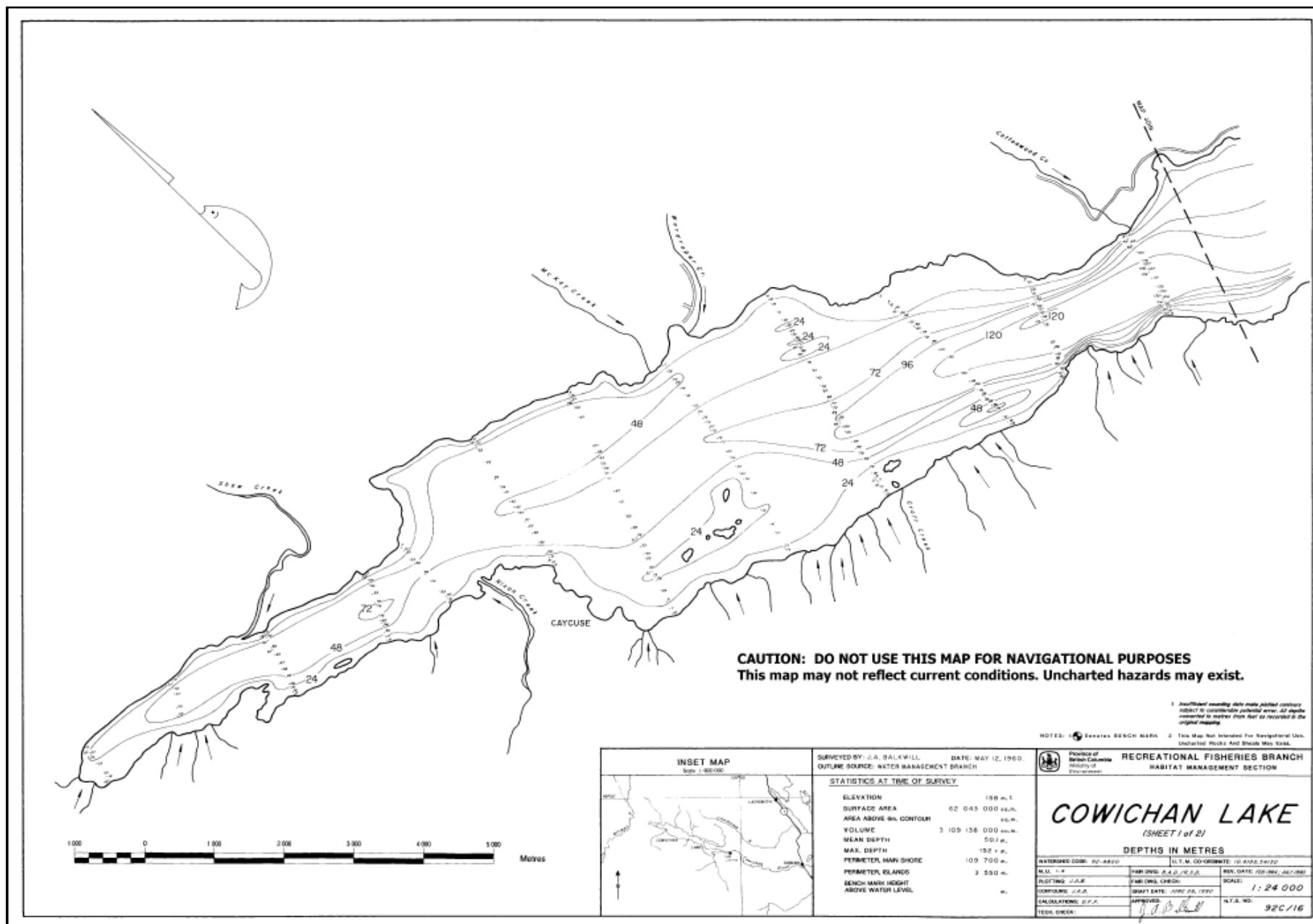


FIGURE 1. Bathymetric map of Cowichan Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

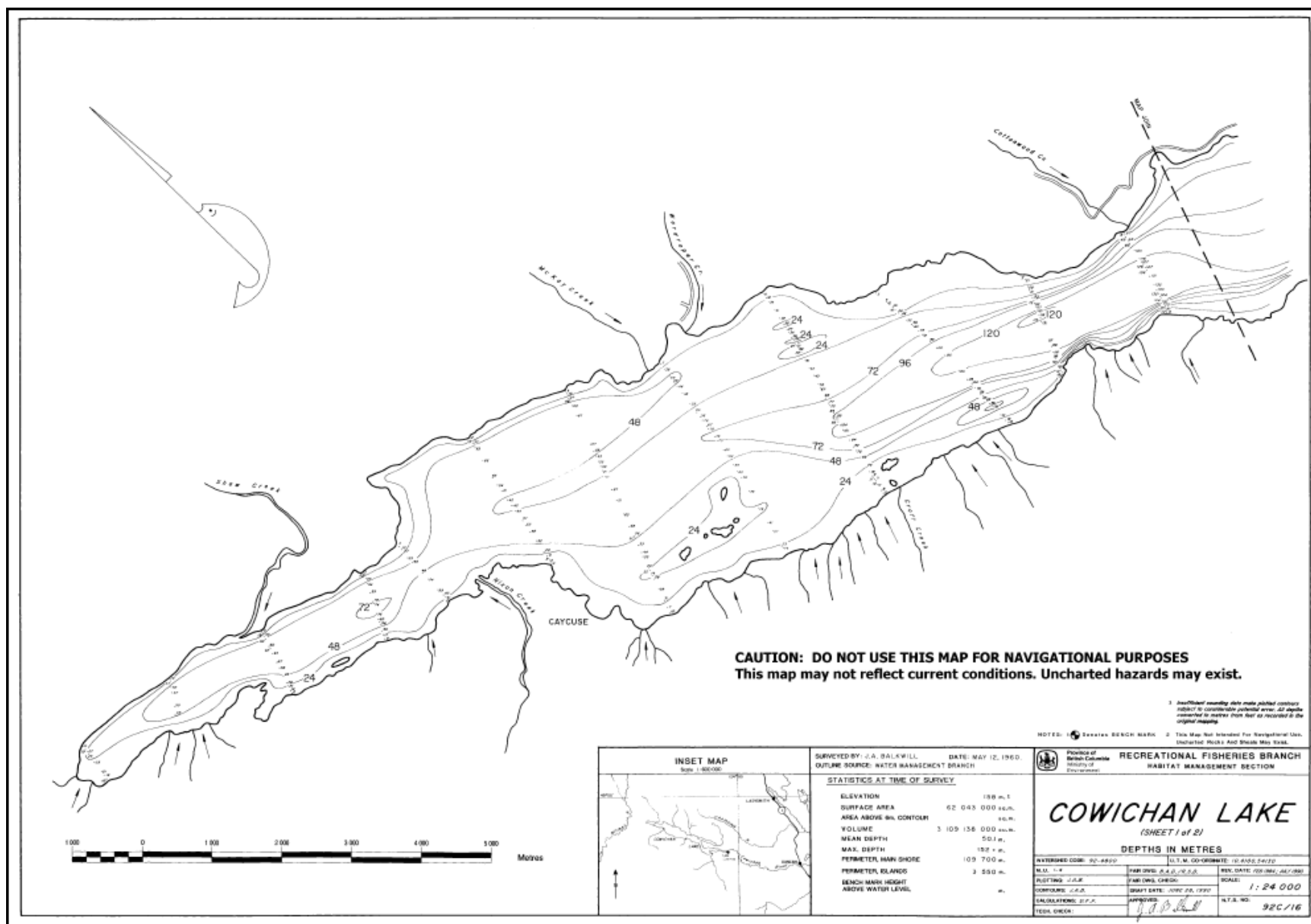


FIGURE 1 (CONTINUED). Bathymetric map of Cowichan Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Angling Data

In 1966, Bull summarized data from an angler creel survey conducted on the Cowichan River (Table 1). Between 1962 and 1965, anglers caught male rainbow that averaged ~400 mm and females that averaged ~350 mm.

Bull (1966) found that anglers most frequently caught age 2 and 2+ and 3 and 3+ Lake rainbow trout when angling in Cowichan River (Table 1). Older fish, including age 6 and 6+ rainbow comprised ~1% of the total catch of rainbow trout caught.

TABLE 1. Percent of each age class of adfluvial rainbow trout caught by anglers in the Cowichan River and Cowichan Lake from 1962-1965 (N=83) (Source: Bull, 1966).

Age at Capture	Percent
1+	3.6
2+	42.2
3+	32.5
4+	15.7
5+	4.8
6+	1.2

Length and Weight

TABLE 2. Mean weight and length of adfluvial rainbow trout caught in Cowichan River by anglers 1962-65 (Source: Bull, 1966)

Length (mm)			Weight (g)		
Male	Female	Unsexed	Male	Female	Unsexed
399	349	332	487	1003	657

We've presented the length-weight relationship for rainbow trout captured by angling in 1953, trap nets in 1996, and gillnet in 2009 and 2011 in Figure 2. Most rainbow trout captured were <200 mm and <200 g. In 1953, 300 mm fish averaged >400 g, while in 1996 and 2009, 300 mm fish averaged ~350 g. Note that only 4 fish were captured in 1953.

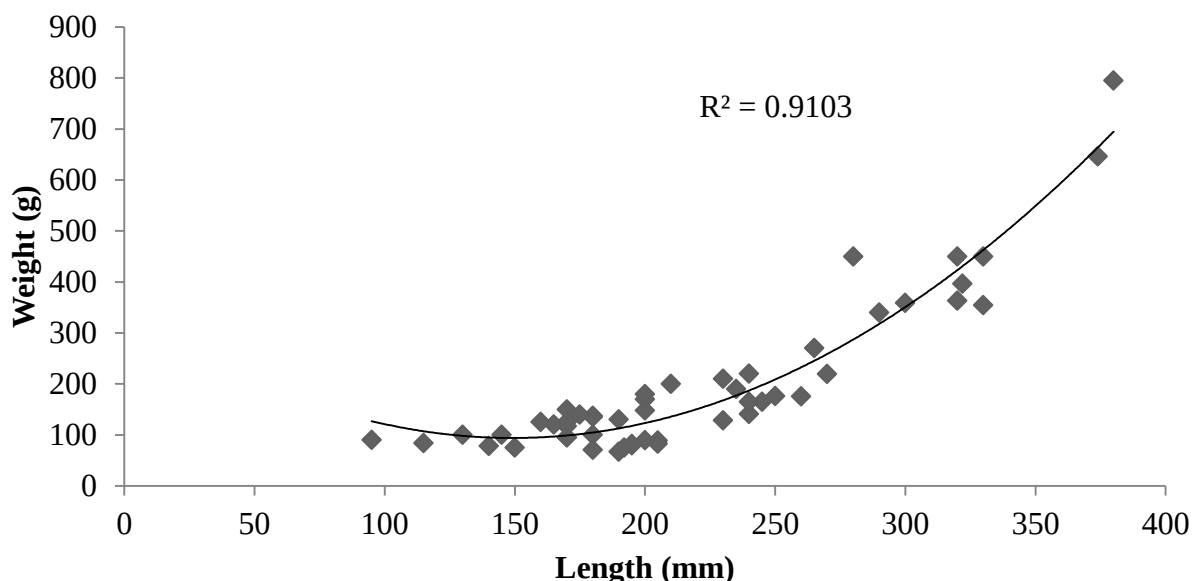


FIGURE 2. Length weight relationship of rainbow trout captured by angling in 1953 (N=4), net trap in 1996 (N=28), and by gillnet in 2009 (N=6) and 2011 (N=14) in Cowichan Lake (Source: FLNRO files, Nanaimo).

Stock Status Indicators

Cutthroat Trout

Population Data

Cowichan Lake has been sampled by gillnet in 1989, 2009 and 2011 (Table 3). Two sinking gillnets were set in Cowichan Lake on July 24, 1989 in shoal areas near the mouth of Robertson River. These two nets were set at mid-day on July 24 and left in place for 18 hours and 21 hours respectively, resulting in a catch of eight cutthroat trout. A single large male cutthroat measured 424 mm in length and the stomach content contained a small kokanee salmon along with stickleback. The remaining seven cutthroat trout ranging in length between 165 mm – 195 mm and a mean length of 181 mm. Most of the cutthroat sampled had been feeding on aquatic insects and plankton (Griffith, 1989).

TABLE 3. Total numbers and minimum, maximum and mean fork length of cutthroat trout captured by gillnet in Cowichan Lake in 1989, 2009 and 2011 (Source: FLNRO files, Nanaimo; FISS, Griffith 1989; Lough 2012; Lough et al, 2011a).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1989	8	165	424	---	---
2009	35	145	450	274	249
2011	24	113	525	328	428

On July 25, 1989, a third net was hung vertically near the centre of the lake in an area where numerous fish rises were observed at the time, but yielded no fish. In August 26, 2009, two floating gillnets and two sinking gillnets were set near the mouths of Shaw Creek and Nixon Creek in Cowichan Lake. A total of 35 cutthroat trout were sampled by gillnet in 2009, ranging in

length from 145 mm to 450 mm, with a mean length of 266 mm. Two years later, the gillnet set was repeated.

On August 26, 2011, two floating gillnets and two sinking gillnets were set near the previous 2009 net set location at the mouths of Shaw Creek and Nixon Creek. A total of 25 cutthroat trout were sampled by gillnet in 2011 ranging in length from 113 mm to 525 mm, with a mean length of 328 mm. Overall, the mean length increased from 181 mm in 1989 to 266 mm in 2009 to 328 mm in 2011. Gillnetting was conducted during July and August for all three sampling years. The total number of cutthroat trout captured in gillnets in Cowichan Lake has ranged from 1 to 35 with catches averaging ~10 fish/sample. Fork lengths have ranged from 113 mm to 525 mm, and have averaged 348 mm.

Electrofishing and habitat assessments were conducted by Griffith (1989) between July 17 and August 25, 1989 in a total of 35 primary and secondary tributaries to Cowichan Lake and two outlet tributaries (Table 4). Electrofishing was conducted over two separate periods in 1989, July 7 to August 3 and then again from August 14 through to August 25. A total of 28 cutthroat trout were sampled by electrofishing in July-August 1989 ranging in length between 61 mm – 178 mm. A second electrofishing survey was completed in August 1990 where a total of 16 cutthroat trout were captured ranging in length from 81 mm to 114 mm. In August 2012, Nixon Creek and Sutton Creek were sampled by electrofishing resulting in a total of 38 trout ranging in length from 29 mm to 150 mm. The 2012 electrofishing did not determine whether the trout were cutthroat or rainbow species.

TABLE 4 Total numbers and minimum, maximum and mean fork length of cutthroat trout captured by electrofishing in the tributaries to Cowichan Lake in 1989, 1990. Note: Electrofishing conducted in 2012 at Sutton and Nixon Creek indicated trout species only (Source: FLNRO files, Nanaimo; FISS; Griffith, 1989; Stewart, 1990).

Year	N	Length (mm)		
		Minimum	Maximum	Mean
1989	28	61	178	99
1990	16	81	148	114

Three cutthroat trout were captured by angling in May 1953 ranging in length from 546 mm to 609 mm (Table 5). In 1989, an informal angler creel survey was conducted between July and October, by an Environmental Youth Team, sponsored by the Ministry of Environment. The total catch reported by anglers during the 1989 creel was 36 cutthroat trout, ranging from 140 mm – 600 mm. Griffith (1989) noted that angler activity was low during most of the summer due to poor weather and that the majority of cutthroat captured by anglers occurred during a fishing derby held on October 7-8, 1989. A second angler creel survey was conducted the following year in 1990 between the months of August and October, resulting in a total catch of 52 cutthroat trout, of which 49 had lengths ranging from 190 mm – 660 mm. Angler creel surveys were conducted between 2009 and 2011 where a total of 119 cutthroat ranging from 150 mm to 660 mm were caught.

TABLE 5. Total numbers and minimum, maximum and mean fork length of cutthroat trout captured by angling in 1953, 1989, 1990, 2009, 2010 and 2011 (Source: FLNRO files, Nanaimo; FISS; Griffith, 1989; Stewart, 1990).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1953	3	546	609	575	2119
1989	36	140	600	314	---
1990	49	190	660	383	---
2009	33	150	660	341	---
2010	60	150	540	330	---
2011	26	150	560	290	---

Net traps were set in Cowichan Lake in November 1996 resulting in a capture of 35 cutthroat trout ranging in length from 150 mm – 390 mm (Table 6). A second net trap study was conducted in May 1998, resulting in 186 cutthroat ranging from 84 mm – 370 mm.

TABLE 6. Total numbers and minimum, maximum and mean fork length of cutthroat trout captured by net trap in November 1996 and June 1998 (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1996	35	150	390	228	224
1998	186	84	370	145	---

Cutthroat Trout Length Frequency Distributions

Percent length frequency of cutthroat trout sampled by gillnet in 2009 and 2011 is shown in Figure 3. In 2009, the highest percentage (20%) of fish captured were 251 mm – 275 mm, while in 2011 the highest percentage (20%) of fish were 326 mm – 350 mm indicating better survival of older fish in 2011 compared to 2009. The 1989 sample year was not shown due to small sample size. Percent length frequency of cutthroat trout sampled during angler creel surveys in 1989, 1990 and 2010-2011 is shown in Figure 3. The majority (21%) of fish caught in 2010-2011 were 376 mm – 400 mm in length including 11% of the catch greater than 500 mm in length. The 1989 and 1990 creel data shows anglers catching cutthroat greater than 500 mm in length. Figure 4 shows the length frequency of cutthroat trout caught by net trap in 1996 and 1998 where most were less than 200 mm. The length frequency of cutthroat trout captured by electrofishing in Cowichan Lake tributaries in 1989 (N=28) and 1990 (N=16) and in Sutton and Nixon Creek in August 2012 (Figure 6).

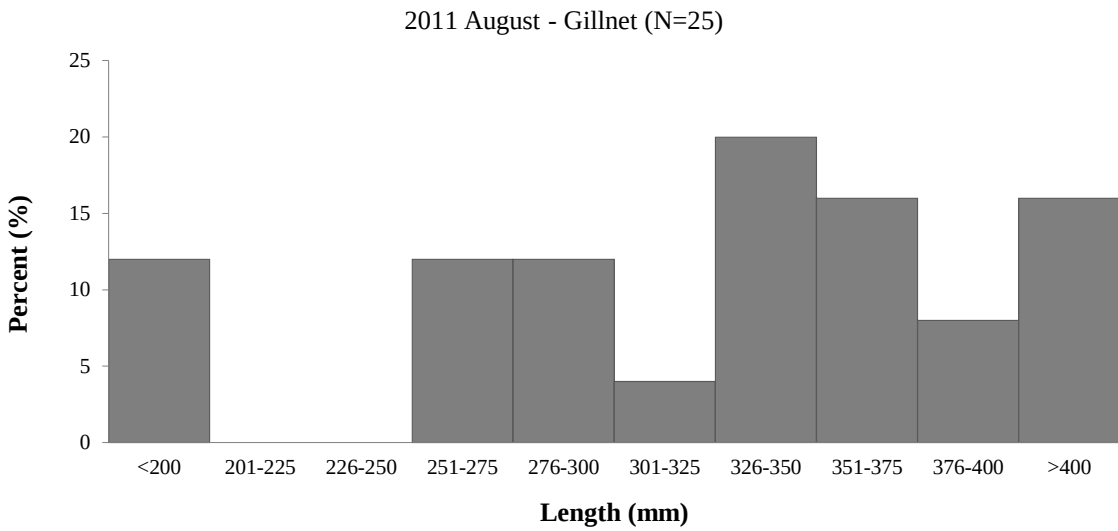
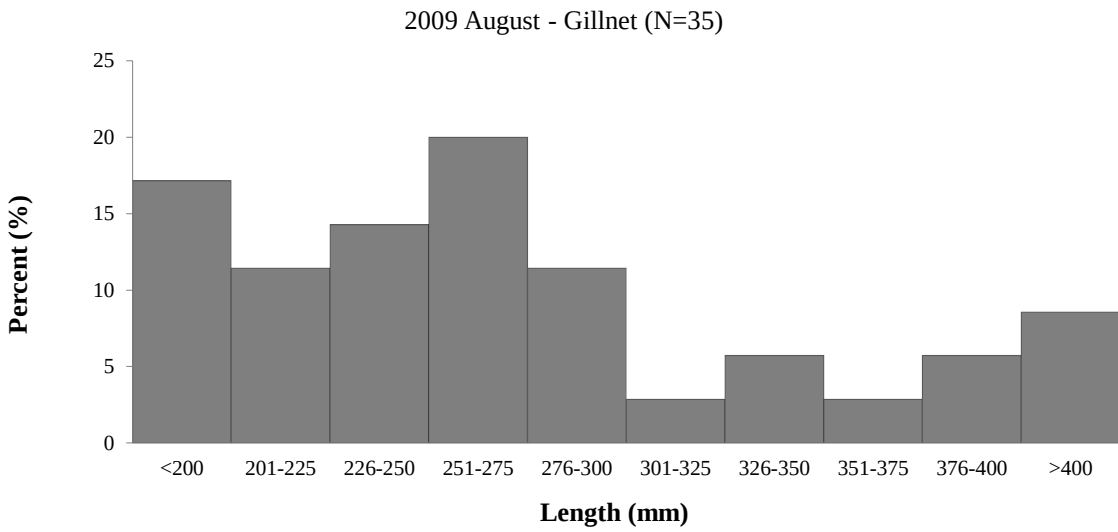


FIGURE 3. Length frequency of cutthroat trout captured by gillnet in Cowichan Lake, 2009 (N=35) and 2011 (N=25) (Source: FLNRO files, Nanaimo).

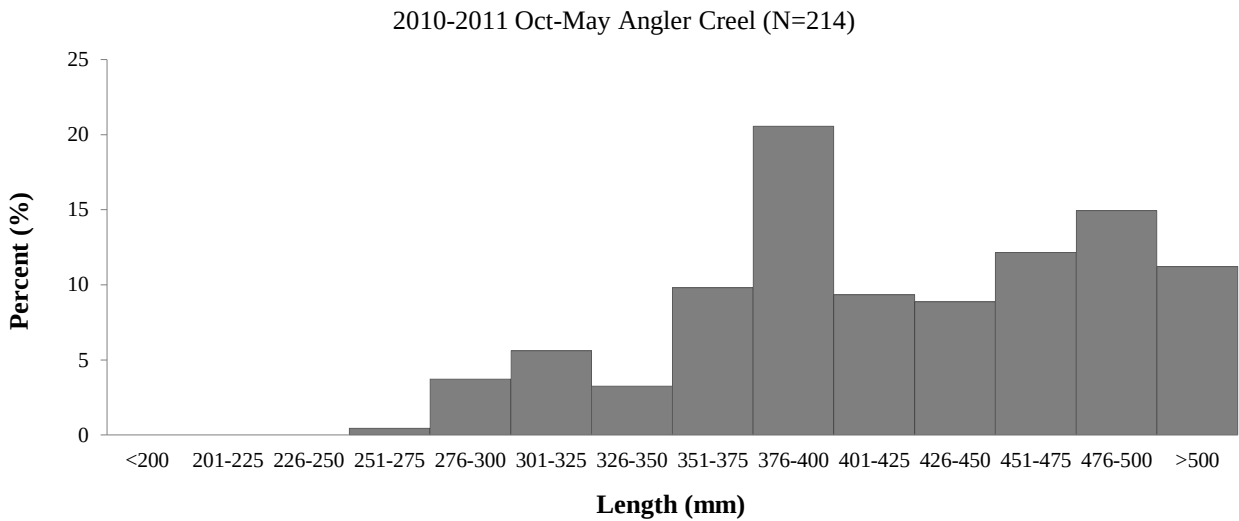
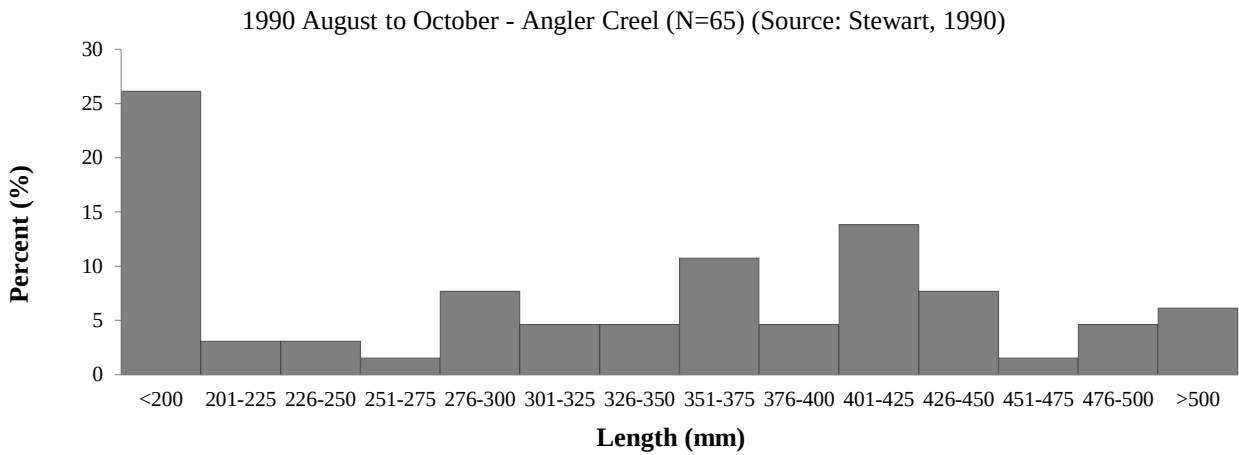
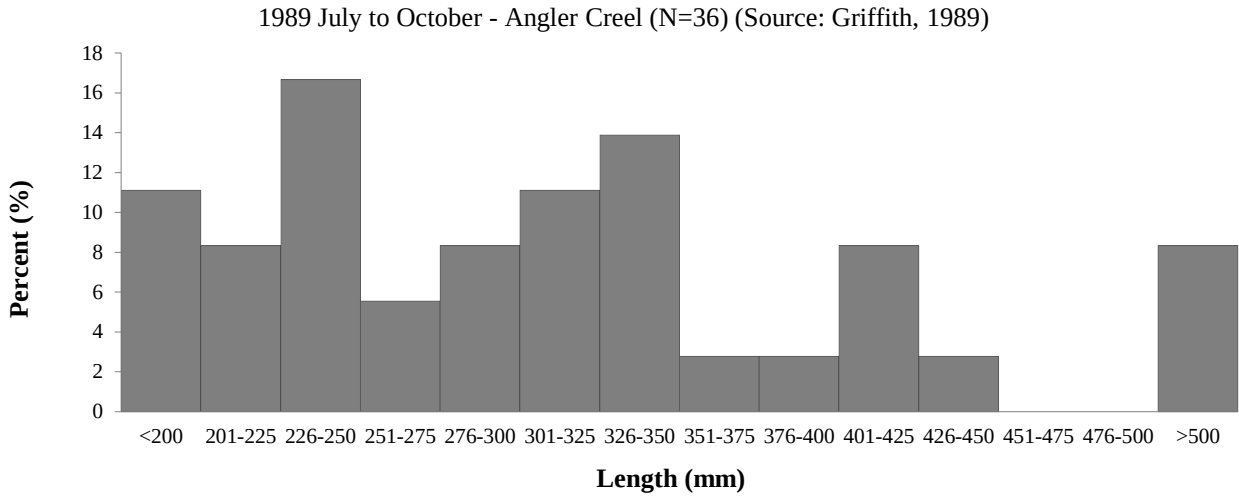


FIGURE 4. Length frequency of cutthroat trout captured by anglers in Cowichan Lake, 1989 (N=36) (Source: Griffith 1989); 1990 (N=65); 2010-2011 (N=214) (Source: Stewart, 1990; FLNRO files, Nanaimo).

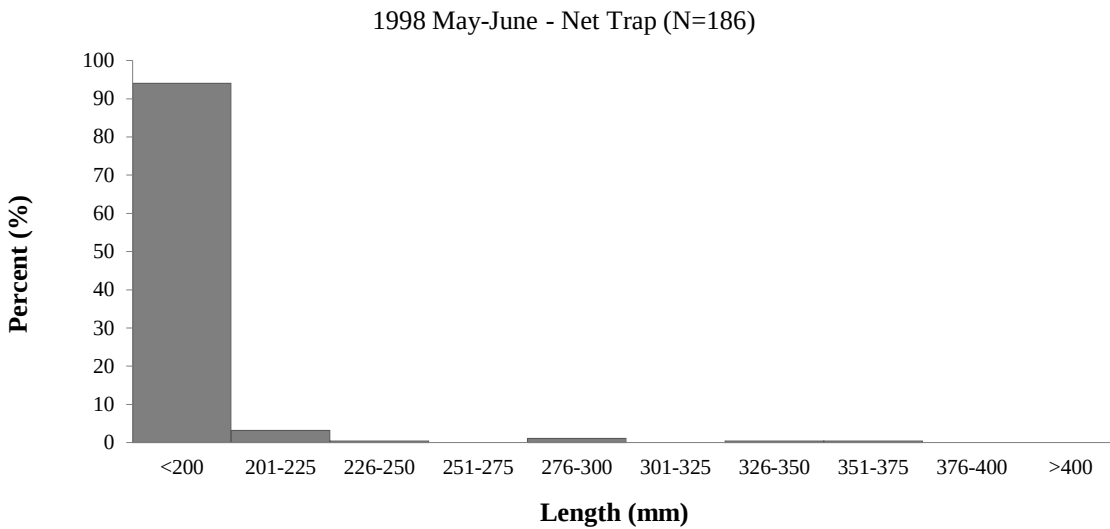
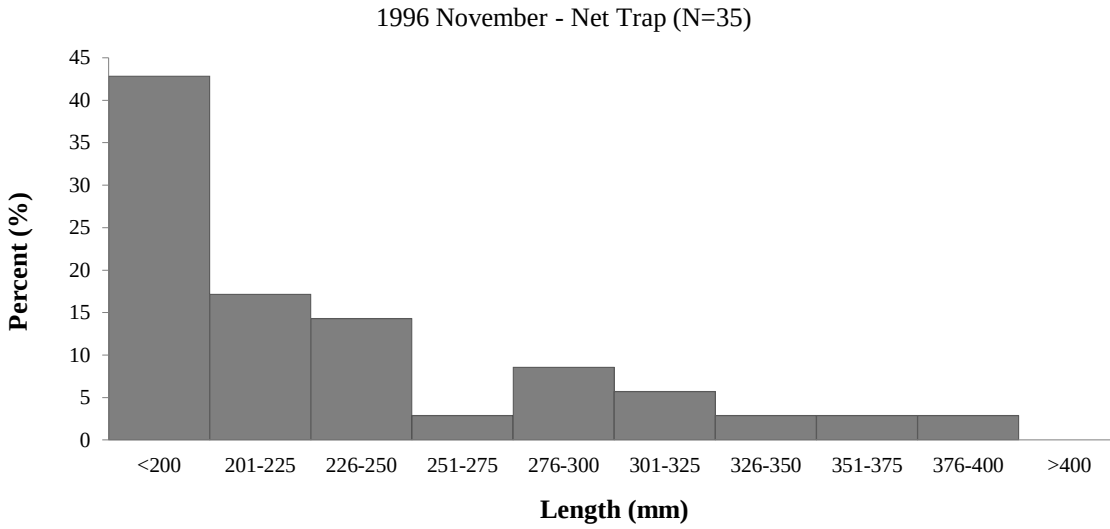


FIGURE 5. Length frequency of cutthroat trout captured in trap nets in Cowichan Lake, 1996 (N=35); 1998 (N=186) (Source: FLNRO files, Nanaimo).

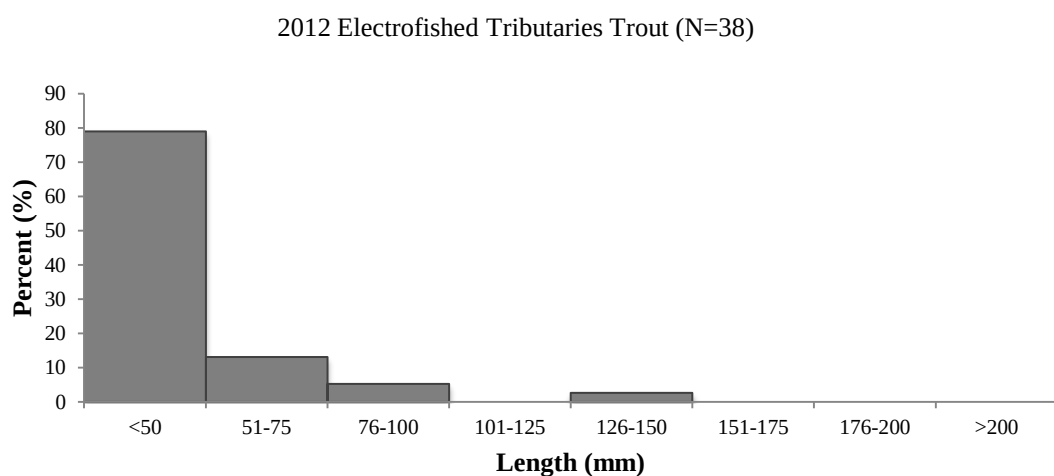
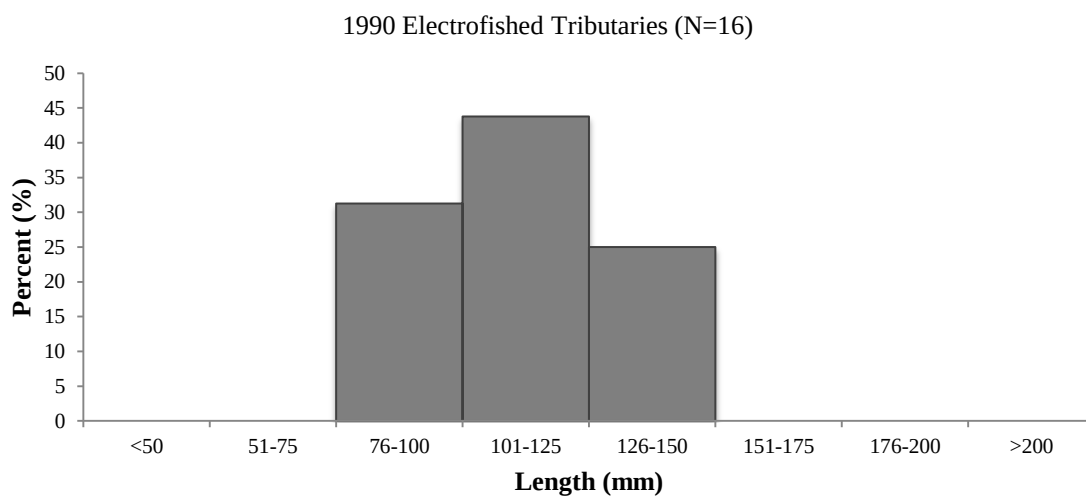
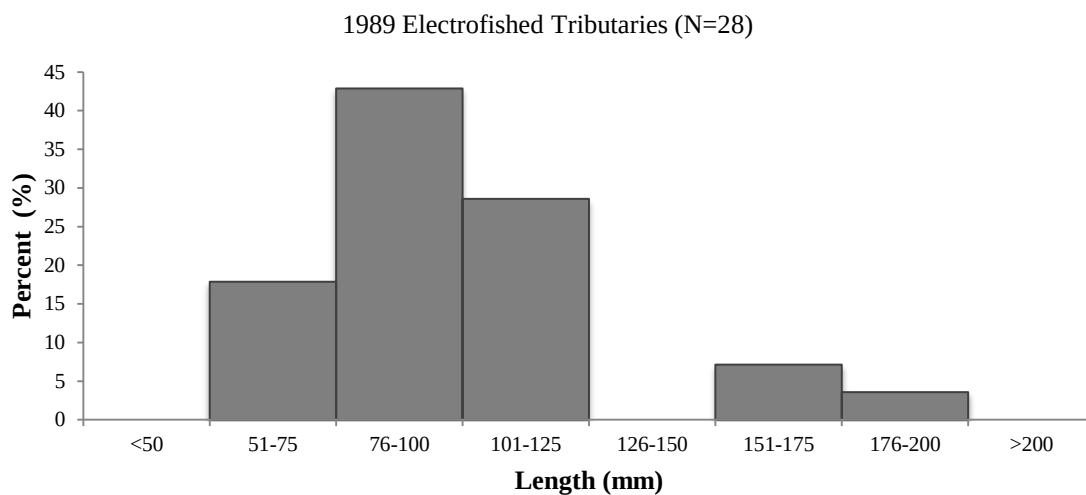


FIGURE 6. Length frequency of cutthroat trout captured by electrofishing in Cowichan Lake tributaries, 1989 (N=28); 1990 (N=16); 2012 (N=38) (Source: Griffith, 1989; Stewart, 1990); FLNRO files, Nanaimo).

Length-Weight Relationship

The length-weight relationship for cutthroat trout captured in Cowichan Lake between 1953 and 2011 is shown in Figure 7. Most fish captured in trapped nets were ~200 – 250 mm and ~500 g. The largest fish captured in the trap net was ~400 mm and ~600 g while the fish captured by anglers were much larger and ranged from 600 mm – 650 mm and were ~2,500 g.

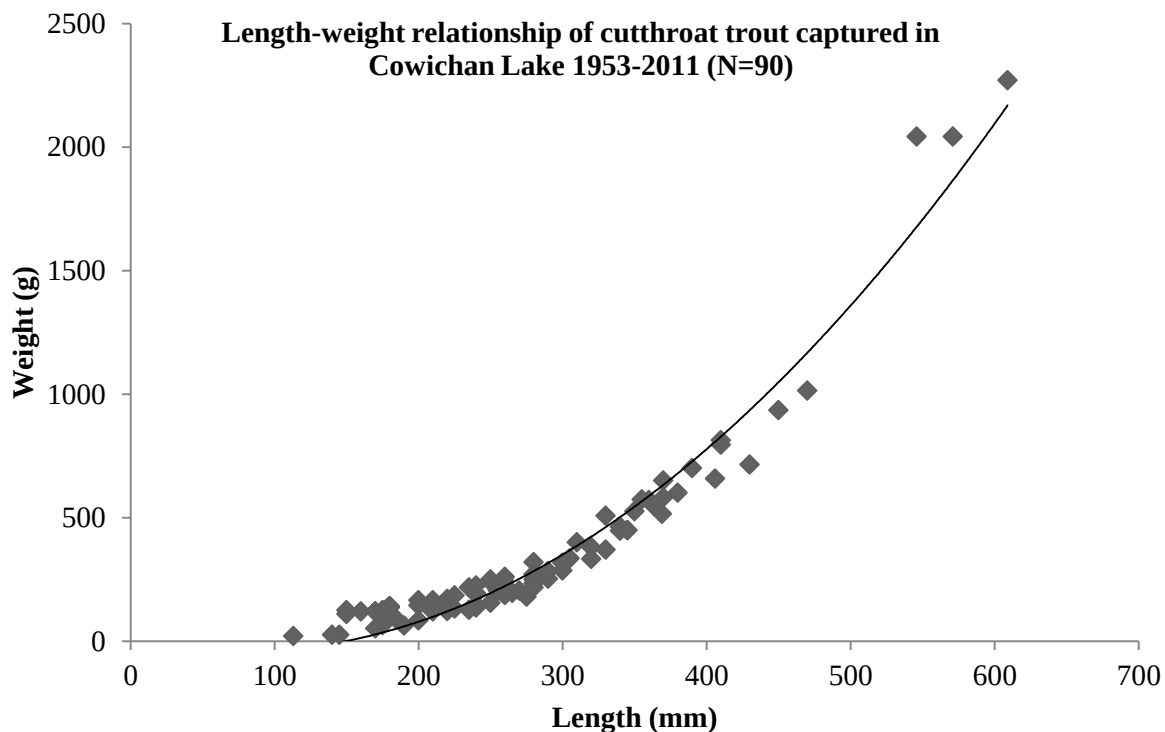


FIGURE 7. Length weight relationship of cutthroat trout captured by angling in 1953 (N=3); net trap in 1996 (N=35), and gillnets in 2009 (N=32) and 2011(N=20) in Cowichan Lake (Source: FLNRO files, Nanaimo).

Sex and Maturity

Female cutthroat trout captured by anglers in 1989 ranged between 230 mm – 450 mm, while males ranged from 230 mm – 554 mm (Table 7). In 1989, the mean size of male cutthroat (343 mm) was slightly larger than that of females (322 mm). Female cutthroat trout captured in gillnets in 2009 ranged between 200 mm – 450 mm, while males ranged from 220 mm – 360 mm (Table 8). In 2009, the mean size of female cutthroat (303 mm) was larger than that of males (278 mm).

TABLE 7. Male vs. female cutthroat numbers and minimum, maximum and mean length (mm) size captured by anglers in Cowichan Lake in 1989 (N=19) and by gillnets in 2009 (N=13); 2011 (N=17) (Source: Griffith, 1989; FLNRO files, Nanaimo).

	1989 Angler Creel Survey		2009 Gillnetting		2011 Gillnetting	
Factor	Female	Male	Female	Male	Female	Male
N	11	8	4	9	8	9
Minimum Length (mm)	230.0	230.0	200.0	220.0	257.0	290.0
Maximum Length (mm)	450.0	554.0	450.0	360.0	470.0	380.0
Mean Length (mm)	322.2	343.0	302.5	278.3	350.3	344.9

In 1966, Bull summarized data from a creel conducted on the Cowichan River and found that between 1962 and 1965, anglers caught male cutthroat that averaged 427 mm and females that averaged 488 mm (Table 8).

TABLE 8. Mean weight and length of adfluvial cutthroat and rainbow trout caught in Cowichan River by anglers 1962-65 (Source: Bull, 1966).

Length (mm)			Weight (g)		
Male	Female	Unsexed	Male	Female	Unsexed
427	488	370	914	1387	724

Snorkel Survey Summaries

The total number of adult cutthroat trout observed in snorkel surveys of the Cowichan River from 1976 to 2012 is shown in Figure 8. Swimmers observe on average, 20 adult cutthroat during the July/August swims which covers 4 reaches from Cowichan Lake to Stoltz Crossing ~ 20 km downstream.

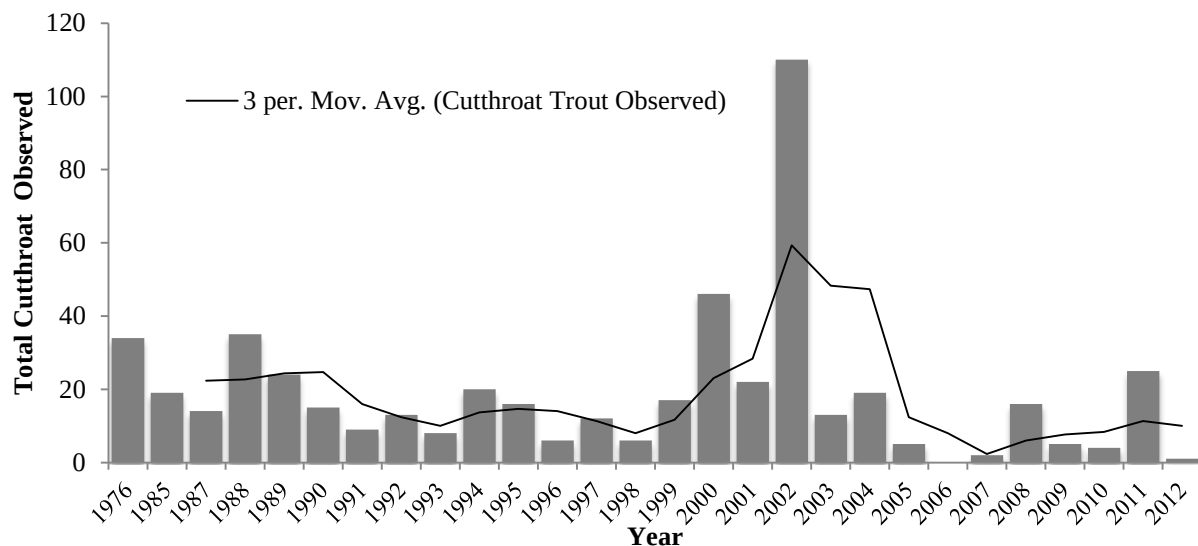


FIGURE 8. Total number of cutthroat trout observed in snorkel surveys of the Cowichan River 1976 – 2012. All swims were conducted during the months of July except for in 1995, 2011 and 2012 when the swim took place in early August. Snorkel swims were completed in sections 1-3 from 1976 to 1992 and in sections 1-4 from 1993 to 2010. The 2011 and 2012 swims were completed in sections 1-2 only. Note: no swim was conducted in 2006 (Source: FLNRO files, Nanaimo).

Reach descriptions are described in Table 9. In 2002, >100 cutthroat trout were reported in the snorkel survey, which may indicate errors identifying cutthroat because the rainbow numbers were down proportionately that year.

TABLE 9. Stream reach sections for snorkel swims conducted by the FLNRO files, Nanaimo (Source: FLNRO files, Nanaimo).

Section	Description
1	Stanley Creek to 70.2 Mile Trestle
2	70.2 Mile Trestle to Skutz Falls
3	Skutz Falls to Stoltz Pool
4	Stoltz Pool to Sandy Pool

The Ministry conducted snorkel surveys in the spring to enumerate spawning cutthroat trout and we've provided the results of those surveys in Table 10.

TABLE 10. Total number of cutthroat trout observed in snorkel surveys in the Cowichan River March to May 1990 – 2005 (N= 124) (Source: FLNRO files, Nanaimo).

Year	Date	Number Observed
2001	14-Mar	9
1992	02-Apr	1
1991	12-Apr	3
1990	17-Apr	1
1993	01-May	2
1994	01-May	15
1994	01-May	5
1995	01-May	10
1998	01-May	4
2003	01-May	9
2004	01-May	1
2005	05-May	3
2002	13-May	5
1990	14-May	16
1991	15-May	3
1995	17-May	15
1990	22-May	6
1992	25-May	6
1996	27-May	10

MJ Lough Environmental Consultants completed snorkel surveys in the spring of 2011 to document the spawning behavior of cutthroat trout in Cowichan Lake tributaries (Figure 9). The snorkel surveys took place between February 22 and May 27, 2011 at four tributaries to Cowichan Lake: Robertson River, Sutton Creek, Nixon Creek and Shaw Creek. A total of 234 cutthroat trout spawners were observed during the snorkel surveys. Lough (2011a) noted that the counts were useful to confirm species but were a poor indicator of total spawning activity in the streams, therefore, Lough relied on red counts as the a more accurate means for

determining spawning activity. A total of 266 cutthroat trout redds were counted in the index sites of the four streams during the study period. Lough (2011a) found that spawning activity started between March 21 and March 28 in the Robertson River, Nixon Creek and Shaw Creek. Sutton Creek spawning activity started later between March 28 and April 8. Lough noted spawning continued until May 27.

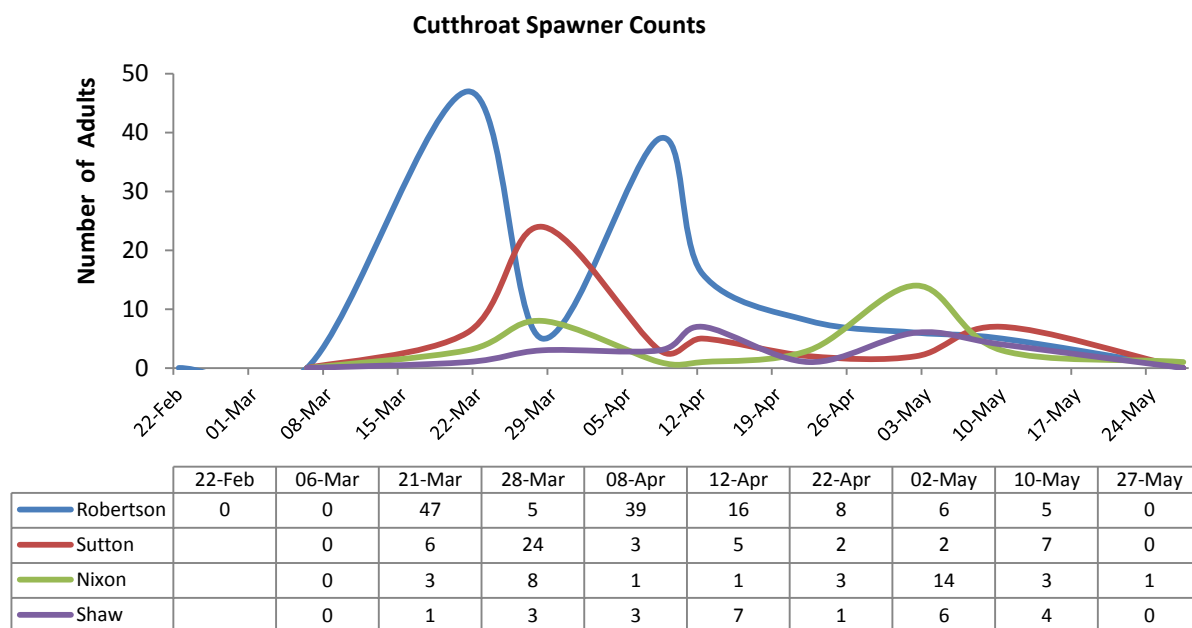


FIGURE 9. Total number of cutthroat trout spawners counted during each snorkel survey at Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from: Lough 2011a).

Lough (2011a) collected visual fork length estimates for 142 cutthroat spawners observed during the snorkel surveys in 2011. Spawners ranged in length between 300 mm – 650 mm.

TABLE 11. Visual fork length estimates of spawning cutthroat trout observed during snorkel surveys at Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from: Lough 2011a).

	Male			Female		
	n	Mean FL (cm)	s	n	Mean FL (cm)	s
Robertson	34	42	6.4	33	39	6.8
Sutton	16	50	7.7	14	42	7.4
Nixon	14	44	5.9	11	41	4.6
Shaw	12	46	6.7	8	41	8.2
All	76	45	7.3	66	41	6.8

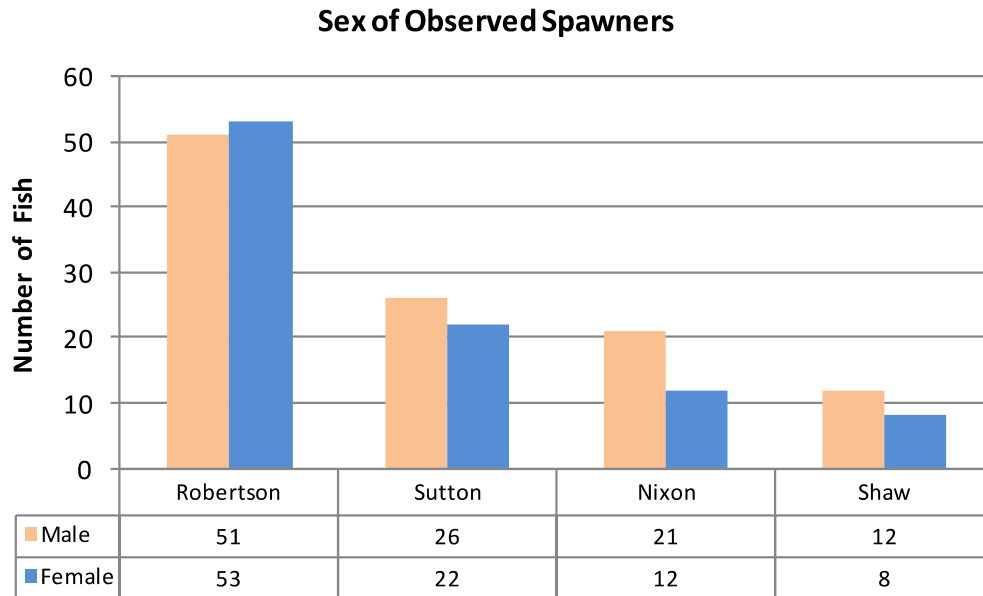


FIGURE 10. Sex of spawning cutthroat trout observed during snorkel surveys at Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from: Lough 2011a).

TABLE 12. Overall sex ratio of cutthroat trout spawners observed during snorkel surveys at Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from: Lough 2011a).

Stream	Male:Female Sex Ratio
Robertson	1 : 1.0
Sutton	1 : 1.2
Nixon	1 : 1.8
Shaw	1 : 1.5

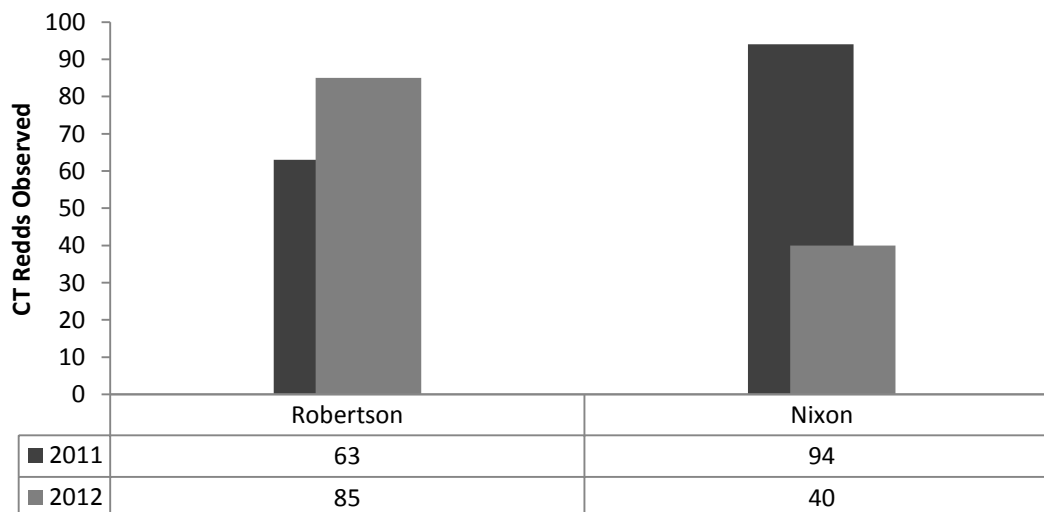


FIGURE 11. Peak redd counts at standard index sites in Robertson River and Nixon Creek between February 22 and May 27, 2011 and May 9-10, 2012. Note: In 2012, the cutthroat redds in both streams were generally observed at the same gravel pads and tail outs as the 2011 survey (Reprinted from: Lough et al, 2011a).

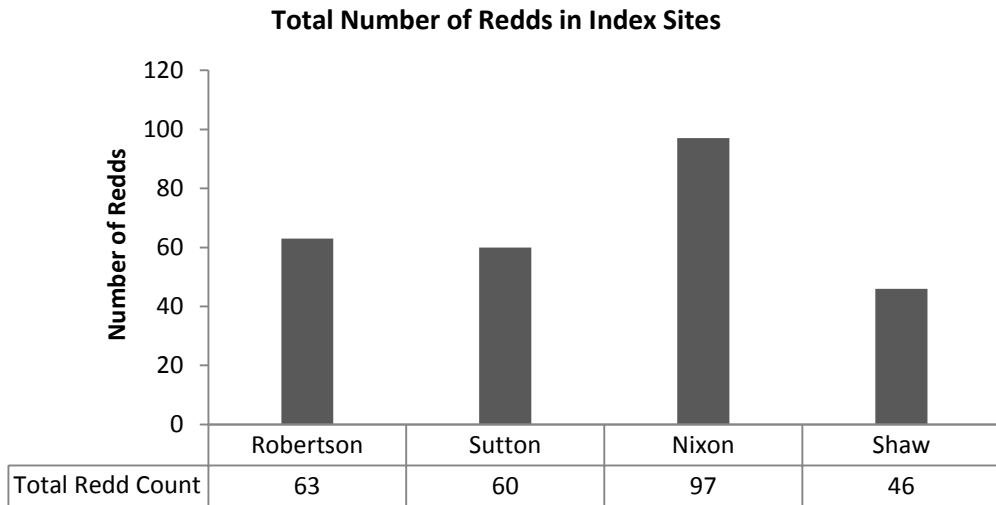


FIGURE 12. Total redd counts observed during snorkel surveys at Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from: Lough et al., 2011a).

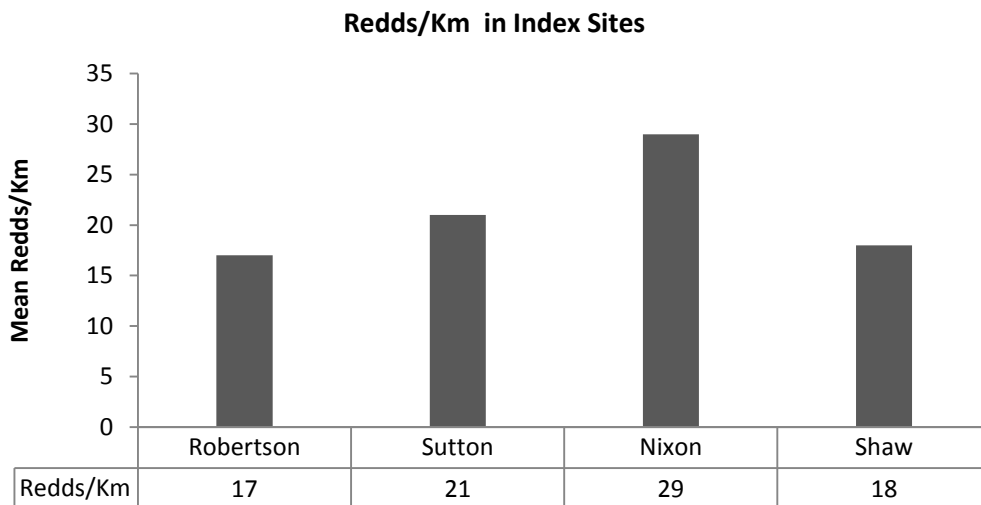


FIGURE 13. Mean redd counts per kilometer observed during snorkel surveys at Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from: Lough et al, 2011a).

Spawning Activity

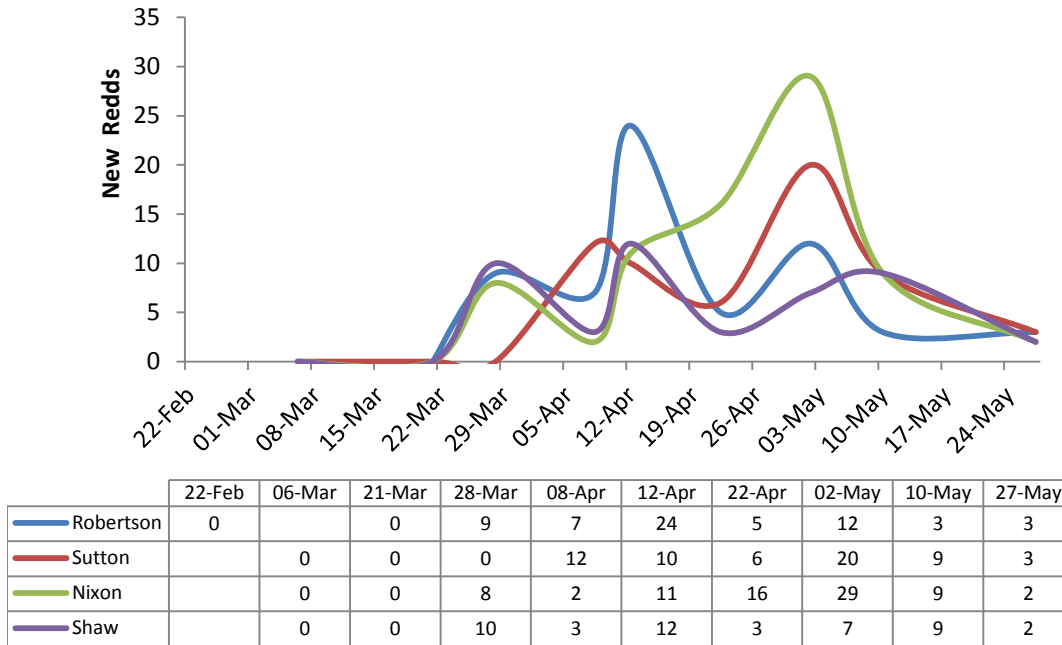


FIGURE 14. Timing of cutthroat trout spawning activity as measured by counts of new redds at index sites in Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from: Lough et al., 2011a).

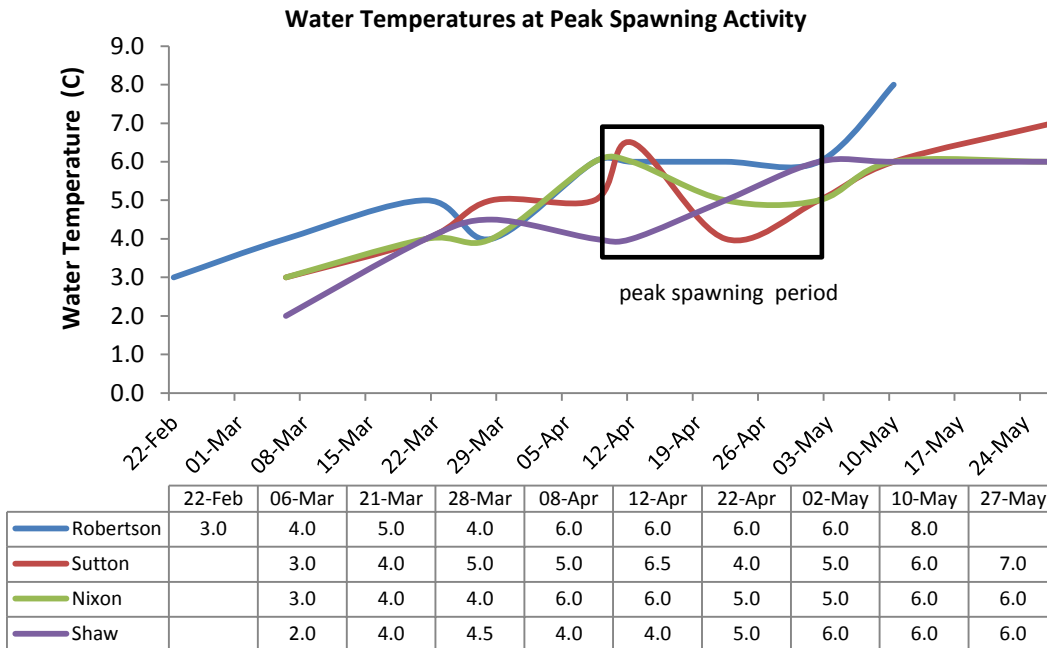


FIGURE 15. Spot water temperatures taken during snorkel surveys at Robertson River, Sutton Creek, Nixon Creek and Shaw Creek between February 22 and May 27, 2011 (Reprinted from Lough et al., 2011a).

A summary of calculated p-recap values derived from 2-capture electrofishing sites is provided in Table 13. Separate values were derived by species and size class (fry versus parr). Length-weight condition factors derived from field samples are provided in Table 14.

TABLE 13. Mean p-recap values derived from 2-capture electrofishing sites in tributaries to Cowichan Lake in July and August 1989 (N=23 sites) (Source: Griffith, 1989).

Species/size class	p-recap	C1 Total	C2 Total	SD
Cutthroat fry	0.73	112	30	0.21
Rainbow fry	0.82	134	24	0.31
Trout fry total	0.76	270	64	0.26
Cutthroat parr	0.88	16	2	0.08
Rainbow parr	0.92	37	3	0.16
Trout parr total	0.91	53	5	0.14
Dolly Varden fry	0.83	46	8	0.31
Dolly Varden parr	0.76	29	7	0.46

TABLE 14. Length-weight condition factors derived from field samples (Source: Griffith, 1989).

Species/size class	Condition Factor	Sample Size
Cutthroat fry	1.02	64
Cutthroat parr	01.08	25
Rainbow fry	01.07	104
Rainbow parr	1.13	70
Dolly Varden	1.12	48

Griffith (1989) described in his report two major implications with respect to cutthroat trout electrofishing results done between July 7 and August 2, 1989. The first was the evidence of widespread hybridization with rainbow, since some degree of blended characteristics in cutthroat and rainbow fry populations was observed at nearly all sample sites. The second implication was the wide but relatively dilute distribution of cutthroat throughout the streams sampled. Where cutthroat presence was identified, densities tended to be low. With exceptionally low occurrence and abundance of Dolly Varden, the same was felt to apply to this species.

During the second electrofishing sampling completed during August 14 to 25, 1989, a total of 48 sites were explored for the presence of cutthroat and Dolly Varden in all accessible streams. A major finding was the absence of both cutthroat and Dolly Varden at sample sites in all the major tributaries on the north side of the lake (Meade, Cottonwood, McKay, and Shaw Creeks). Similarly, no cutthroat or Dolly Varden were captured in any secondary tributaries to these streams. Both cutthroat and Dolly Varden were found with regularity on the south side of the lake, notably Nixon and Sutton Creeks, the Robertson River, and certain tributaries to these streams. Table 15 provides a summary of mean sampled fry and parr densities (n/m^2) of cutthroat trout, rainbow trout and Dolly Varden sampled by Griffith (1989).

TABLE 15. Summary of mean sampled fry and parr densities (n/m^2) of cutthroat trout, rainbow trout and Dolly Varden sampled by electrofishing in July-August, 1989 (Source: Griffith, 1989).

Stream	CT Fry	CT Parr	RB Fry	RB Parr	DV Fry	DV Parr
Sutton Creek	0.49	0.01	0.57	0.04	0.15	0.07
Nixon Creek	0.2	0.06	0.2	0.04	0.25	0.09
Robertson River	0.09	0.06	0.38	0.07	0.02	0.03
Shaw Creek	0	0	0.16	0.06	0	0
McKay Creek	0	0	0.63	0.28	0	0
Cottonwood Creek	0	0	0.52	0.05	0	0
Meade Creek	0	0	1.03	0.13	0	0

Stewart (1990) summarized electrofishing data collected during August to October 1990 as well as electrofishing data by Griffith (1989) conducted during July to October 1989. Stewart (1990) also summarized angler creel survey data collected in the summer/fall of 1989 and 1990. Scale samples were taken from fish electrofished and fish caught by anglers during both years and ageing results presented in Stewart (1990) and Griffith (1989). The life history data showed that the fish take from 1 to 3 years to enter the lake from the streams. It also showed that most lake fish are 3 to 5 years old before they spawn (Stewart, 1990).

TABLE 16. Site area (m^2), population estimate calculated by Microfish 3.0 (Van Deventer, 2013), fish per unit area (FPU)(Area = $100 m^2$), total coho salmon captured by electrofishing and percent of catch comprised of coho at 2 sites electrofished on Nixon and Sutton Creek, August, 2012 (Source: FLNRO files, Nanaimo).

Parameter	Nixon Creek		Sutton Creek	
	Site 1	Site 2	Site 1	Site 2
Site Area (m^2)	400.53	510.3	262.55	384
Population Estimate	136	240*	335	233
FPU	34	47	128	61
Total Coho	118	156	145	131
% of Catch Comprised by Coho	90.1	97.5	85.3	94.2

*Microfish 3.0 automatically and arbitrarily estimated the population at 1.5 times the total catch because there was a non-descending catch of fish at this site.

Bull (1966) summarized the results of an angler creel survey conducted by the Ministry of Environment on the Cowichan River between 1962 – 1965 and found that age 2 and 2+ and 3 and 3+ fish were the most commonly caught lake cutthroat trout (Table 17). Anglers also caught smaller percentages of up to age 5 and 5+ cutthroat trout.

TABLE 17. Percent of each age class of adfluvial cutthroat trout caught by anglers in the Cowichan River and Cowichan Lake 1962-65 (N=139) (Source: Bull, 1966).

Age at Capture	Percent
1+	8.6
2+	40.3
3+	36
4+	11.5
5+	3.6

Rainbow Trout

Population Data

The total number of rainbow trout captured in gillnets in Cowichan Lake has ranged from 1 to 15 with catches averaging ~10 fish/sample (Table 18). Fork lengths have ranged from 180 mm to 374 mm, and have averaged 348 mm (Figure 7). In July 1989, only one rainbow trout was caught in gillnets with a fork length of 260 mm. In August 2009, gillnets caught only six rainbow trout ranging between 195 mm – 300 mm. In August 2011, gillnets caught a total of 15 rainbow trout ranging between 180 mm – 374 mm.

TABLE 18. Total numbers and minimum, maximum and mean fork length of rainbow trout captured by gillnet in Cowichan Lake in July 1989, August 2009 and August 2011 (Source: FLNRO files, Nanaimo; FISS, Griffith, 1989; Stewart 1990).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1989	1	260	260	260	---
2009	6	195	300	234	162
2011	15	180	374	251	211

Electrofishing and habitat assessments were conducted by Griffith (1989) between July 17 and August 25, 1989 in a total of 35 primary and secondary tributaries to Cowichan Lake and two outlet tributaries (Table 19). A total of 66 rainbow trout were sampled by electrofishing in 1989 ranging in length between 61 mm – 185 mm. A second electrofishing survey was completed in August 1990; however no rainbow trout were captured. In August 2012, Nixon Creek and Sutton Creek were sampled by electrofishing resulting in a total of 38 trout ranging in length from 29 mm to 150 mm. The 2012 electrofishing did not determine whether the trout were cutthroat or rainbow species.

TABLE 19. Total numbers and minimum, maximum and mean fork length of rainbow trout captured by electrofishing in the tributaries to Cowichan Lake in 1989. No rainbow were captured in the 1990 electrofishing survey. The 2012 electrofishing indicated trout species only (Source: FLNRO files, Nanaimo; FISS; Griffith 1989; Stewart, 1990)

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1989	66	61	185	103	---

Four rainbow trout captured by anglers in Cowichan Lake in 1953 ranged between 280 mm – 380 mm (Table 20). Interpretation for this year is based on only 4 fish, therefore, open to error. Twenty-five rainbow trout, ranging in length between 215 mm and 595 mm, were captured by anglers in Cowichan Lake, as part of an angler creel survey in 1989. In 1990, anglers caught a total of twenty-five rainbow trout between 172 mm – 503 mm in length. Anglers caught a total of 25 rainbow trout during angler creel surveys conducted between 2009 and 2011. The length of rainbow trout caught by anglers from 2009 to 2011 ranged between 120 mm – 530 mm.

TABLE 20. Total numbers and minimum, maximum and mean fork length of rainbow trout captured by angling in 1953, 1989, 1990, 2009, 2010 and 2011 (Source: FLNRO files, Nanaimo; FISS; Griffith, 1989; Stewart 1990).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1953	4	280	380	328	536
1989	25	215	595	332	---
1990	24	172	503	302	---
2009	5	120	300	194	---
2010	18	150	530	278	---
2011	2	200	250	225	---

Net traps were set in Cowichan Lake in November 1996 resulting in a capture of 28 rainbow trout ranging in length from 95 mm – 290 mm (Table 21). A second net trap study was conducted in May 1998, resulting in 108 rainbow ranging from 80 mm – 293 mm.

TABLE 21. Total numbers and minimum, maximum and mean fork length of rainbow trout captured by net trap in November 1996 and June 1998 (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1996	28	95	290	182	145
1998	108	80	293	117	---

Length Frequency Distributions

The length frequencies of rainbow trout captured in Cowichan Lake between 1989 and 2011 are shown below. Anglers captured fish up to 400 mm in 1990, while rainbow trout up to 300 mm were captured by trap net in 1996 (Figure 16-22). Of the 108 rainbow captured in trap nets in 1998, ~90% were <150 mm.

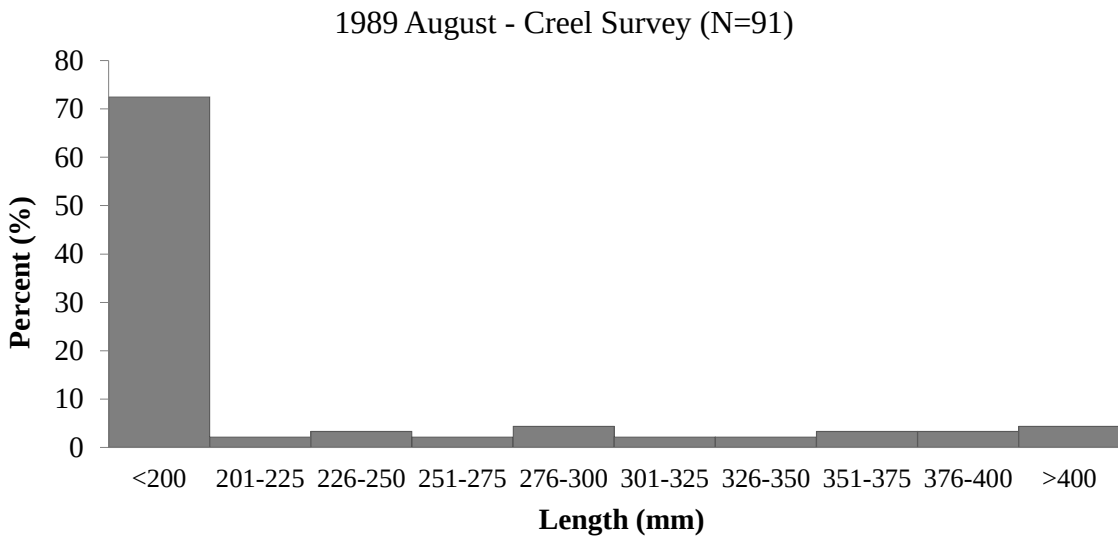


FIGURE 16. Length frequency of rainbow trout captured in Cowichan Lake by anglers between July and October, 1989 (N=91) (Source: Stewart, 1990).

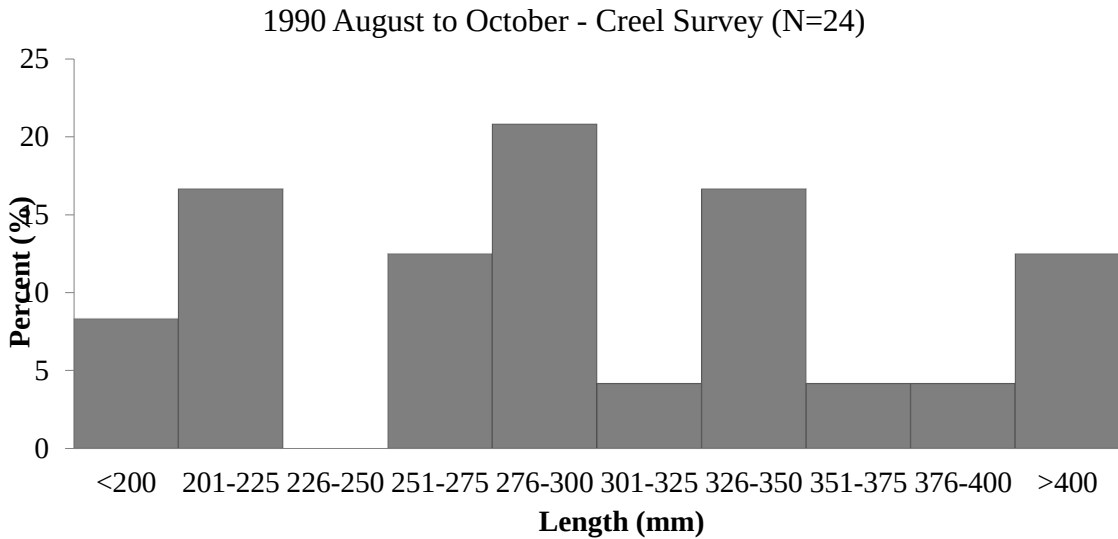


FIGURE 17. Length frequency of rainbow trout captured in Cowichan Lake by anglers between August and October, 1990 (N=24) (Source: Stewart, 1990).

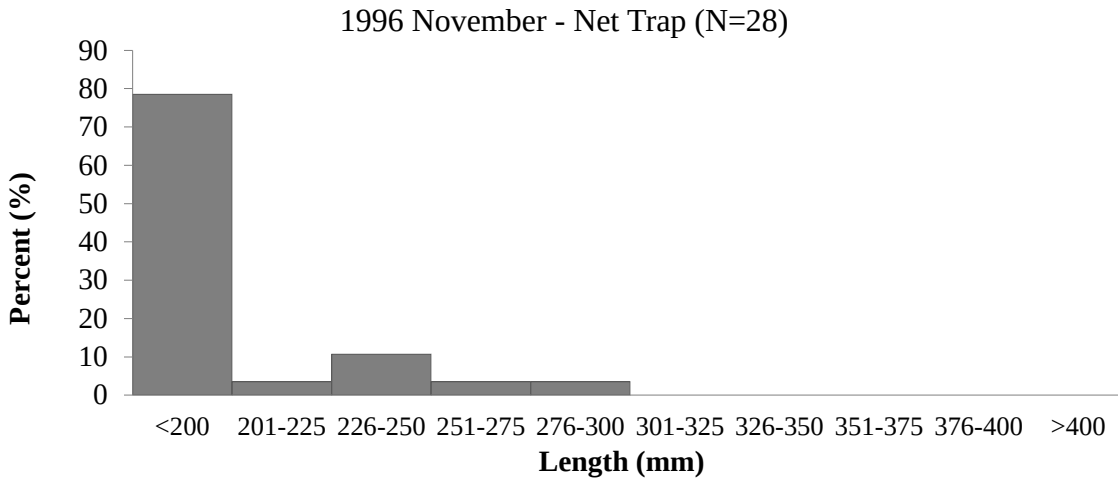


FIGURE 18. Length frequency of rainbow trout captured in Cowichan Lake by trap net, in 1996 (N=28) (Source: FLNRO files, Nanaimo).

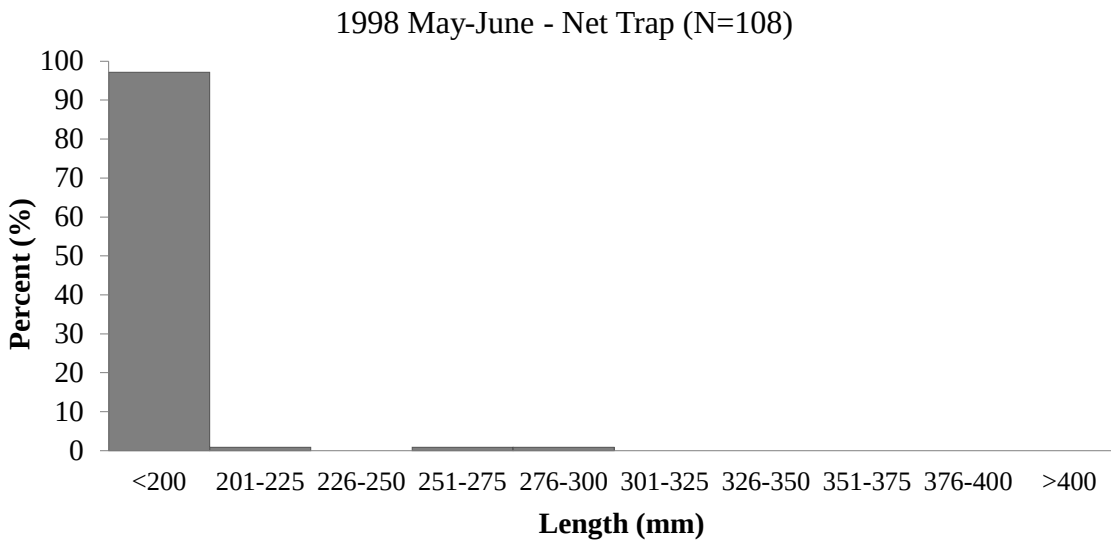


FIGURE 19. Length frequency of rainbow trout captured in Cowichan Lake by trap net in 1998 (N=108) (Source: FLNRO files, Nanaimo).

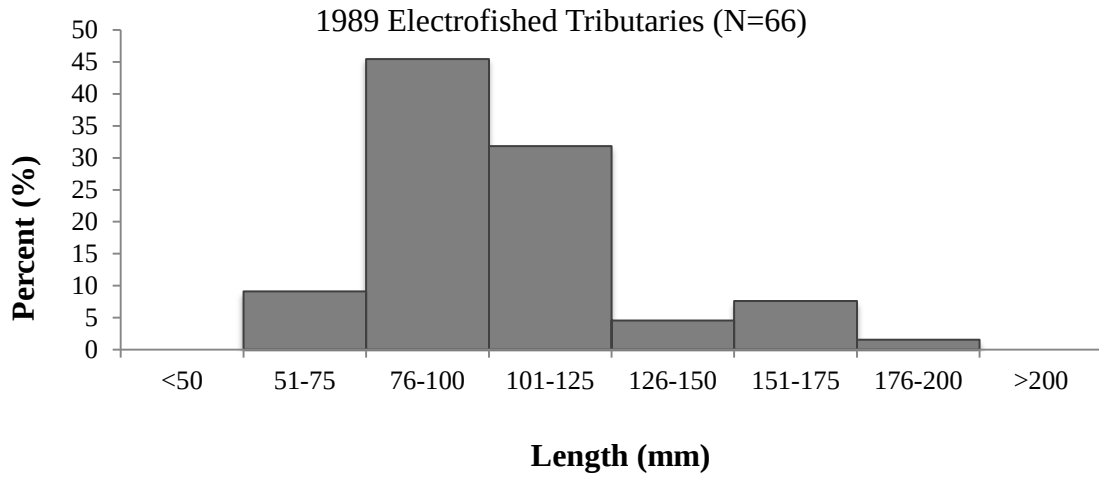


FIGURE 20. Length frequency of rainbow trout captured in Cowichan Lake tributaries by electrofishing in 1989 (N=66) (Source: FLNRO files, Nanaimo).

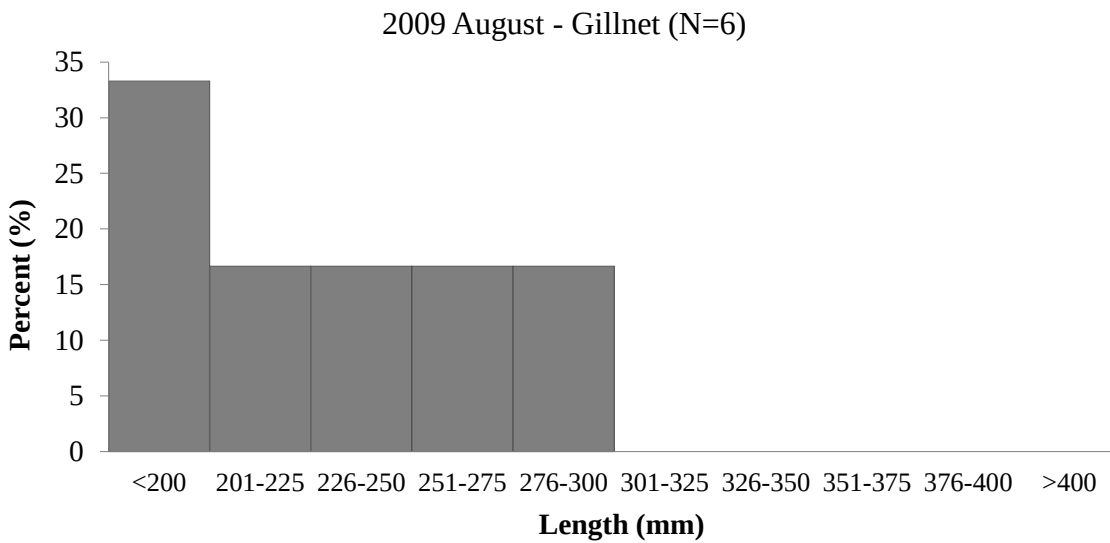


FIGURE 21. Length frequency of rainbow trout captured in Cowichan Lake by gillnet in August 2009 (N=6) (Source: FLNRO files, Nanaimo).

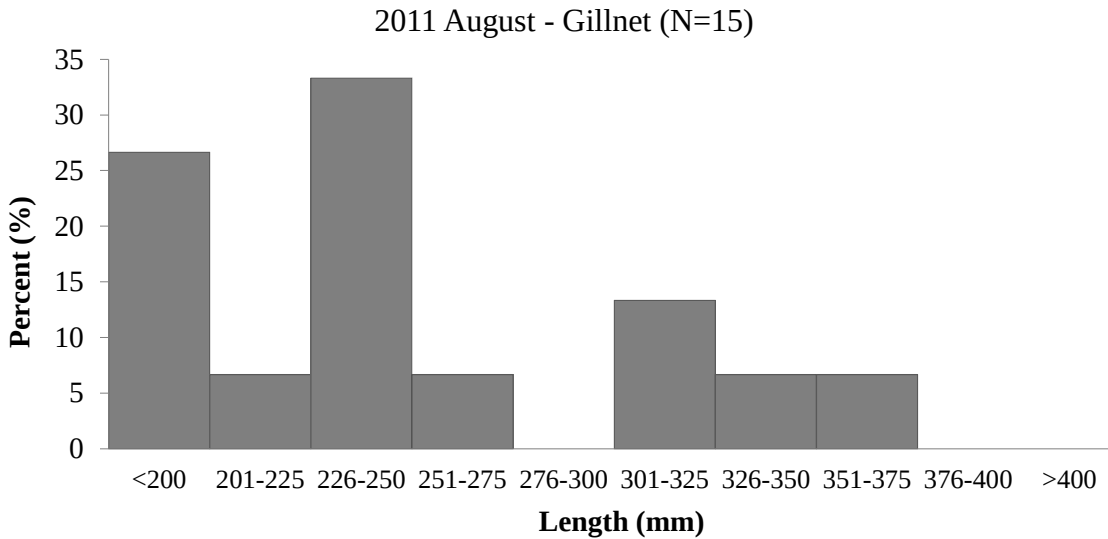


FIGURE 22. Length frequency of rainbow trout captured in Cowichan Lake by gillnet in August 2011 (N=15) (Source: FLNRO files, Nanaimo).

Sex and Maturity

We've presented the minimum, maximum and mean length of male and female rainbow trout captured in Cowichan Lake in 1953, 2009 and 2011 in Table 22. In 2011, 2 females averaging 283 mm were captured in gillnets while 7 males averaging ~250 mm were captured.

TABLE 22. Male vs. female rainbow trout numbers and size captured by anglers in Cowichan Lake in 1953 (N=2) and by gillnetting in 2009 (N=1) and 2011 (N=9) (Source: FLNRO files, Nanaimo).

Factor	1953 Angler Creel Survey		2009 Gillnetting		2011 Gillnetting	
	Female	Male	Female	Male	Female	Male
N	1	1	1	0	2	7
Minimum Length (mm)	----	----	----	----	245.0	180.0
Maximum Length (mm)	----	----	----	----	320.0	374.0
Mean Length (mm)	380.0	330.0	300.0	----	282.5	251.9

Only immature rainbow trout were captured in gillnets in 2009 and 2011 (Table 23). The 6 rainbow captured in 2009 ranged from 180 mm – 250 mm and average ~216 mm while the rainbow captured in 2011 ranged from 190 mm– 330 mm and averaged ~240 mm. No other data was available from other sample years.

TABLE 23. Number and minimum, maximum and mean size (mm) of mature and immature rainbow trout captured by gillnetting in 2009 (N=6) and 2011 (N=15); Note that immature includes fish identified as maturing (Source: FLNRO files, Nanaimo).

Year	2009 Gillnetting (N=6)	2011 Gillnetting (N=5)
Factor	Immature	Immature
N	6	5
Minimum Length (mm)	180.0	190.0
Maximum Length (mm)	250.0	330.0
Mean Length (mm)	215.8	242.0

Dolly Varden

Population Data

The total number of Dolly Varden captured in gillnets in Cowichan Lake has ranged from 6 to 15 with catches averaging ~10 fish/sample (Table 24). Fork lengths have ranged from 100 mm to 420 mm, and have averaged 348 mm (Figure 7). In August 2009, gillnets caught only six Dolly Varden ranging between 275 mm – 420 mm. In August 2011, gillnets caught a total of 15 Dolly Varden ranging between 100 mm – 360 mm.

TABLE 24. Total numbers and minimum, maximum and mean fork length of Dolly Varden captured by gillnet in Cowichan Lake in August 2009 and August 2011 (Source: FLNRO files, Nanaimo; FISS; Griffith, 1989; Stewart 1990).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1989	1	260	260	260	---
2009	6	275	420	364	491
2011	16	100	360	258	304

Length Frequency Distributions

Length frequencies of Dolly Varden captured by gillnet in Cowichan Lake in 2009 and 2011 and by net trap in 1996 is shown in Figure 25 and Figure 26.

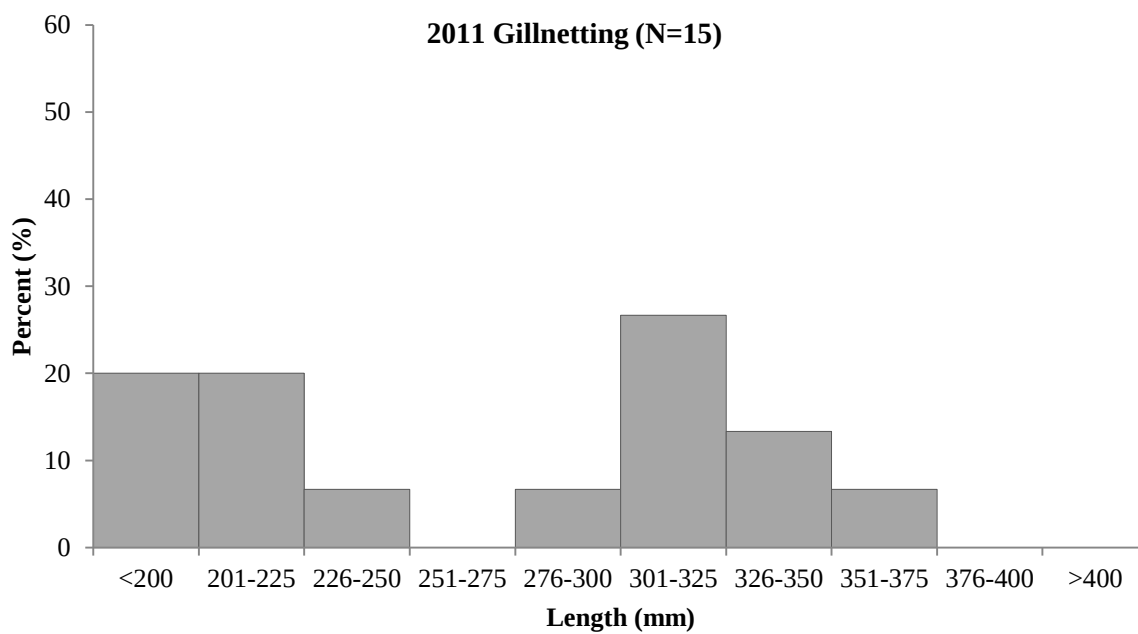
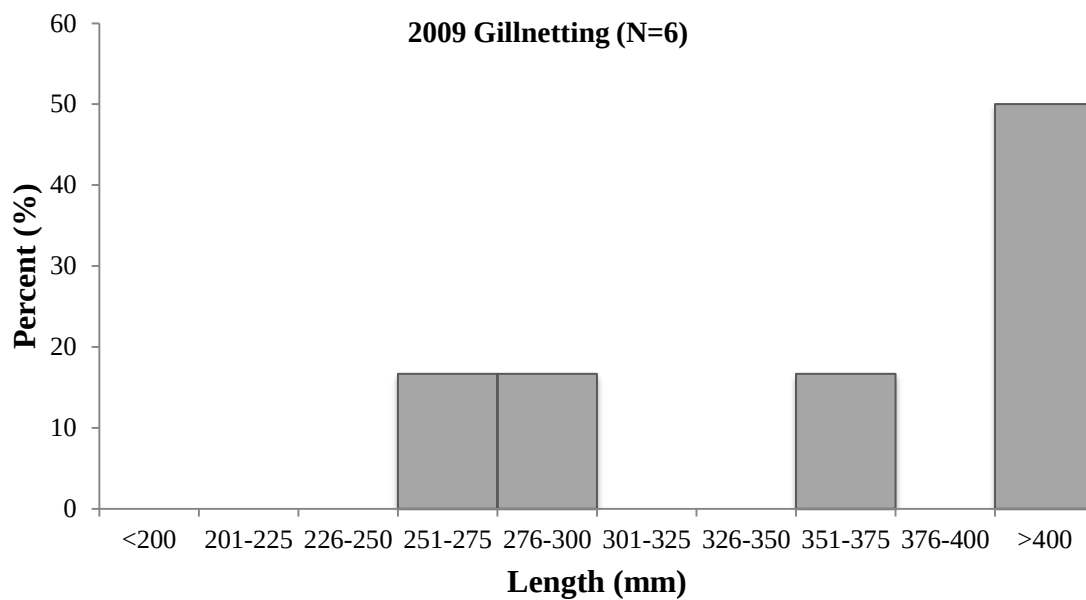


FIGURE 25. Percent length frequency analysis of Dolly Varden captured by gillnet in Cowichan Lake, August 2009 (N=6) and August 2011 (N=15) (Source: FLNRO files, Nanaimo).

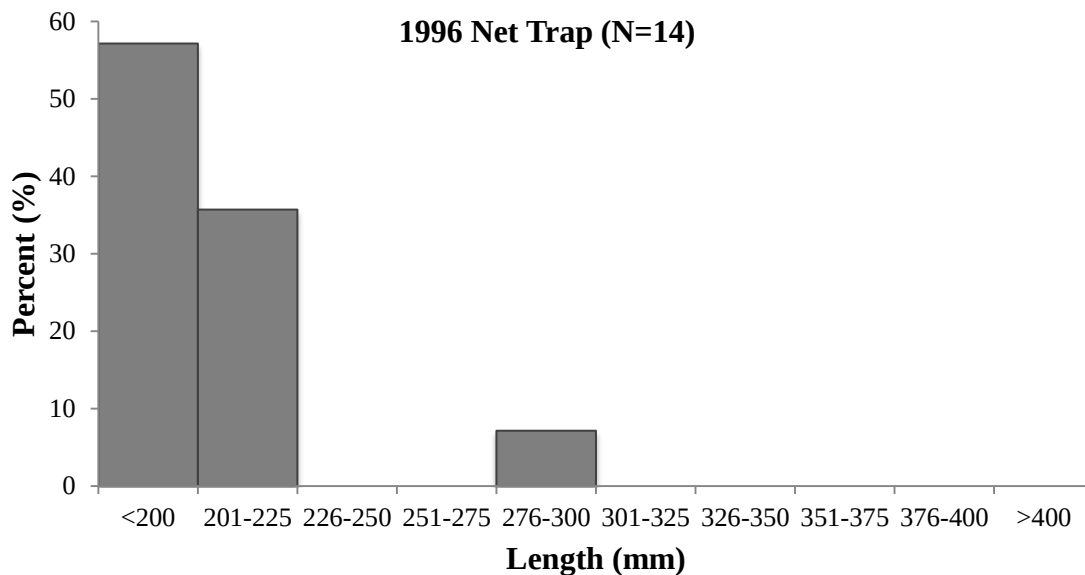


FIGURE 26. Percent length frequency analysis of Dolly Varden captured by trap net in Cowichan Lake, November 1996 (N=14) (Source: FLNRO files, Nanaimo).

Length Weight Relationship

The length-weight relationship of 24 Dolly Varden captured in trap nets in 1996 and gillnets in 2009 and 2011 is shown in Figure 27. The smallest fish captured was ~160 mm and ~150 g, and the largest fish was ~450 mm and 900 g.

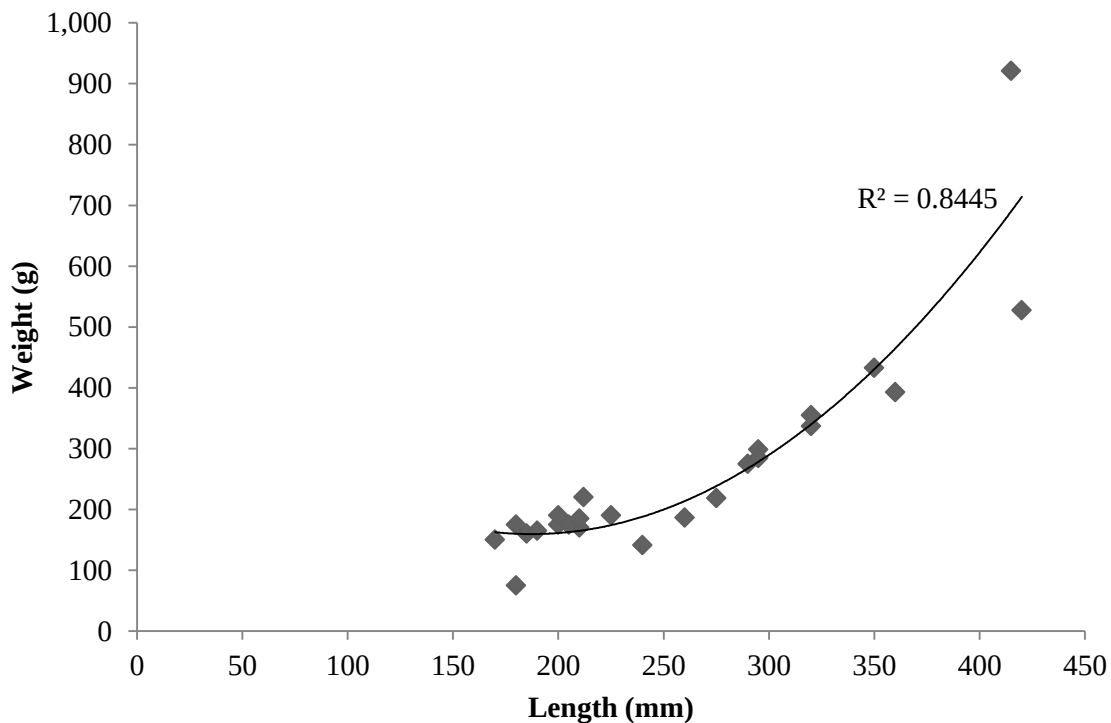


FIGURE 27. Length weight relationship of Dolly Varden captured in trap nets in 1996 (N=13) and gillnets in 2009 (N=4) and 2011 (N=7) (Source: FLNRO files, Nanaimo).

Maturity

We've presented the minimum, maximum and mean length of immature and mature Dolly Varden captured in 1989, 1990, 2009 and 2011 in Table 25. In 1989, immature fish ranged from 92 mm – 111 mm and averaged ~99 mm while the one mature fish captured was 410 mm. The following year, 13 Dolly Varden were assessed for maturity. Of these, 4 were immature and ranged from 60 mm – 115 mm and averaged 83 mm while 9 were mature and ranged from 290 mm – 480 mm and averaged ~400 mm. In 2009 and 2011 4 and 7 Dolly Varden respectively were assessed for maturity. In 2009, 2 immature fish averaging 185 mm and 2 mature fish averaging ~418 mm were captured. In 2011, 6 immature Dolly Varden ranging from 240 mm – 350 mm and averaging almost 300 mm were captured. Only 1 mature fish 360 mm was captured that year.

TABLE 25. Maturity and size of Dolly Varden captured in Cowichan Lake 1989-2011 (Source: FLNRO files, Nanaimo).

Year	1989 (N=8)		1990 (N=13)		2009 Gillnetting (N=4)		2011 Gillnetting (N=7)	
Factor	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature
N	7	1	4	9	2	2	6	1
Minimum Length (mm)	92	----	60	290	275	415	240.0	----
Maximum Length (mm)	111	----	115	480	295	420	350.0	----
Mean Length (mm)	99.1	410.0	83.0	402.8	285.0	417.5	297.5	360

Kokanee Salmon

Population Data

In August 2011, one kokanee was captured in a gillnet set near the mouth of Shaw Creek in Cowichan Lake (Table 26). The single Dolly Varden measured 110 mm in length and weighed 16.2 g.

TABLE 26. Total numbers and minimum, maximum and mean fork length of kokanee captured by gillnet in Cowichan Lake in August 2011 (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
2011	1	110	110	110	16.2

In July 2010, hydroacoustic and trawl assessments were completed on Cowichan Lake to estimate densities of forage species, primarily kokanee salmon and stickleback in Cowichan Lake. (Sebastian and Johnner, 2010) Assessments were conducted over a 2-night period and transects of the lake were completed so that fish densities could be estimated. A trawl assessment was then conducted to sample fish for biological information. A total of 518 kokanee were captured in the 2010 trawl survey (Table 27).

TABLE 27. Number of fish captured by species for 4 trawls completed on Cowichan Lake, July 2010 (Reprinted from: Johner and Sebastian, 2011).

Trawl No.	Kokanee	Lamprey	Sculpin	Stickleback
1	259	-	-	-
2	103	-	1	-
3	84	3	-	-
4	72	3	-	1
Total	518	6	1	1

Length at age data for Cowichan Lake kokanee based on trawl length frequency distribution is shown in Table 28. The majority of the kokanee captured were age 0+ comprising 81.5% of the catch, with age 1+ and age 2+ comprising 9.1% and 9.5% respectively. No age 3+ kokanee were caught in the 2010 survey.

TABLE 28. Length at age for kokanee captured by 4 trawls in Cowichan Lake, July 2010 (Reprinted from: Johner and Sebastian, 2011).

Kokanee age	Average Size (mm)	Range (mm)	Standard Deviation	Sample size (n)
0+	34.5	24 - 32	3.7	258
1+	92.1	64 - 119	15.2	47
2+	143.2	128 - 163	8.2	49

Between 1984 and 1987, annual hydroacoustic and trawl surveys were completed at Cowichan Lake (Rutherford, 1988) and we've presented a summary of their results in Figure 32 and Table 29. These investigators found that kokanee were far more numerous than any other fish species in the limnetic zone; that Cowichan Lake kokanee matured at age 3 at lengths ranging from 153 mm – 172 mm, and that males were more numerous than females in all samples of juveniles examined (Rutherford, 1988).

TABLE 29. Summary of information from stock assessments and biological investigations of kokanee in Cowichan Lake 1984 – 1987 (Source: Rutherford et al, 1988).

Factor	Result
Years Surveyed	1984 - 1987
Total Population (estimated)	3.4 - 5.1 million fish
Observed Densities	540 - 822 fish/ha
Age at Maturation	3 yr.
Spawning Timing	late in year (December) when surface temp. ~7°C.
Locations	upwelling areas along lake margins; no stream spawning suspected
Spawning Population Size (estimated)	>150,000/yr

Rutherford et al (1988) estimated the kokanee population in Cowichan Lake at 3.4 – 5.1 million fish, mostly juveniles, with densities ranging from 540 – 822 fish/ha (Table 25). These researchers point out that these densities are not high in comparison to juvenile sockeye densities in other Vancouver Island lakes, which are typically 600 – 2,500 fish/ha (Hyatt and Stockner, 1985).

Kokanee in Cowichan Lake spawn late in the year (e.g. December) when the surface water temperature is $\sim 7^{\circ}\text{C}$ (Rutherford et al, 1988). This is later than reported for other kokanee populations in British Columbia (Seeley and McCrammon, 1966). Rutherford et al (1988) also determined that the vast majority of kokanee in Cowichan Lake probably spawn in upwelling areas along the margins of the lake. Assuming an average fecundity of 250 eggs/female (Hutchinson, 1984), and an egg-to-fry survival of 10% (Foerster, 1968), Rutherford et al (1988) concluded that the total spawning population of kokanee in Cowichan Lake exceeds 150,000 in most years.

Appendix 13. Elsie Lake

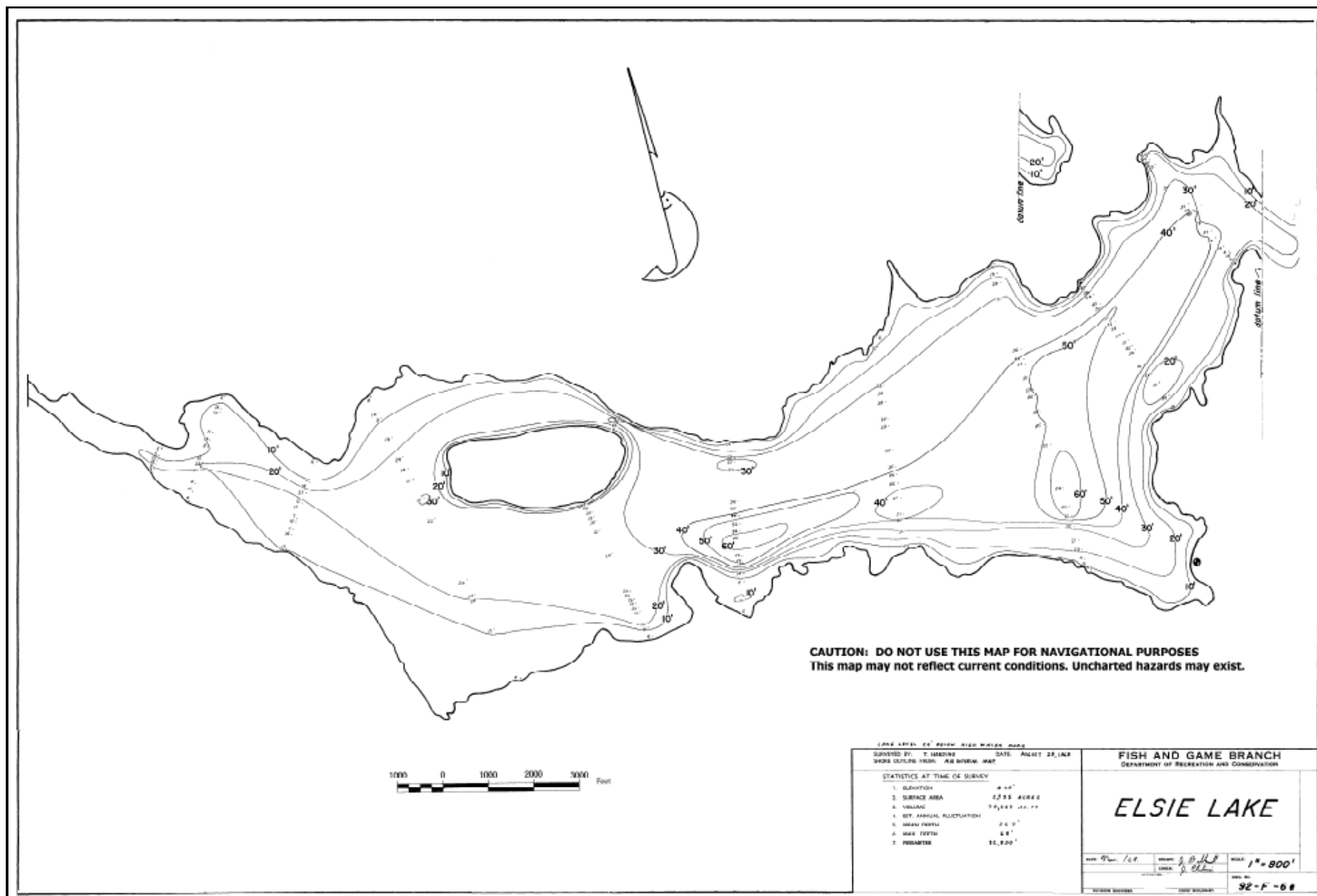


FIGURE 1. Bathymetric map of Elsie Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Stock Status Indicators

All Species

Size and Age Trends from Lewis and Ganshorn, 2005

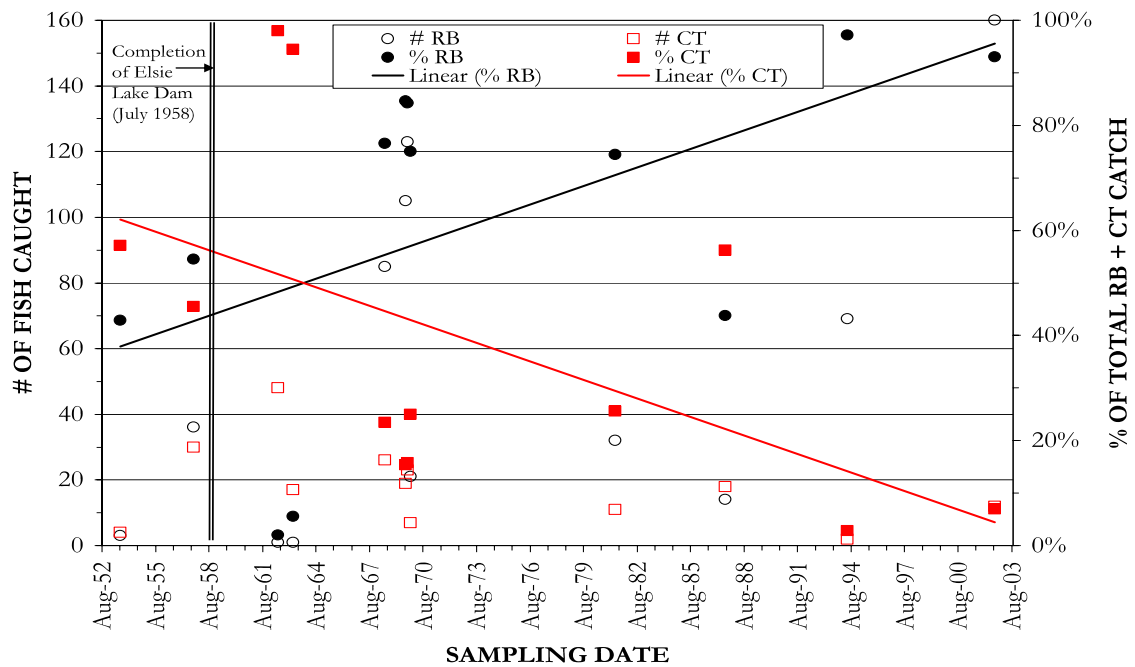


FIGURE 2. Elsie Lake (pre July 1958) and Elsie Lake reservoir (post July 1958) fish sampling data; method of capture consisted of gillnet and traps set in Elsie Lake, but from 1952 until 1960 the method of capture is unknown (Reprinted from: Lewis and Ganshorn, 2005).

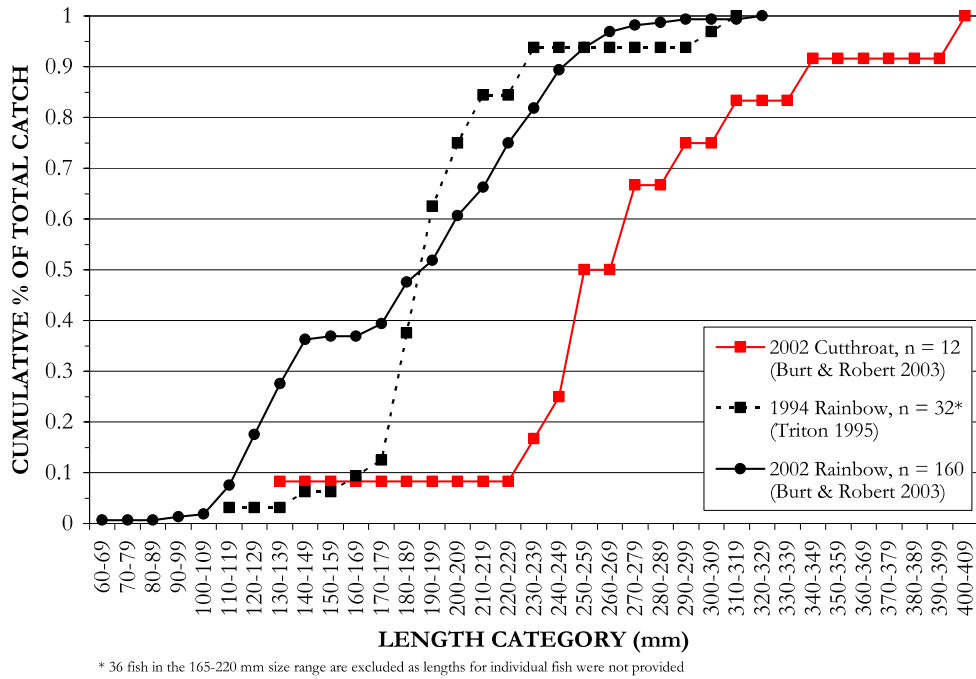


FIGURE 3. Cumulative percentage of total catch of each length category for rainbow and cutthroat trout caught by gillnet in Elsie Lake in May 1994 (Triton 1995, rainbow only) and August 2002 by length category (Reprinted from: Lewis and Ganshorn, 2005).

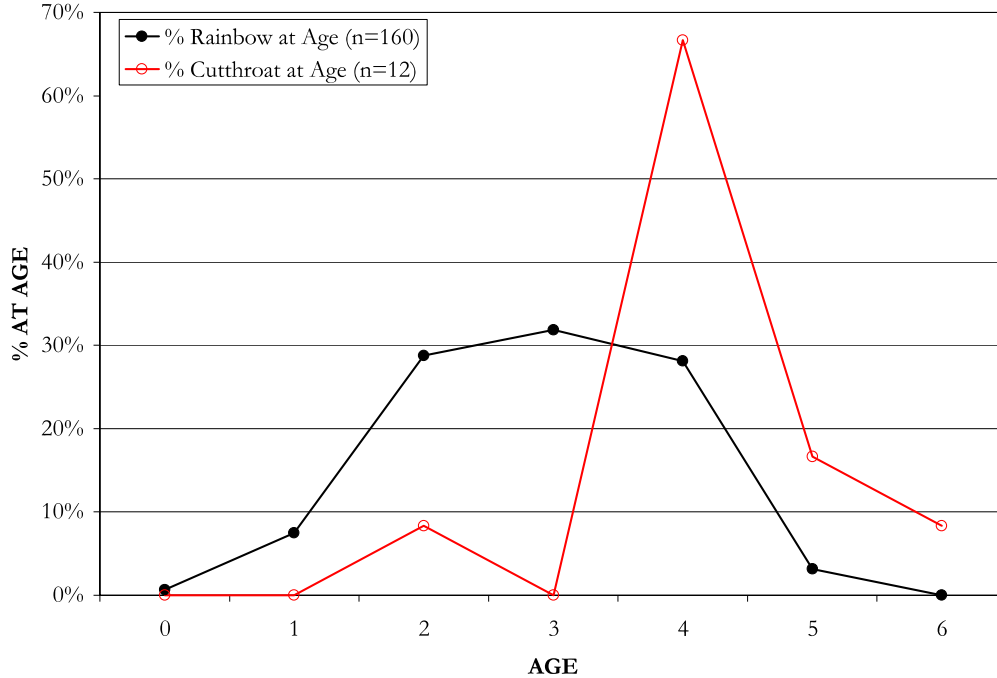


FIGURE 4. Percentage of rainbow and cutthroat trout captured by gillnet in Elsie Lake by age in August 2002 (Reprinted from: Lewis and Ganshorn, 2005).

Cutthroat Trout

Population Data

The minimum, maximum and mean fork lengths of cutthroat trout sampled in Elsie Lake from 1969 – 2002 is shown in Table 1. Minimum sizes of cutthroat ranged from 162 mm in 1987 to 241 mm in 2002 while maximum sizes ranged from 307 mm in 1994 to 475 mm in 1987. On average, cutthroat trout sampled in gillnets between 1969 and 2002 were between 266 and 296 mm.

TABLE 1. Total number, minimum, maximum and mean fork length (mm) of cutthroat trout captured by gillnet in Elsie Lake in November 1969, July 1987, May 1994, October 1996, and August 2002 (Source: Beamish and Northcote, 1989; Triton, 1995; Klohn Crippen, 1999; BC Hydro 2001; Burt and Robert, 2003; Lewis and Ganshorn, 2005).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1969	11	190	392	256.1	227.9
1987	18	162	475	---*	---
1994	2	225	307	266.0	---
1996	9	215	402	290.2	280.3
2002	7	232	400	296.4	197.4

*only ranges of fish caught are noted in the file so it is not possible to calculate a mean.

Length Frequency Distributions

The mode of cutthroat sampled in Elsie Lake in 1969 was 226 mm and 45% of fish sampled fell within the 226 mm – 250 mm length class (Figure 4). In 1996 most cutthroat sampled were within the 251 mm – 275 mm length class (Figure 5).

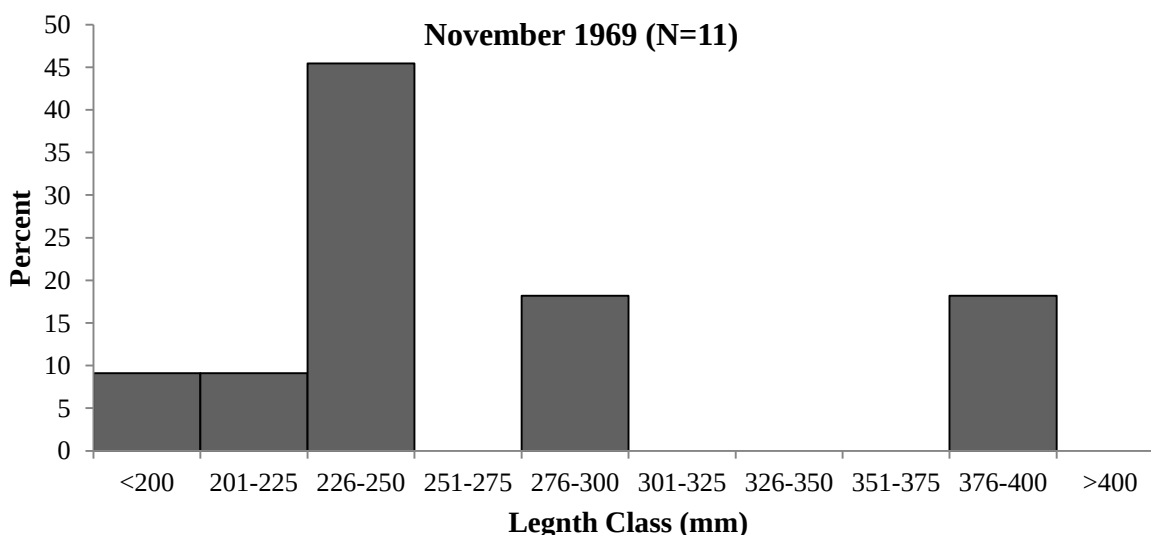


FIGURE 5. Length-frequency of cutthroat trout captured in gillnets in Elsie Lake, November 1969 (N=11) (Source: FLNRO files, Nanaimo).

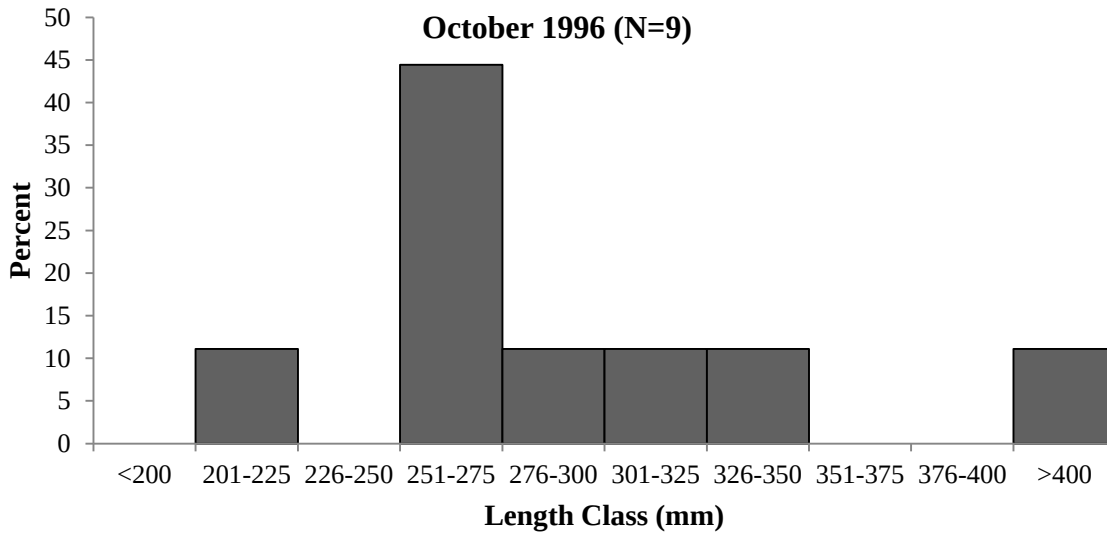


FIGURE 6. Length-frequency of cutthroat trout captured in gillnets in Elsie Lake, October 1996 (N=9) (Source: Burt and Robert, 2003).

Length frequency distributions for cutthroat captured in gillnets and by angling in 2002 are presented in Figures 6 and Figure 7. Approximately 40% (3 fish) of the cutthroat captured by gillnetting and >50% of those captured by angling (2 fish) were within the 251 – 275 mm length category. Note there were small sample sizes for all years, and consequently, results may not represent the true population structure.

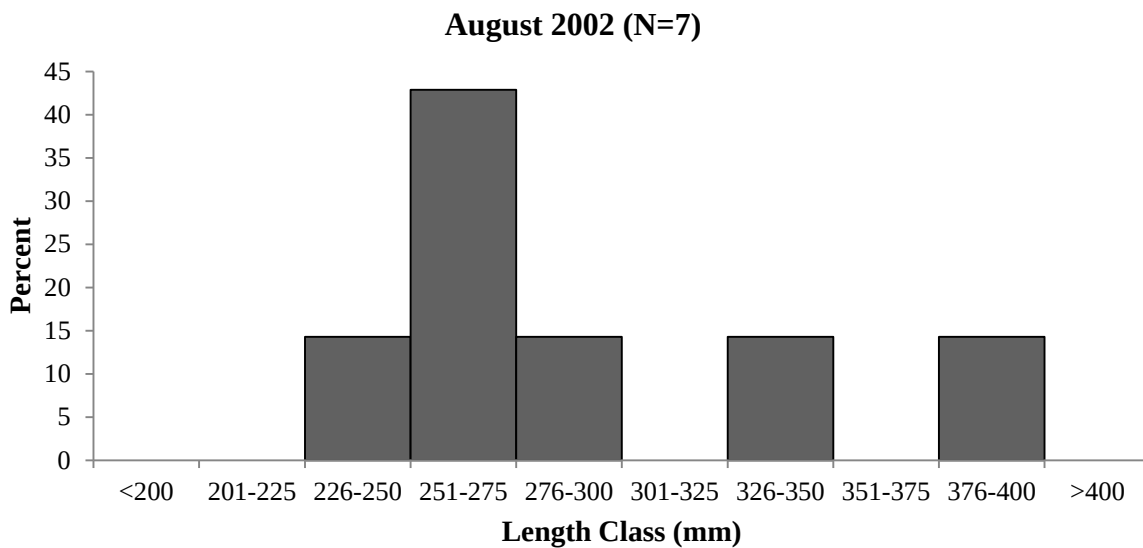


FIGURE 7. Length-frequency of cutthroat trout captured in gillnets in Elsie Lake, August 2002 (N=7) (Source: Burt and Robert, 2003).

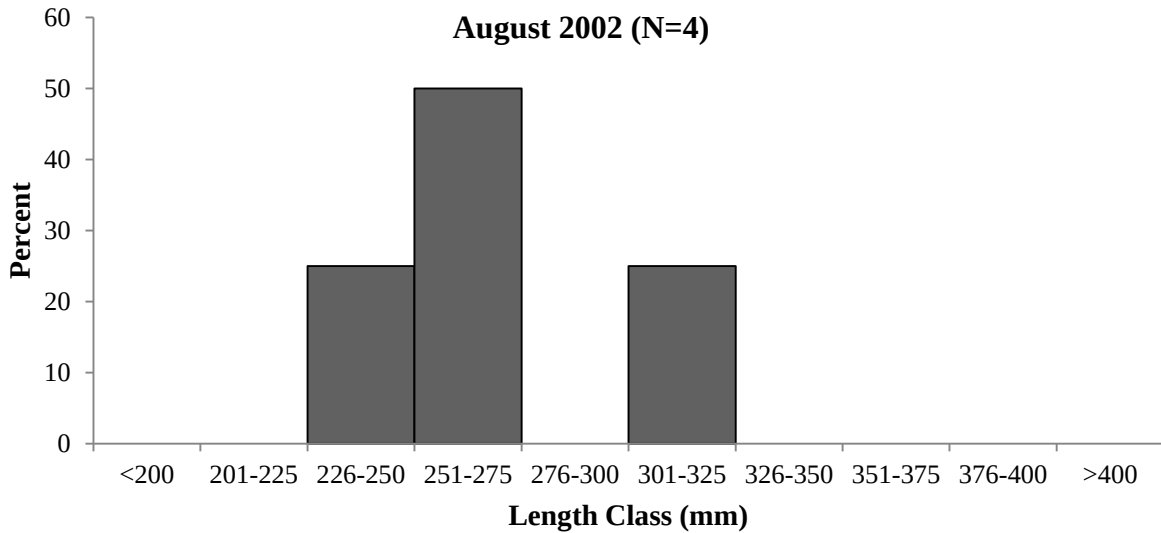


FIGURE 8. Length-frequency of cutthroat trout captured by angling in Elsie Lake, August 2002 (N=4) (Source: Burt and Robert, 2003).

Length Weight Relationship

The length-weight relationship for cutthroat trout captured by gillnetting in Elsie Lake from 1969 - 2002 is shown in Figure 9. Cutthroat range from ~200 mm and <100 g to >400 mm and ~600 g and most cutthroat are ~250 mm and <200 g.

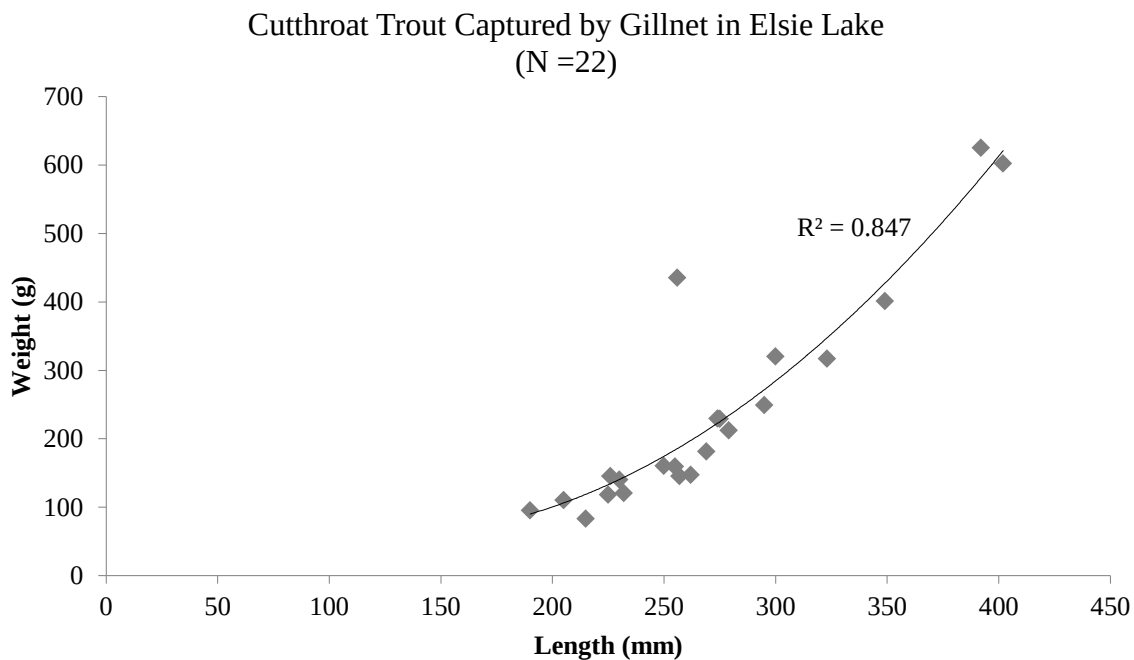


FIGURE 9. Length-weight relationship for cutthroat trout captured in gillnets in Elsie Lake in Nov 1969, May 1994, Oct 1996 and Aug 2002 (N=22) (Source: Triton, 1995; Klohn Crippen 1999; Burt and Robert, 2003).

Age-at-Length

Age frequency distributions of fish sampled in Elsie Lake tributaries (Upper Ash River, Katlum Creek, Ramsay Creek, South Elsie Creek, Creek No. 2) in 1996, 2002 and 2005 is presented in Figures 9-11. Age 0+ cutthroat comprised between ~80% and >90% of each of these samples which suggests that most cutthroat utilizing tributary streams in this watershed recruit to Elsie Lake in their 2nd year (i.e. as 1+ fish).



FIGURE 10. Age frequency distribution for cutthroat trout captured by electrofishing in Elsie Lake tributaries in 1996 (N=63) (Source: Klohn-Crippen, 1999).



FIGURE 11. Age frequency distribution for cutthroat trout captured by electrofishing in Elsie Lake tributaries in 2002 (N=293) (Source: Burt and Robert, 2003).

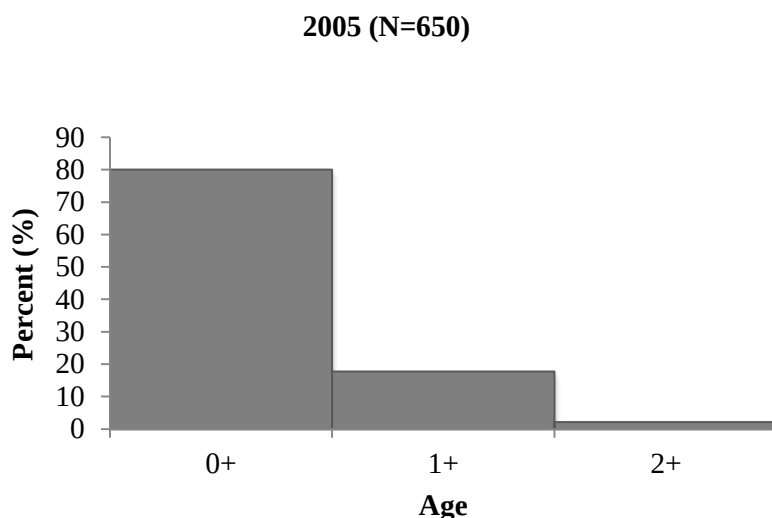


FIGURE 12. Age frequency distribution for cutthroat trout captured by electrofishing in Elsie Lake tributaries in 2005 (N=650) (Source: Robert and Lewis, 2006).

Length, weight, and condition factors for trout captured by Burt and Robert in 2002 are summarised in Table 2. The mean condition factor of age 1+ cutthroat is 1.08 and age 2+ cutthroat trout is 1.02 (Burt and Robert, 2003).

TABLE 2. Mean length, weight, and condition factor for cutthroat trout captured in Elsie Lake tributaries (Upper Ash River, Katlum Creek, Ramsay Creek, and Creek #2) from September 15-19, 2002 (Source: Burt and Robert, 2003).

Age	Species	n	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Mean K
1	Cutthroat	21	94	78-120	9.5	1.08
2	Cutthroat	2	135	133-137	25.1	1.02

Maturity

Only 16 cutthroat trout sampled at Elsie Lake have been assessed for sex and maturity (Table 3). In 1994, 1 mature male cutthroat 307 mm was sampled. In 1996, 8 cutthroat were sampled; 4 females and 4 males. Of the females caught, 3 were immature and ranged from 257 mm – 279 mm and averaged 268 mm, while the mature fish was 401 mm. One immature male was captured that year and it was 262 mm, while 3 mature males ranging from 256 mm - 402 mm and averaging 327 mm were caught. In 2002, 2 females were caught, both of which were mature and ranged from 255 mm – 344 mm and averaged ~300 mm. The 5 males captured were all mature and ranged from 232 mm – 400 mm and averaged 295 mm.

TABLE 3. Size (mm) of mature and immature male and female cutthroat captured in Elsie Lake in 1994 and 1996, 2002 (Source: FLNRO files, Nanaimo).

Length (mm)	1994 (N=1)	1996 (N=8)				2002 (N=7)	
	Male (n=1) Mature	Male (n=4) Immature (n=1)	Mature (n=3)	Female (n=4) Immature (n=3)		Male (n=5) Mature (n=5)	Female (n=2) Mature (n=2)
Range	307	262	256-402	257-279	349	232-400	255-344
Mean	-----	-----	327	268.3	-----	295.2	299.5

Juveniles

A length-weight relationship of cutthroat trout juveniles captured by Burt and Robert in Elsie Lake tributaries is presented in Figure 12. Most cutthroat in tributaries are <60 mm length and <5g. A small proportion of fish are 80 mm – 100 mm and ~10 g.

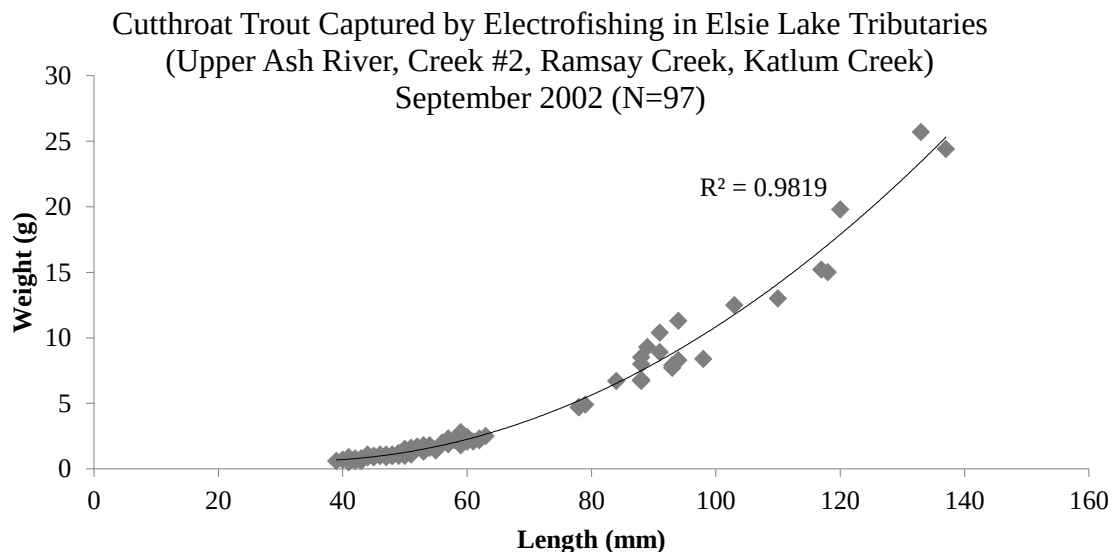


FIGURE 13. Length-weight relationship for cutthroat trout captured by electrofishing in tributaries to Elsie Lake (Upper Ash River, Creek No. 2, Ramsay Creek, Katlum Creek) in September 2002 (N=97) (Source: Burt and Robert, 2003).

Rainbow Trout

Population Data

The minimum, maximum and mean fork lengths of rainbow trout sampled in Elsie Lake from 1969 – 2002 is shown in Table 4. Minimum sizes of cutthroat ranged from 95 mm in 2002 to 181 mm in 1996 while maximum sizes ranged from 220 mm in 1994 to 329 mm in 2002. On average, rainbow trout sampled in Elsie Lake were 192 mm – 233 mm.

TABLE 4. Total number, minimum, maximum and mean fork length of rainbow trout captured by gillnet in Elsie Lake in November 1969, May 1994, October 1996, and August 2002 (Source: Beamish & Northcote, 1989; Griffith, 1991; Triton, 1995; Klohn Crippen, 1999; BC Hydro 2001; Burt and Robert 2003; Lewis and Ganshorn 2005).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1969	21	130	255	197.9	106
1994	32	119	310	200.2	81.1
1994	36	165	220	-----*	
1996	5	181	278	233.0	125
2002	158	95	329	192.3	90.5

*only ranges of fish caught are noted in the file so it is not possible to calculate a mean.

Length Frequency Distributions

Length frequency analyses of rainbow trout collected in November 1969, May 1994 and August 2002 are presented in Figures 13-15. In 1969 the modal length was 201 mm – 225 mm with ~35 % of the sample falling within that category. In total, >80% of that sample was <225 mm.

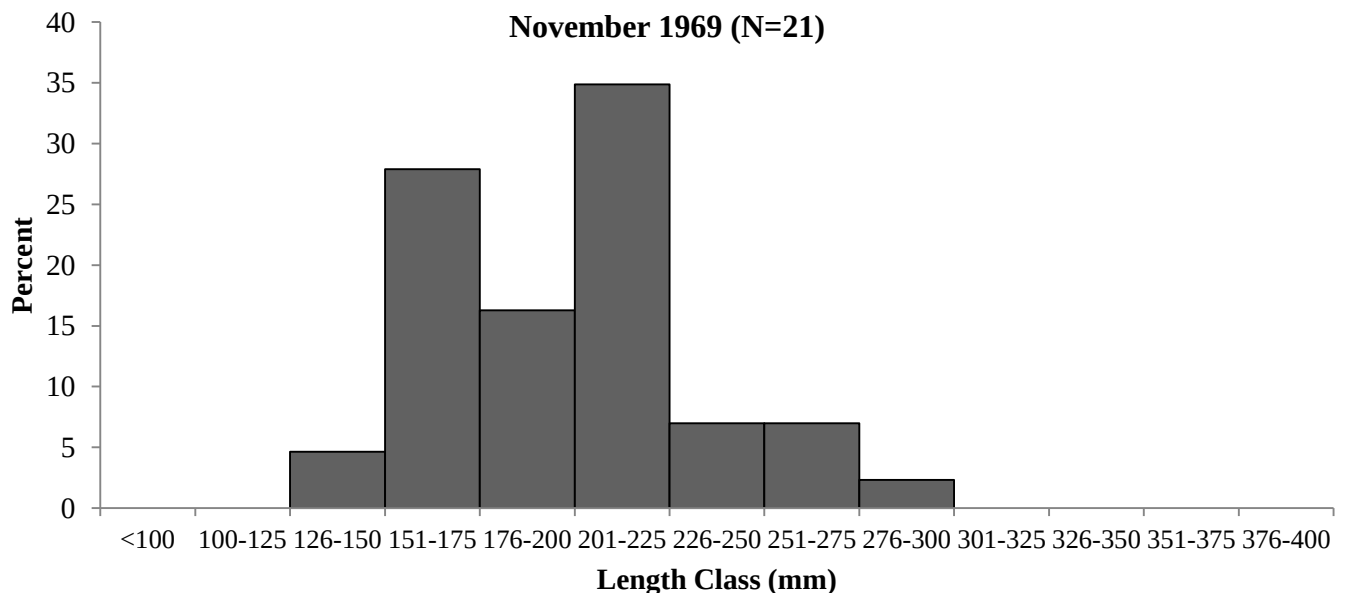


FIGURE 14. Percentage of rainbow trout captured in Elsie Lake reservoir by length category in November 1969 (N=21) (Source: Triton 1995; Lewis and Ganshorn, 2005).

In 1994, the mode was 176 mm – 200 mm with almost 50% of the sample within that length class. Although a small number of rainbow 201 – 325 mm were captured, most fish were <250 mm.

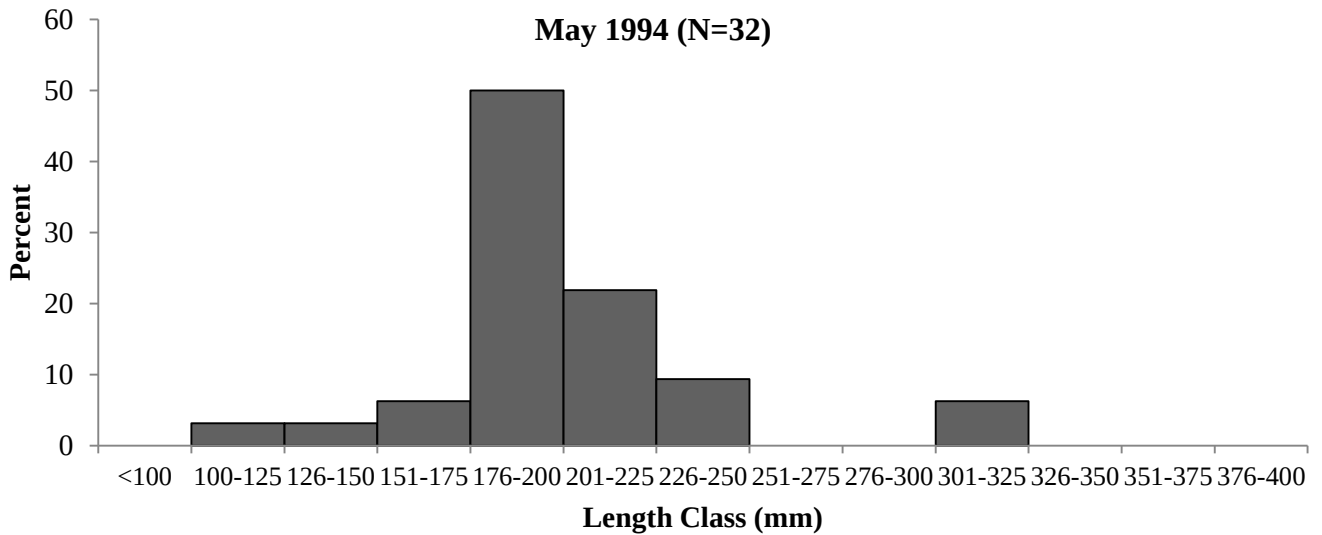


FIGURE 15. Percentage of rainbow trout captured in Elsie Lake reservoir by length category in May 1994 (N=32) (Source: Lewis and Ganshorn, 2005).

In 2002, rainbow ranging up to 350 mm were captured in Elsie Lake, however, 20% of the sample was comprised of fish 126 mm – 150 mm and the mode had shifted to 142 mm (Figure 16).

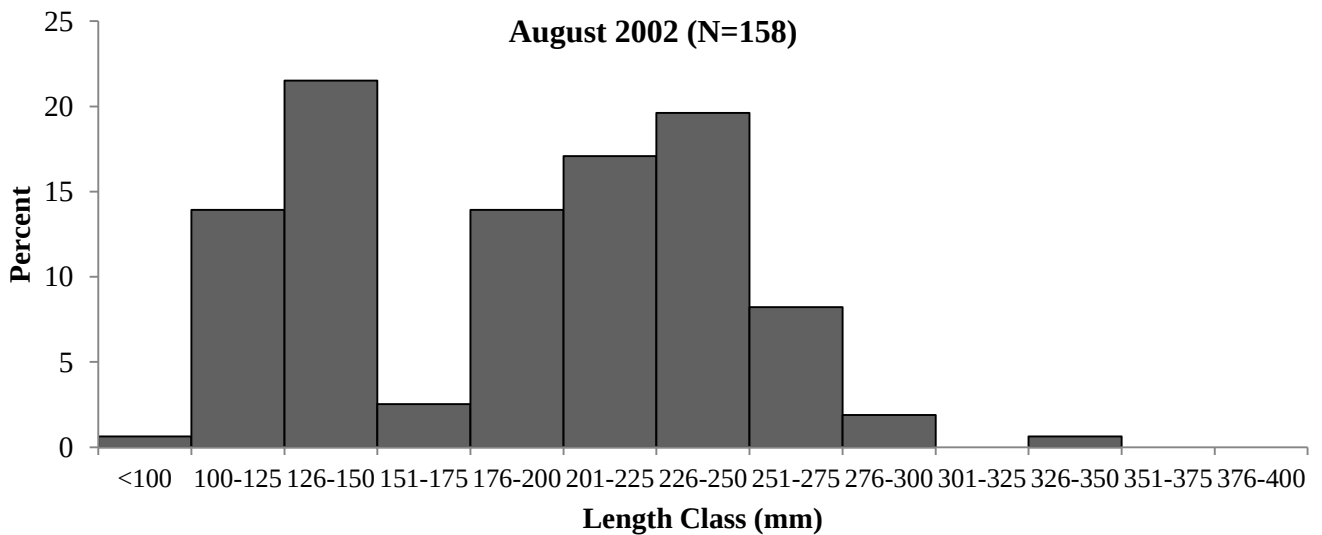


FIGURE 16. Percentage of rainbow trout captured in Elsie Lake reservoir by length category in August 2002 (N=158) (Source: Lewis and Ganshorn, 2005).

Length Weight Relationship

Burt and Robert (2003) analyzed the weight and condition factor of each age class of the 160 rainbow trout sampled in Elsie Lake in 2002 (Table 5). Age 2+ fish ranged from 118 mm – 152

mm and averaged 135 mm and 29 g; age 3+ fish ranged from 171 mm to 231 mm and averaged 200 mm and 87 g while age 4+ fish ranged from 217 mm – 275 mm and averaged 242 mm and 142 g. Condition factors for these fish were 1.18 for 2+ fish; 1.09 for age 3+ fish and 1.00 for age 4+ fish. Age 5+ rainbow trout ranged from 243 mm to 329 mm, averaged 284 mm and 215 g and had an average K-value of 0.93 (Table 5) (Figure 17).

TABLE 5. Mean length, weight, and condition factor by age for rainbow trout captured by gillnet in Elsie Lake, August 7-9, 2002. Note all fish captured by gillnet with the exception of the one age 0+ fish captured in a minnow trap (Source: Burt and Robert, 2003.)

Age	Sample Size (n)	Length Range (mm)	Mean Length (mm)	Mean Weight (g)	Mean K
0+	1	-----	66	2.9	1.00
1+	12	95-121	113.9	18.6	1.24
2+	46	118-152	134.0	29.0	1.18
3+	51	171-231	2199.6	87.2	1.09
4+	45	217-275	241.8	142.4	1.00
5+	5	243-329	283	215.6	0.93

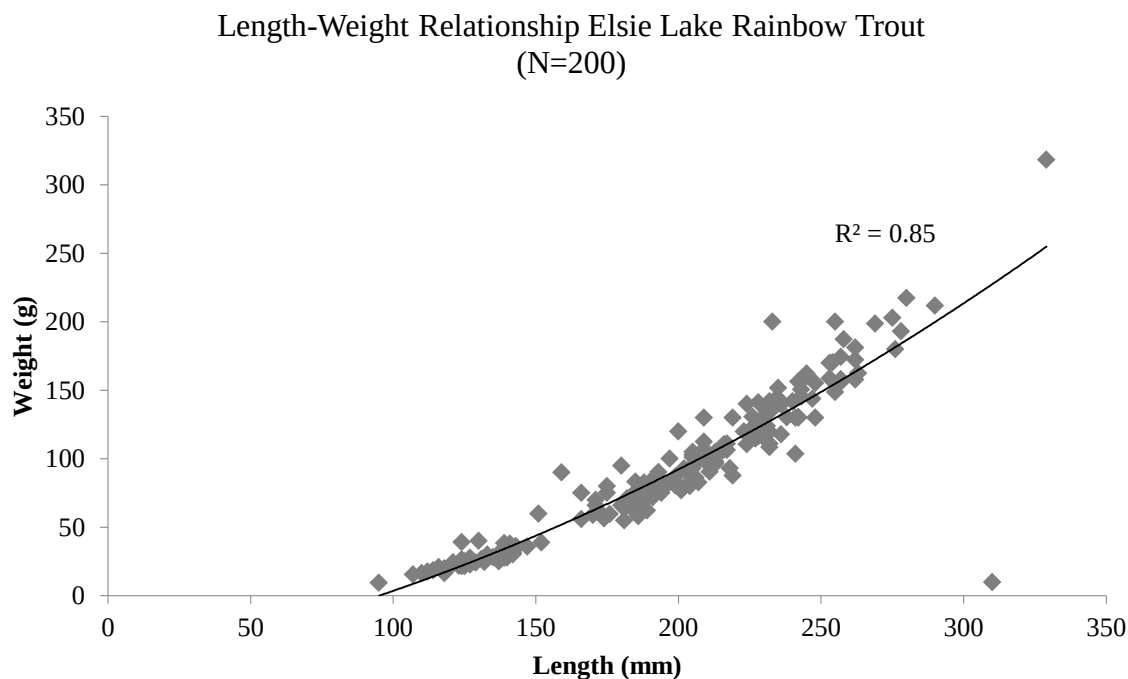


FIGURE 17. Length-weight relationship for rainbow trout captured in gillnets in Elsie Lake in 1969 (n=20), 1994 (n=30) and 1996 (n=5) and 2002 (n=145) (Source: FLNRO files, Nanaimo).

Maturity

The sex and maturity of rainbow trout captured in 1994, 1996 and 2002 is presented in Table 6. Of the 9 rainbow trout caught in 1994, 4 were mature males ranging in length from 184 mm – 196 mm and averaging 189 mm. Of the 5 females captured that year, 1 was mature and 210 mm while 4 were immature and ranged from 119 mm – 233 mm and averaged 182 mm. In 1996, 1 mature male 233 mm was captured in Elsie Lake. That year, 3 mature females ranging

from 232 mm – 278 mm and averaging 250 mm were caught as was 1 immature female ~180 mm.

TABLE 6. Size (mm) of mature and immature male and female rainbow trout captured in Elsie Lake in 1994 and 1996, 2002 (Source: FLNRO files, Nanaimo; Burt and Robert, 2003).

Length (mm)	1994 (N=9)			1996 (N=5)			2002 (N=100)		
	Male (n=4)		Female (n=5)	Male (n=1)	Female (n=4)		Male (n=40)	Female (n=60)	
	Mature (n=4)	Mature (n=1)	Immature (n=4)	Mature (n=1)	Mature (n=3)	Immature (n=1)	Mature	Mature (n=56)	Immature (n=4)
Range	184-196	310	119-233	233	232-278	181	139-275	171-329	116-172
Mean	189	-----	182		250.3	-----	214.3	228.2	138.8

In 2002, 40 male and 60 female rainbow trout were sampled. All of the males were mature and these ranged from 139 mm – 329 mm and averaged 228 mm. Fifty-six mature females ranging from 171 mm – 329 mm and averaging 228 mm and 4 immature females ranging from 116 mm – 172 mm and averaging ~140 mm were caught. Burt and Robert (2003) compared their 2002 maturity data with their aging results and suggest that rainbow trout are either maturing or mature and that first spawning occurs in their third or fourth year of life.

Juveniles

The length frequency distributions of rainbow trout captured by electrofishing in tributaries to Elsie Lake in 1996, 2001 and 2002 are presented in Figures 18 - 20. Most rainbow trout captured in the tributaries were within the 26 mm – 50 mm length class while fish captured in the spillway pools were larger on average and ranged up to 225 mm.

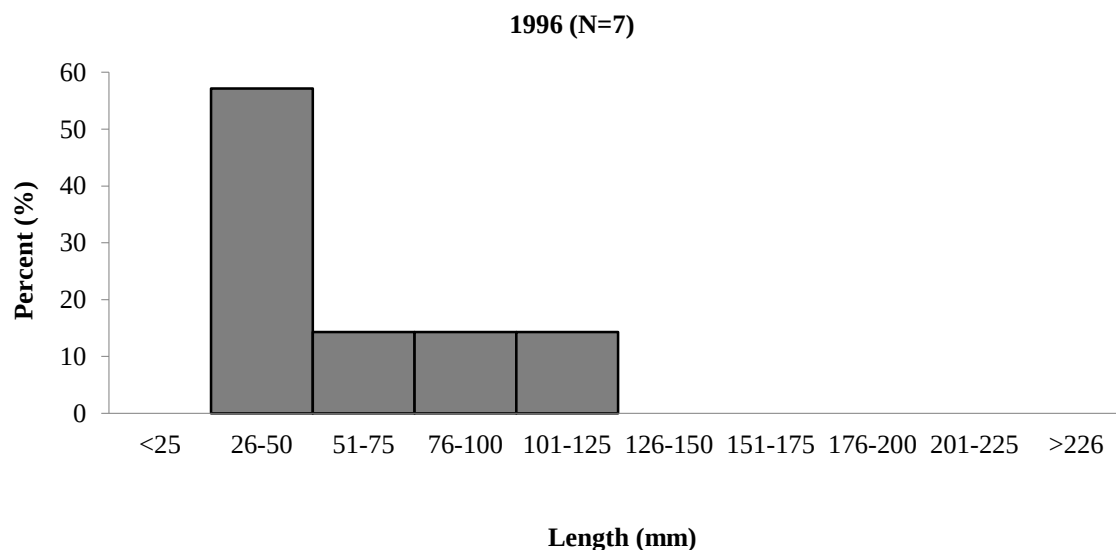


FIGURE 18. Length frequency of rainbow trout captured by electrofishing in Elsie Lake tributaries (Ramsay Creek, Katlum Creek and South Elsie Creek) in October 1996 (N=7) (Source: Klohn-Crippen, 1999).

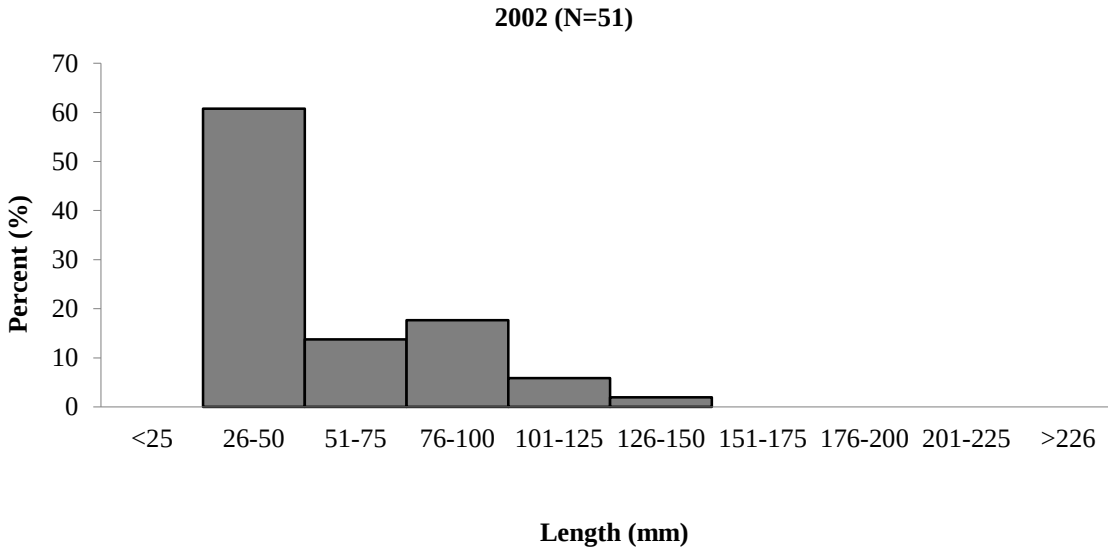


FIGURE 19. Length frequency of rainbow trout captured by electrofishing in Elsie Lake tributaries (Upper Ash River, Katlum Creek, Ramsay Creek and Creek #2) in September, 2002 (N=51) (Source: Burt and Robert, 2003).

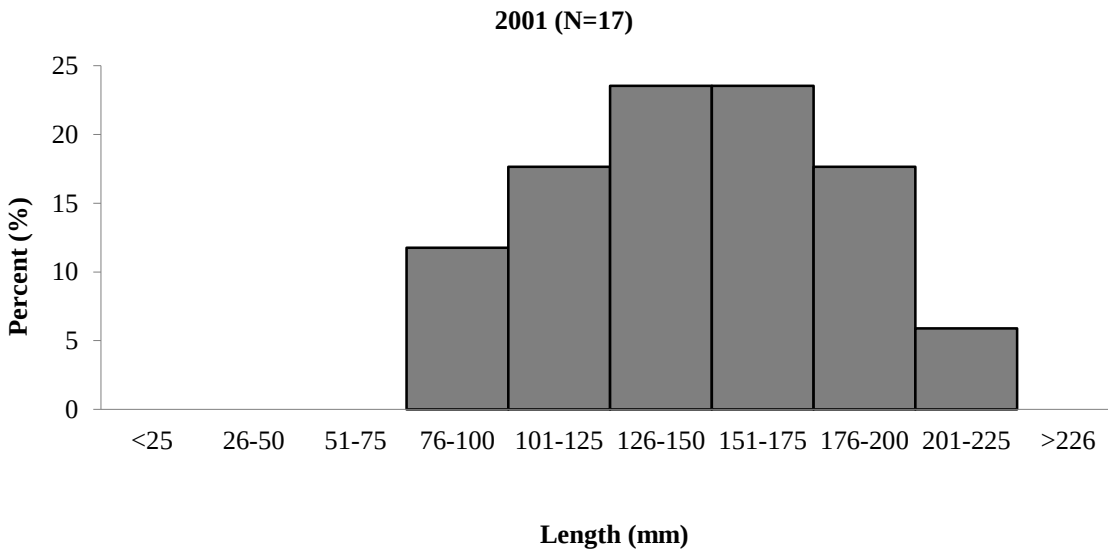


FIGURE 20. Length frequency of rainbow trout captured by electrofishing in the Elsie Dam spillway pools between Elsie Lake and Ash River in June/July 2001 (Source: Ecocat; Wickman, 2001).

Burt and Robert (2003) summarized the length, weight, and condition factor statistics for all rainbow trout captured by electrofishing in 2002 (Table 7). Over 90% of the fish captured were in their first year (age 0+). Of the 270 0+ trout captured, most ranged from 28 mm – 63 mm and averaged 43 mm indicating that spawning occurred in the late spring or early summer.

TABLE 7. Mean Length, weight, and condition factor for rainbow trout captured by electrofishing in Elsie Lake tributaries (Upper Ash River, Katlum Creek, Ramsay Creek, and Creek #2) from September 15-19, 2002 (Source: Burt and Robert, 2003).

Age	Species	n	Length Range (mm)	Mean Length (mm)	Mean Weight (g)	Mean K
0	Trout	270	28-63	43	0.9	1.01
1	Rainbow	12	97-102	83	6.5	1.11
2	Rainbow	4	85-129	112	16.8	1.15

A number of researchers electrofished Elsie Lake tributaries and their data are presented in Table 8. The highest numbers of rainbow trout captured in these habitats were 0+ and 1+ fish. On average, age 0+ fish ranged from 38 mm – 54 mm, age 1+ fish ranged from 91 mm – 111 mm. A small number of 2+ rainbow trout were captured and these were <134 mm.

TABLE 8. Mean lengths of 0+, 1+ and 2+ rainbow trout captured in Elsie Lake tributaries by electrofishing 1991, 1996 and 2002 (Source: Griffith, 1992; Klohn-Crippen, 1999; Burt and Robert, 2003).

Age	0+		1+		2+	
Year Number Sampled	N	Mean Length (mm)	N	Mean Length (mm)	N	Mean Length (mm)
1991 (N=9)	6	38-54*	2	111	1	134
1996 (N=6)	4	44	2	91		
2002 (N=51)	35	38.3	12	82.6	4	111.5

* only ranges of lengths of 0+ age fish noted in data.

It appears that, like cutthroat trout, rainbow that fry rarely recruit to the lake since fewer than 1% of the rainbow trout captured in Elsie Lake are <100 mm in fork length (Robert and Lewis, 2006). Moreover, based on the electrofishing results, fry that utilize tributary streams spend up to 2 years rearing in those streams before recruiting to Elsie Lake (Figure 21).

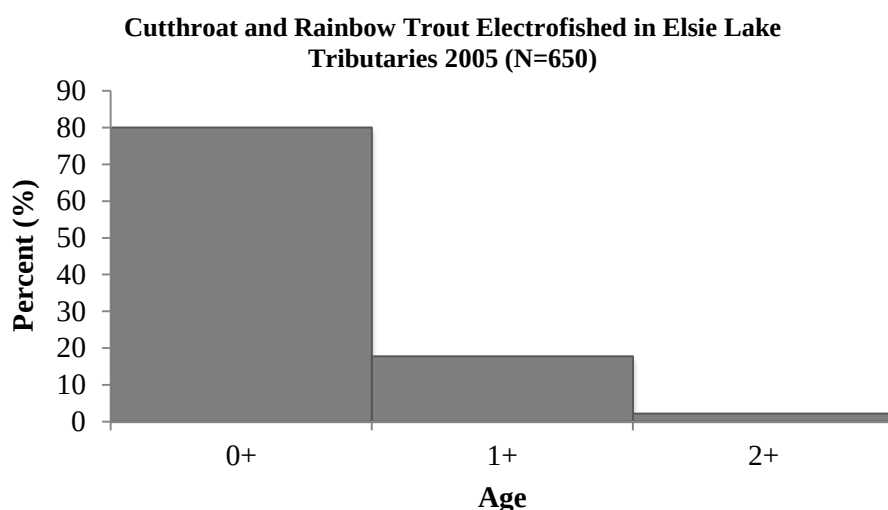


FIGURE 21. Age frequency distribution for pooled species (rainbow and cutthroat trout captured by electrofishing in Elsie Lake tributaries in 1996 (N=63), 2002 (N=293) and 2005 (N=650) (Source: Klohn-Crippen, 1999; Burt and Robert, 2003; Robert and Lewis, 2006).

Electrofishing was conducted in August 1991 at 7 sites in the Ash River drainage upstream of Dickson Falls (Griffith, 1992). Fish were sampled for fork length and weights and data was used to determine species and age/size specific length/weight conversion factors for biomass estimates. We've presented a summary of rainbow trout numerical fish densities in Table 9, however, complete analysis of data including biomass densities can be found in Griffith (1992).

Griffith sampled age 0+ rainbow in each tributary of the Ash River, however, he found age 1+ fish only in 3 of the 6 sample sites and these were at low densities (Table 9, Table 10). Griffith's findings support the premise that, by and large, juvenile trout rear for 1 year in tributaries and recruit to Elsie Lake in their 2nd year (i.e. age 1+).

TABLE 9. Summary of rainbow trout numerical fish densities (fish/m²) sampled in the Ash River, above Dickson Falls, August 7-9, 1991 (Source: Griffith 1992).

Site No.	Age 0+	Age 1+	Age 2+	Total
Mainstem 1	0.85	0.03	-	0.88
Mainstem 2	0.08	-	-	0.08
Mainstem 3	0.39	-	-	0.39
Mainstem 4	0.40	0.10	0.03	0.53
Mainstem 5	0.03	-	-	0.03
Mainstem 6	0.17	-	-	0.17
Mainstem Mean	0.32	0.02	0.01	0.35
Tributary 7	0.84	-	-	0.84

TABLE 10. Summary of rainbow trout length range, mean length, mean weight and numbers sampled by electrofishing in the Ash River, above Dickson Falls, August 7-9, 1991 (Source: Griffith 1992).

Site No.	Age	n	Length Range (mm)	Mean Length (mm)	Mean Weight (g)
Mainstem 1	0+	30	38-69	48.8	1.4
	1+	1	111	111	15.3
Mainstem 2	0+	5	44-51	48.2	1.2
Mainstem 3	0+	7	43-55	49.9	1.4
Mainstem 4	0+	11	38-63	50.1	1.5
	1+	3	78-88	82	6.2
	2+	1	134	134	26.9
Mainstem 5	0+	2	54-55	54.5	1.7
Mainstem 6	0+	5	35-64	48.5	1.2
Tributary 7	0+	23	37-68	50.3	1.5

Snorkel Survey Summaries

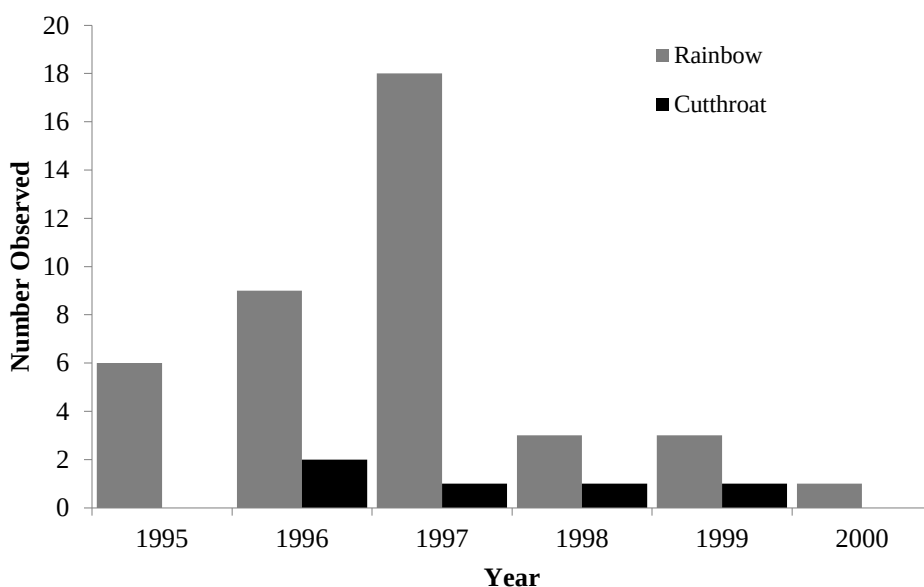


FIGURE 22. Numbers of rainbow (n=40) and cutthroat (n=5) trout observed during snorkel surveys conducted by Ministry staff September/ October, 1995-2000. The objective of these surveys was to enumerate steelhead, and counts of rainbow and cutthroat were incidental, consequently there are no conclusions regarding numbers of these species over the years (Source: FLNRO files, Nanaimo).

Robert and Lewis (2006) conducted snorkel surveys in 2005 to quantify the numbers of spawners in Elsie Lake tributaries from April – June and we've presented their observed counts for pooled species of fish >200 mm in Table 11. Note that only fish >200 mm were counted as these were believed to be mature (Wright, H, 2010, pers. com; Robert and Lewis 2006). The highest counts were observed in the Ash River, and the highest counts in all tributaries were mid June.

TABLE 11. Summary of fish >200 mm observed during snorkel surveys of Ash River, Ramsay Creek, Katlum Creek and Creek 2 conducted from April – June 2005 (Source: Robert and Lewis, 2006).

Water body	Date	Counts	Counts	Total	Density (fish/km)
		200-300 mm	>300 mm		
Ash River	Apr-21	1	0	1	0.15
	Apr-25	4	0	4	0.59
	Jun-12	82	1	83	12.21
	Jun-17	20	3	23	3.38
Creek No.2	Jun-10	15	0	15	18.52
Katlum Creek	Jun-09	21	0	21	8.75
Ramsay Creek	Jun-10	8	0	8	2.29
	Jun-18	3	0	3	0.86

Dolly Varden

Population Data

Dolly Varden have been observed at the mouth of the Ash River (Lewis and Ganshorn, 2005), but surveys conducted by Griffith in 1992 did not identify this species in the Lower Ash River (Griffith, 1993). Griffith (1993) does note, however, that juvenile Dolly Varden are difficult to sample even by electrofishing, so a lack of capture does not necessarily indicate a lack of presence.

The presence of Dolly Varden in the Middle Ash River is also uncertain. Lewis and Ganshorn (2005) suggested that Dolly Varden may be present throughout the Middle Ash River and in isolated headwater lakes. Griffith captured 2 Dolly Varden fry near Elsie Lake in 1991 (Griffith, 1992), however, he found no evidence of this species when he sampled Dickson Lake in 1992 (Griffith, 1993). Nonetheless, FISS reports the presence of Dolly Varden in Dickson Lake (FLNRO files, Nanaimo).

Kokanee

Population Data

The presence of kokanee in Elsie Lake is uncertain. While kokanee are not noted in FISS records or recent gillnet surveys, one kokanee was captured below the Elsie dam spillway in 2002 during fry salvage activities (Axford R., pers. com. cited in Burt and Robert, 2003). Burt and Robert (2003) considered that kokanee may be present in the middle portions of Elsie Lake, and/or may occupy depths greater than gillnet sets.

Appendix 14. Great Central Lake

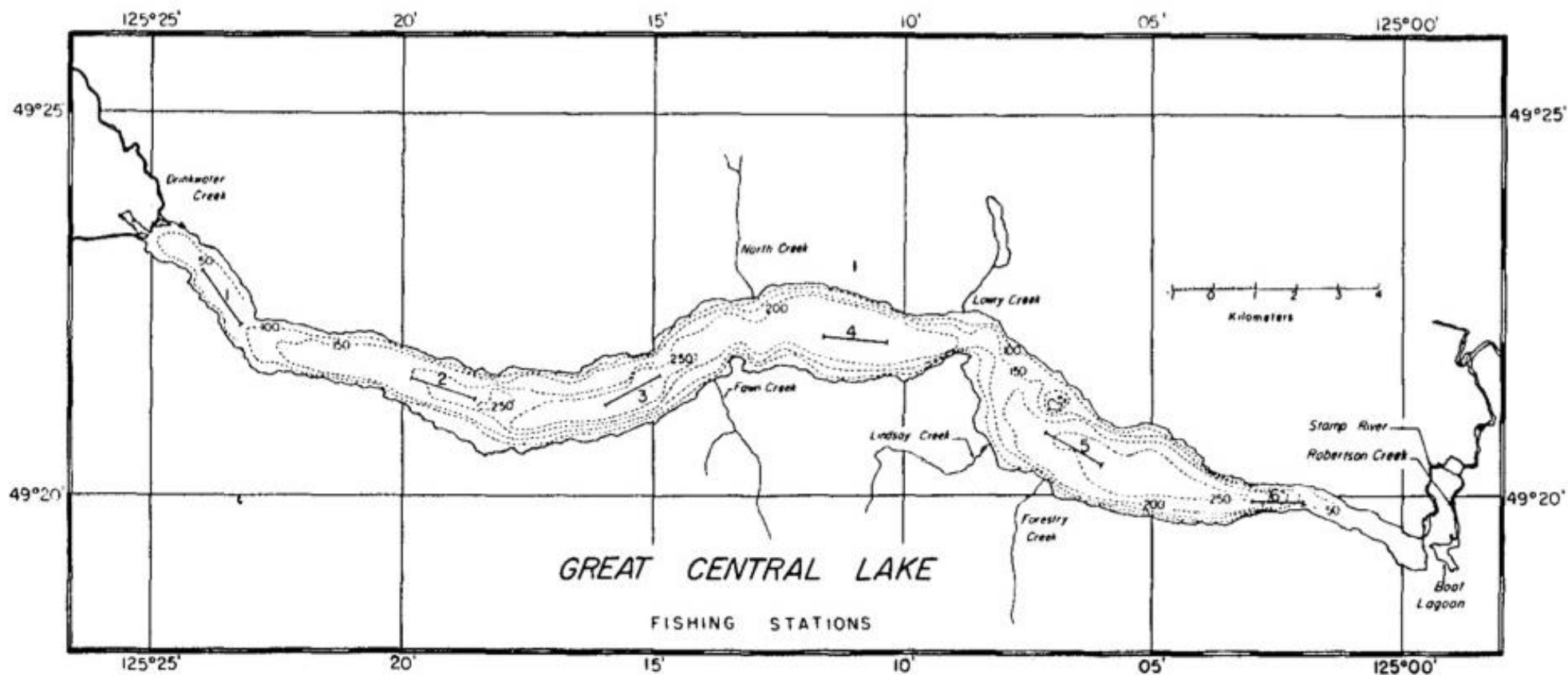


FIGURE 1. Bathymetric map of Great Central Lake (Source: Barraclough & Robinson, 1972).

Angling Data

Cutthroat trout and rainbow trout catches in the sport fishery of Great Central Lake were sampled in the fall of 1969 and spring-summer of 1970 and are shown in Table 1; Table 2. The 324 cutthroat trout caught ranged in length from 197 mm - 598 mm, while the 23 rainbow trout caught ranged in length from 240 mm – 548 mm.

TABLE 1. Total numbers and minimum, maximum and mean fork length of cutthroat trout captured by angling in Great Central Lake, Ark Resort Fishing Derby, in 1969-1970 (Source: Narver, 1975).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1969-1970	324	197	598	366	170 – 2100

TABLE 2. Total numbers and minimum, maximum and mean fork length of rainbow trout captured by angling in Great Central Lake, Ark Resort Fishing Derby, in fall 1969 and spring 1970 (Source: Narver, 1975).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1969-1970	23	240	548	366	---

The minimum, maximum and mean fork lengths of cutthroat and rainbow trout caught by anglers in Great Central Lake from the 2009 and 2010 Ark Resort Fishing Derbies are shown in Table 3; Table 4. On average, cutthroat trout caught in 2009 and 2010 in Great Central Lake were ~790 mm, while rainbow trout averaged between ~500 mm to ~700 mm.

TABLE 3. Total numbers and minimum, maximum and mean weight of cutthroat trout captured by angling in Great Central Lake, Ark Resort Fishing Derby, in 2009 and 2010 (Source: Ark Resort, Port Alberni).

Year	N	Weight (g)		
		Minimum	Maximum	Mean
2009	103	45	2131	786
2010	22	269	2466	795

TABLE 4. Total numbers and minimum, maximum and mean weight of rainbow trout captured by angling in Great Central Lake, Ark Resort Fishing Derby, in 2009 and 2010 (Source: Ark Resort, Port Alberni).

Year	N	Weight (g)		
		Minimum	Maximum	Mean
2009	26	136	3614	691
2010	28	184	1049	496

Stock Status Indicators

Cutthroat Trout

Population Data

Fifty-two cutthroat trout between 118 – 1400 mm were captured in gillnets in Great Central Lake in 1978 (Table 5). No data was recorded on weight, sex, or maturity.

TABLE 5. Minimum, maximum and mean fork length (mm) of cutthroat trout captured in gillnets in Great Central Lake 1978 (N=52) (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1978	52	118	1400	258	---

Length Frequency

Length frequency distribution of cutthroat trout captured in gillnets in 1978 are presented in Figure 2.

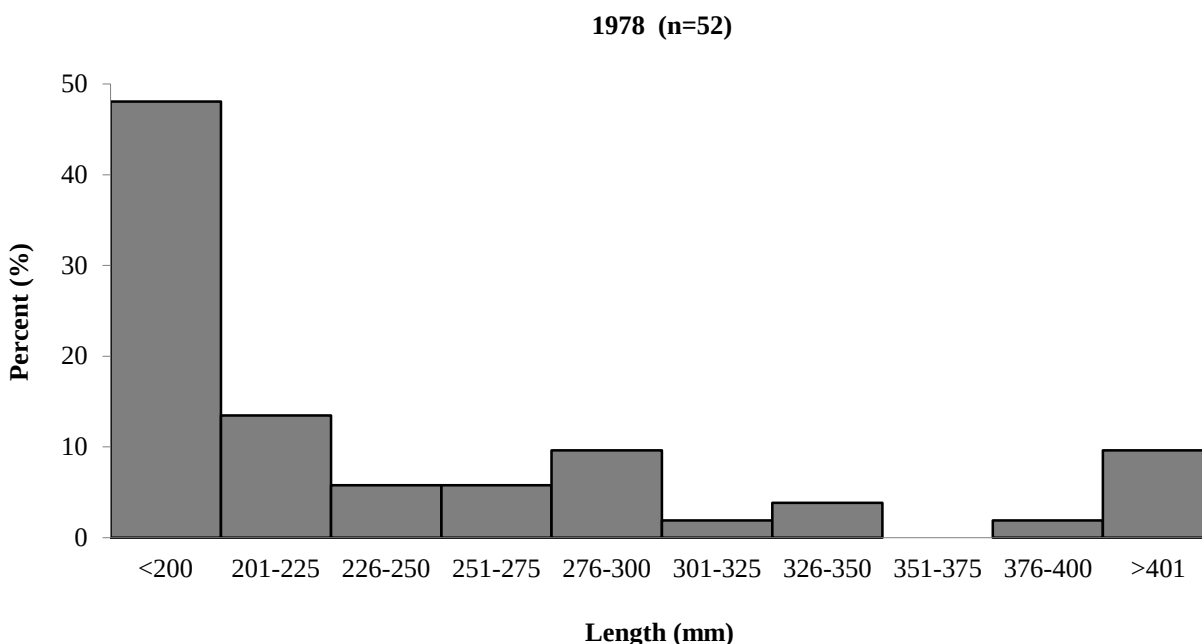


FIGURE 2. Length frequency of cutthroat trout captured in gillnets in Great Central Lake 1978 (N=52) (Source: FLNRO files, Nanaimo).

Age-at-Length of Cutthroat Trout

Narver (1975) sampled trout catches in the sport fishery of Great Central Lake in the fall of 1969 and spring-summer of 1970 to determine age and growth of trout before experimental lake fertilization. Of the 349 fish sampled, 324 were cutthroat, 23 rainbow and 2 Dolly Varden. The sex composition of 60 cutthroat sampled for stomach contents in 1970 was 41.7% males and

58.3% females. Cutthroat trout ranged in age from 1+ to 7+ and in length from 197 to 598 mm (mean = 366). The most common age groups were 3, 4 and 5 which comprised 86% of the total sample with age 4 fish being the most common at 34%. Cutthroat scales had a characteristic pattern of slow growth in the first 2 or occasionally 3 years, followed immediately by 1 or 2 years of rapid growth and then years of successively slower growth. This probably represents stream and subsequent lake growth. The mean length of fish at time of each annulus formation was estimated at 45 mm for age 1, 94 mm for age 2, 206 mm for age 4, 319 mm for age 4, 405 mm for age 5 and 465 mm for age 6. Narver (1975) found that the major food items in percent occurrence were total fish (35%), juvenile sockeye salmon (10%), three-spine stickleback (8%), carpenter ant (60%) and cicada (28%). Non-fish, aquatic food items occurred in 15% of the cutthroat and empty stomachs occurred in 10%. Results are in Table 6.

Mean length of each age class of cutthroat trout caught by anglers in Great Central Lake between 1969 and 1970 is shown in Table 6. Of the 324 cutthroat trout caught in these two years, 240 fish had no scale regeneration and thus were suitable for age and growth interpretation (Narver, 1975). The mean size of age 1+ fish was 45 mm while age 2+ fish averaged 94 mm. Age 3+ fish averaged 206 mm, age 4+ fish averaged 319 mm, and age 5+ fish averaged 405 mm. Age 6+ averaged 465 mm while age 7+ fish were slightly smaller at a mean length of 428 mm.

TABLE 6 Total number, mean fork length in mm and ages of cutthroat trout captured by anglers in Great Central Lake in October 1969 and May to July 1970 (N=240) (Reprinted from: Narver, 1975).

Year	Age													
	1+		2+		3+		4+		5+		6+		7+	
	n	Mean Length (mm)	n	Mean Length (mm)	n	Mean Length (mm)	n	Mean Length (mm)	n	Mean Length (mm)	n	Mean Length (mm)	n	Mean Length (mm)
1969-1970	1	45	13	94	62	206	83	319	61	405	18	465	2	428

The 1969-1970 angling sample consisted mainly of fish of age groups 3, 4 and 5 (Table 7) which represented 86% and age 4 fish were the most common at 35%. From these data the best estimate of mean length at time of annulus formation is 45mm for age one, 94mm for age two, 206mm for age three, 319mm for age four, 405mm for age five, 465mm for age six, and 428 mm for age seven.

TABLE 7. Mean cutthroat lengths (mm) as determined by back calculation to each annulus, Great Central Lake, October 1969 and May to July 1970 (Reprinted from: Narver, 1975).

October, 2006 and May, to July, 2010 (repaired from Harvey, 2012).									
			Annuli						
Age Group	%	N	1	2	3	4	5	6	7
			Length (mm)						
1	0	1	50						
2	5	13	52	108					
3	26	62	51	99	218				
4	35	83	48	100	209	322			
5	25	61	45	93	202	330	415		
6	8	18	46	88	169	283	409	523	
7	1	2	36	72	107	229	305	355	428
Mean Length (mm)			44.6	93.8	205.5	319.4	404.5	464.5	428

Narver (1975) noted the difference between the estimated lengths at annulus formation and the actual lengths of fish decreases with age, and offered two explanations for this difference: one is the plus growth included in the actual fish length and the other is the probable bias in the sport fishery for larger faster growing fish. He commented that there was considerable difference in the age-mean length relationships of the fall 1969 and spring 1970 groups of cutthroat. In the three most common age groups in 1969 (age 3, 4, 5) mean length was greater than the same age groups in 1970. The mean lengths of these fish for 1969 and 1970 respectively were 305 and 274 mm for age 3, 414 mm and 341 mm for age 4, and 474 mm and 423 mm for age 5 (Table 8, Table 9). Narver (1975) explained that this age specific difference in size between the fall 1969 fish and the spring 1970 fish is because the former had an additional 2 or 3 months of growth.

TABLE 8. Mean and range (mm) of 111 cutthroat trout lengths and of lengths back calculated to annuli, Great Central Lake, October 1969. Differences between estimated length at last annulus and fork length are due to plus growth (Reprinted from: Narver, 1975).

Age Group (n)	Fork Length (mm)	1	2	3	4	5	6
1 (1)	197	50					
2 (13)	237	52	108				
	210-267	31-76	84-126				
3 (38)	305	49	100	218			
	216-375	26-91	70-192	108-312			
4 (31)	414	56	106	227	343		
	317-571	37-83	67-144	114-311	211-495		
5 (22)	474	48	97	217	341	424	
	305-584	32-72	65-152	110-297	215-460	275-532	
6 (6)	435	41	77	142	240	319	386
	406-457	35-48	60-99	102-212	186-312	283-399	362-418
Mean	367	50.7	94.8	215.9	331.8	401.5	386

TABLE 9. Mean and range (mm) of 129 cutthroat trout lengths and of estimated lengths back calculated to each annuli, Great Central Lake, May to July 1970. Differences between estimated length at last annulus and fork length are due to plus growth (Reprinted from: Narver, 1975).

Age Group (n)	Fork Length	1	2	3	4	5	6	7
3 (24)	274	42	96	217				
	197-349	22-80	63-225	113-296				
4 (52)	341	40	95	197	306			
	235-522	20-84	49-211	89-308	173-428			
5 (39)	423	36	90	192	318	402		
	254-546	20-74	54-192	99-321	179-480	259-592		
6 (12)	451	43	89	176	290	430	558	
	286-598	24-68	61-143	108-330	179-489	278-710	342-892	
7 (2)	489	36	72	107	229	305	355	428
	470-508	33-38	70-72	102-113	178-283	263-342	322-390	427-432
Mean	366	39.4	92.7	195.8	307.2	404.7	529	428

Narver (1975) found the general scale pattern of Great Central Lake cutthroat trout indicated 2 or 3 years of slow growth followed by years of more rapid growth but decreasing with each

successive year. This pattern suggests that of a sea run salmonid. In fact the age designation for the age 5 cutthroat in Fig 2 could be in the anadromous form of 3, 2+. However it is the common pattern in rainbow trout in large lakes such as Babine (Griffiths 1968). To what degree this pattern represents stream and lake growth respectively or a change in diet is not known. Griffiths did show that the Babine rainbow utilized more fish (mainly sockeye fry) and fewer insects after they were age 3 and older than when they were younger.

In the case of Great Central Lake cutthroat, the first 2 or 3 years are probably spent in tributary streams, primarily Drinkwater and McBride Creeks, at the head of the lake. However this growth difference could also be a result of a major change in food habits at a certain size or age (i.e. zooplanktivorous changing to piscivorous).

Food Habits

Narver (1975) identified 13 categories of food items were identified during the analysis of the 60 samples of cutthroat trout stomachs. In most cases stomach contents were seriously decomposed; this was mainly related to fish not being cleaned until hours after capture when the angler returned to the Ark Resort. In terms of percent occurrence, the major food items were juvenile sockeye salmon, threespine stickleback, carpenter ant and cicada.

Fish occurred in some stomachs in all sampling periods with an overall occurrence of 35% and a mean of 0.8 fish per stomach (Appendix 3). Sockeye were important only in the earliest sampling periods (May 24-31 and June 6-13) corresponding to the main smolt outmigration. This was after the thermocline was established at about 11-14 m but before surface waters reached 16 C (Parsons et al, 1972). Mean length of sockeye occurring in the stomachs was 58.6 mm (range 40-110). The most sockeye contained in one fish was 4 (45-55 mm) in a 546 mm cutthroat trout. Stickleback occurrence was rather low throughout the sampling periods at 8%. The mean length of 23 stickleback that occurred in the stomachs of three cutthroat was 50.4 mm (range 30-75). A cutthroat, 476 mm in length, contained 10 stickleback.

Terrestrial insects, mainly winged carpenter ants and cicada, were extremely common with an overall occurrence of 73%. Some individual fish during May 24-31 had as many as 150 ants in their stomachs (Appendix 3). One individual caught during June 6-13 contained 181. The nuptial flight of the carpenter ant is apparently earlier than that of cicada with an overlap during June 20-23, 1970 (Table 2). The incidence of non-fish, aquatic food items in the stomachs was relatively low (15%) and the occurrence of empty stomachs was even lower (10%). Some annelids were probably earthworms lost from the hooks of anglers but some were leeches - decomposition made identification difficult.

It is not possible to estimate how important sockeye are in the diet of cutthroat with the limited available data. Of the six trout containing at least one juvenile sockeye, the average number of sockeye was 2.3. It may be that sockeye are only available as smolts in the spring. At this time they occur in the near surface schools and in littoral areas where they may be more susceptible to predation. By late May, when the lake becomes thermally stratified, the non-migrant sockeye (age 0 and 1) are almost exclusively limnetic and undertake a diel vertical movement (Barraclough and Robinson 1972) which places them in the near surface waters for only the hours of darkness. It may be that this behaviour pattern of sockeye substantially reduces predation in addition to a possible savings in energetics (Narver, 1970).

Rainbow Trout

Population Data

Seven rainbow trout between 176 – 510 mm were captured in gillnets in Great Central Lake in 1978 (Table 10). No data was recorded on weight, sex, and maturity.

TABLE 10. Minimum, maximum and mean fork length (mm) of rainbow trout captured in gillnets in Great Central Lake 1978 (N=7) (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1978	7	176	510	322	---

Narver (1975) sampled 23 rainbow trout ranged in length from 240 mm to 548 mm and ranged from age 2 to age 6. The age-mean length relationship for 1969 fish with usable scales is shown in Table 11.

TABLE 11. Age and mean fork length (mm) of rainbow trout captured by angling in Great Central Lake 1969 (N=23) (Reprinted from: Narver, 1975).

Age	2+	3+	4+	5+	6+
N	1	2	3	7	4
Mean Length (mm)	241	238	301	432	489

Rainbow Trout Percent Length Frequency

We've presented the length frequency distributions of rainbow trout captured in gillnets in 1978 in Figure 3.

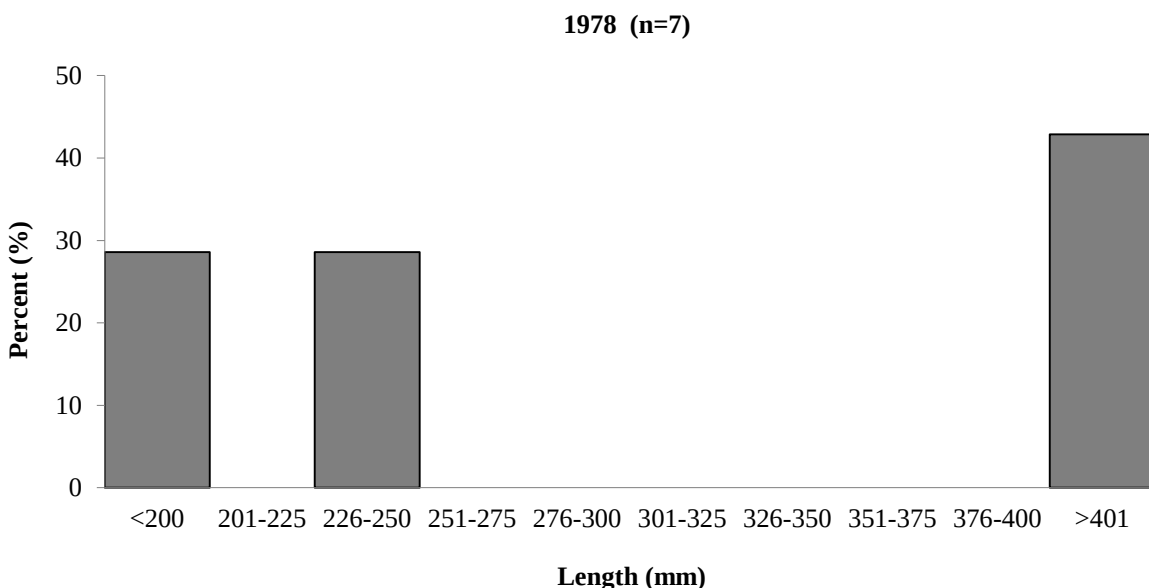


FIGURE 3. Length frequency of rainbow trout captured in gillnets in Great Central Lake, 1978 (N=7) (Source: FLNRO files, Nanaimo).

Appendix 15. Henderson Lake

Stock Status Indicators

Cutthroat Trout

Population Data

The minimum, maximum and mean fork lengths of cutthroat trout captured by gillnet in Henderson Lake in 1977 is shown in Table 1. The seven cutthroat trout caught in ranged in length from 199 mm - 450 mm. On average, cutthroat trout sampled in Henderson Lake were 248 mm.

TABLE 1. Minimum, maximum and mean fork length (mm) of cutthroat trout captured in gillnets in Henderson Lake May 1977 (N=7) (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1977	7	199	450	248.3	---

Dolly Varden

Population Data

No Dolly Varden have been sampled from Henderson Lake and it is unlikely that there are any Dolly Varden entering the lake fishery. Only 4 small Dolly Varden have been captured in the watershed and these were taken using minnow traps in Clemmons creek and a small intermittent tributary to that creek. (FLNRO files, Nanaimo) which suggests that the captured Dolly Varden were stream residents.

Kokanee/Sockeye Salmon

Kokanee salmon were captured by gillnets in 1977 ranged between 70 – 90 mm with a modal and mean length of 80 mm (Figure 1). It is possible these fish were mis-identified and were actually sockeye which are present in Henderson Lake. If these are sockeye, they are likely 0+ fish as sampling occurred in May and fish >100 mm would already have smolted and migrated to salt water.

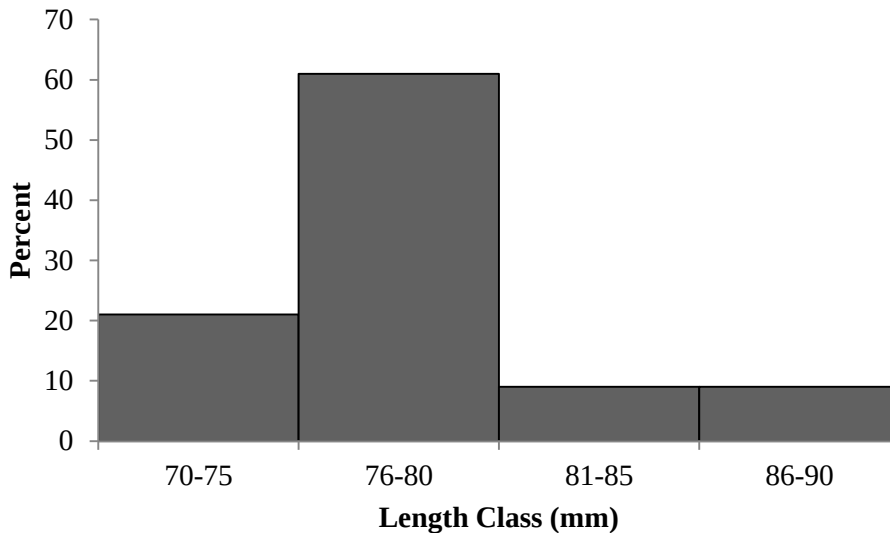


FIGURE 1. Percent length frequency of kokanee or sockeye captured in Henderson Lake, May 1977 (N=13) (Source: FLNRO files, Nanaimo).

Length Frequency Distributions

Sixty percent of the sockeye capture in gillnets in May in Henderson Lake were 76-80 mm and all sockeye captured were <100 mm (Figure 4). These results suggest that juvenile sockeye rear in Henderson Lake for one year after hatching. It is these fish that would be available to cutthroat trout as prey.

Sockeye spawning escapements comprise the largest run of fish into Henderson Lake (Table 2). Sockeye returns have ranged from 3,000 to 120,000 with an average escapement of 36,000 (Shortreed et al., 2001). Juvenile sockeye rear one year in the lake before smolting. It is expected these fish would be available as forage for cutthroat trout. No escapement records exist for steelhead, cutthroat or pink salmon.

TABLE 2. Summary of Chinook, chum and sockeye salmon spawning escapements to Henderson Lake and tributary streams (Source: DFO files, Port Alberni).

Species	Ten Year Start / End	Ten Year Mean / Max	Max. Escapements
Chinook	1989 / 1998	30 / 50	1,500
Chum	1989 / 1998	308 / 400	35,000
Sockeye	1989 / 1998	35,245 / 123,913	123,913

Appendix 16. Huaskin Lake

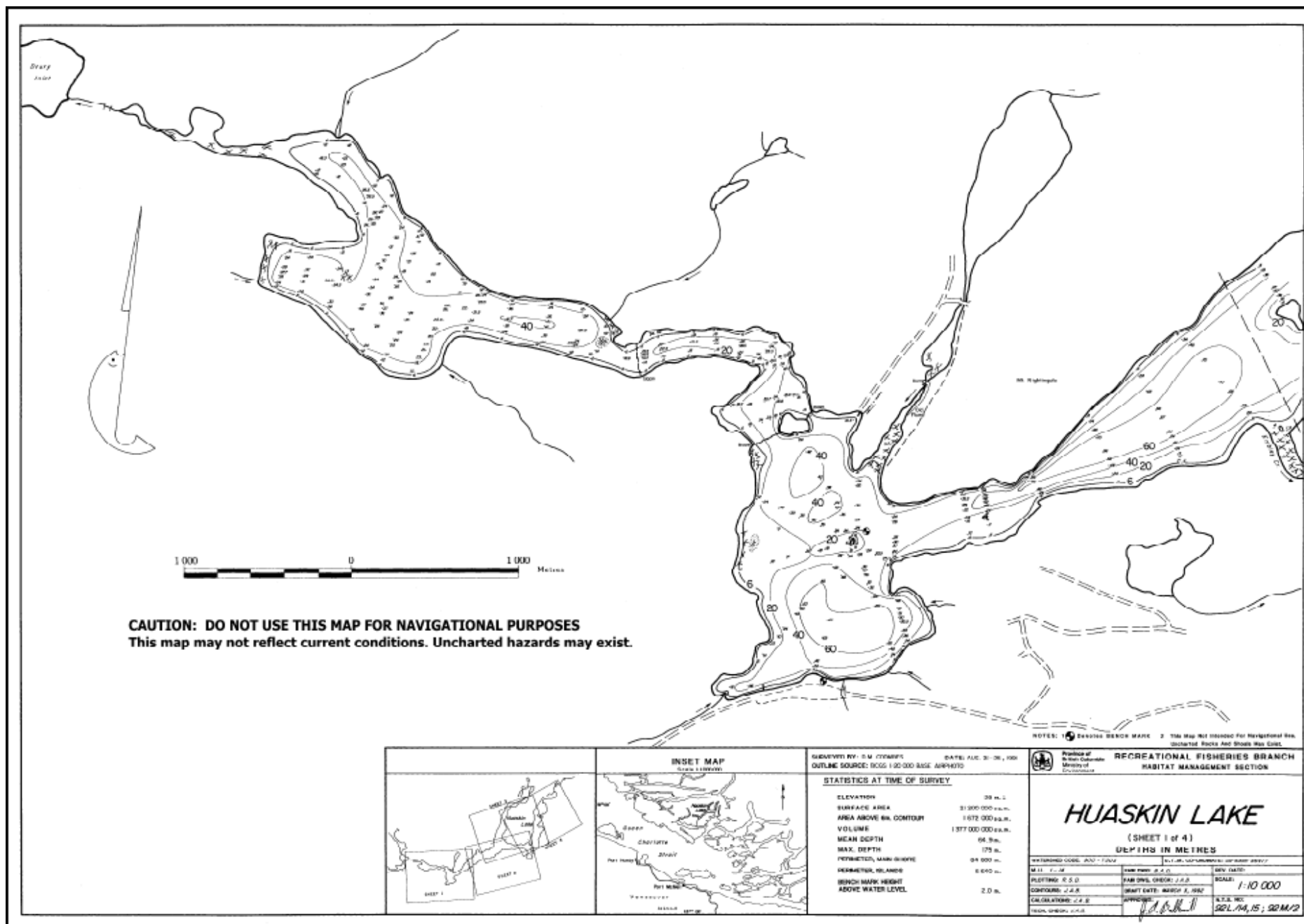


FIGURE 1. Bathymetric map of Huaskin Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

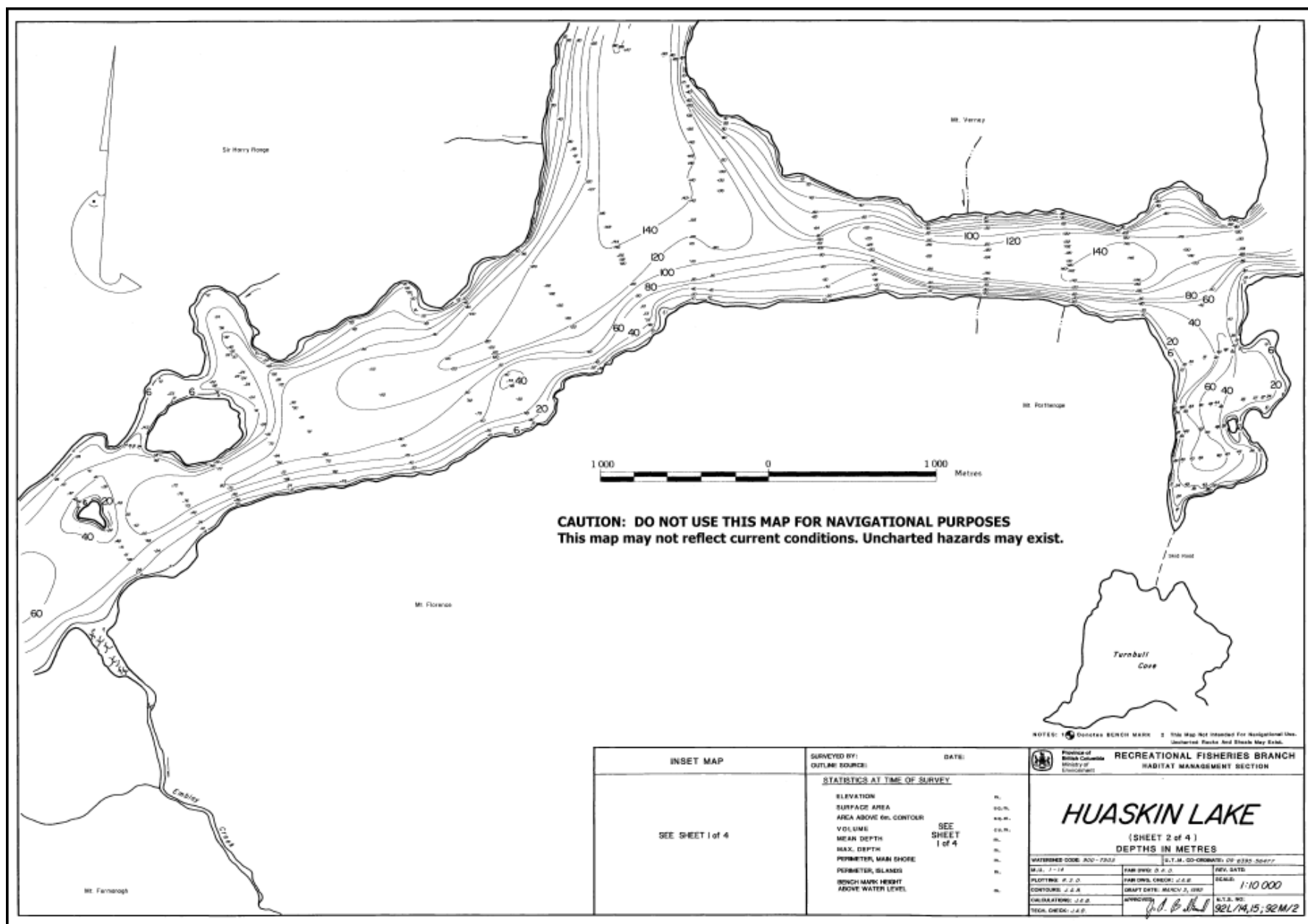


FIGURE 1 (CONTINUED). Bathymetric map of Huaskin Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

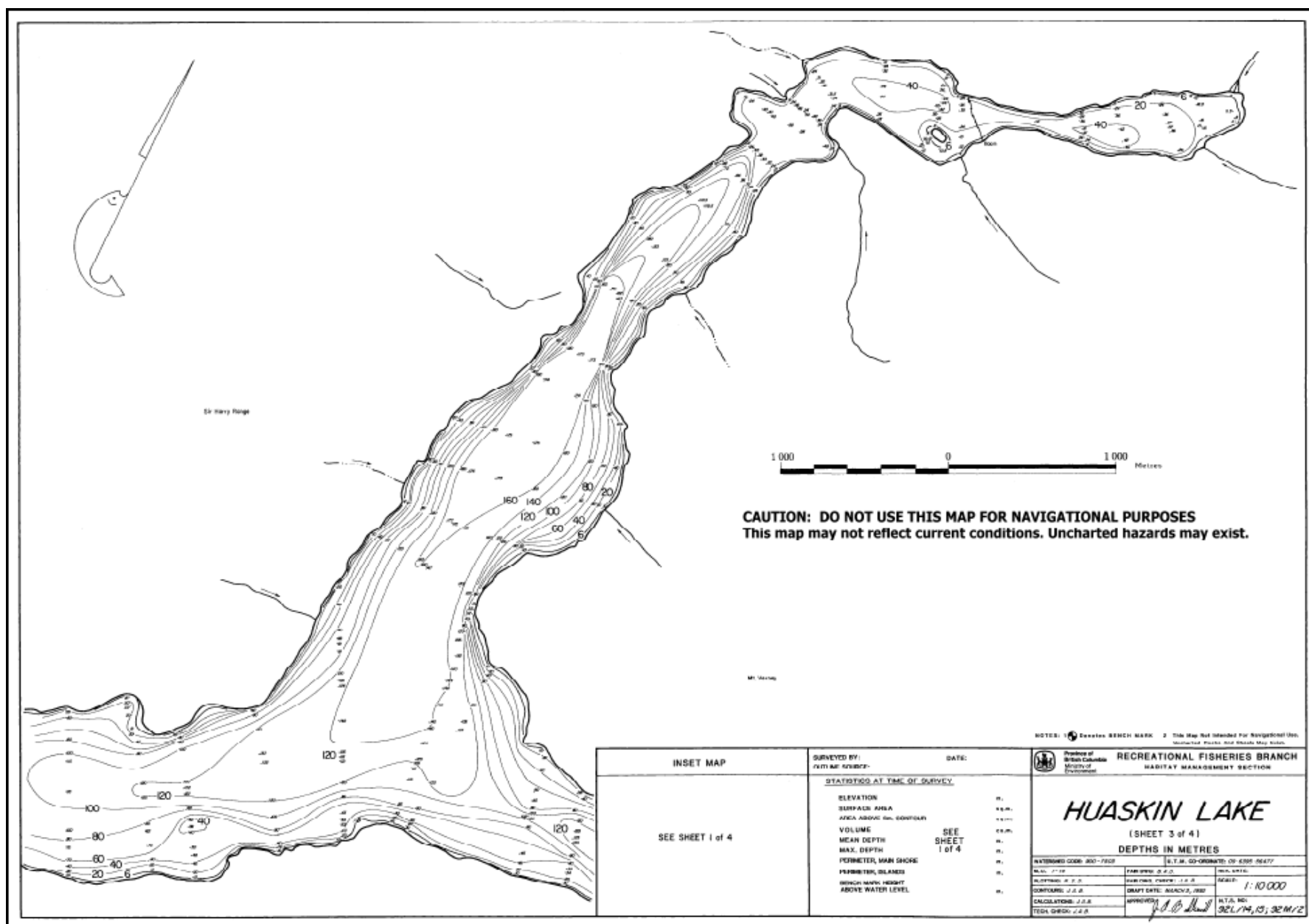


FIGURE 1 (CONTINUED). Bathymetric map of Huaskin Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

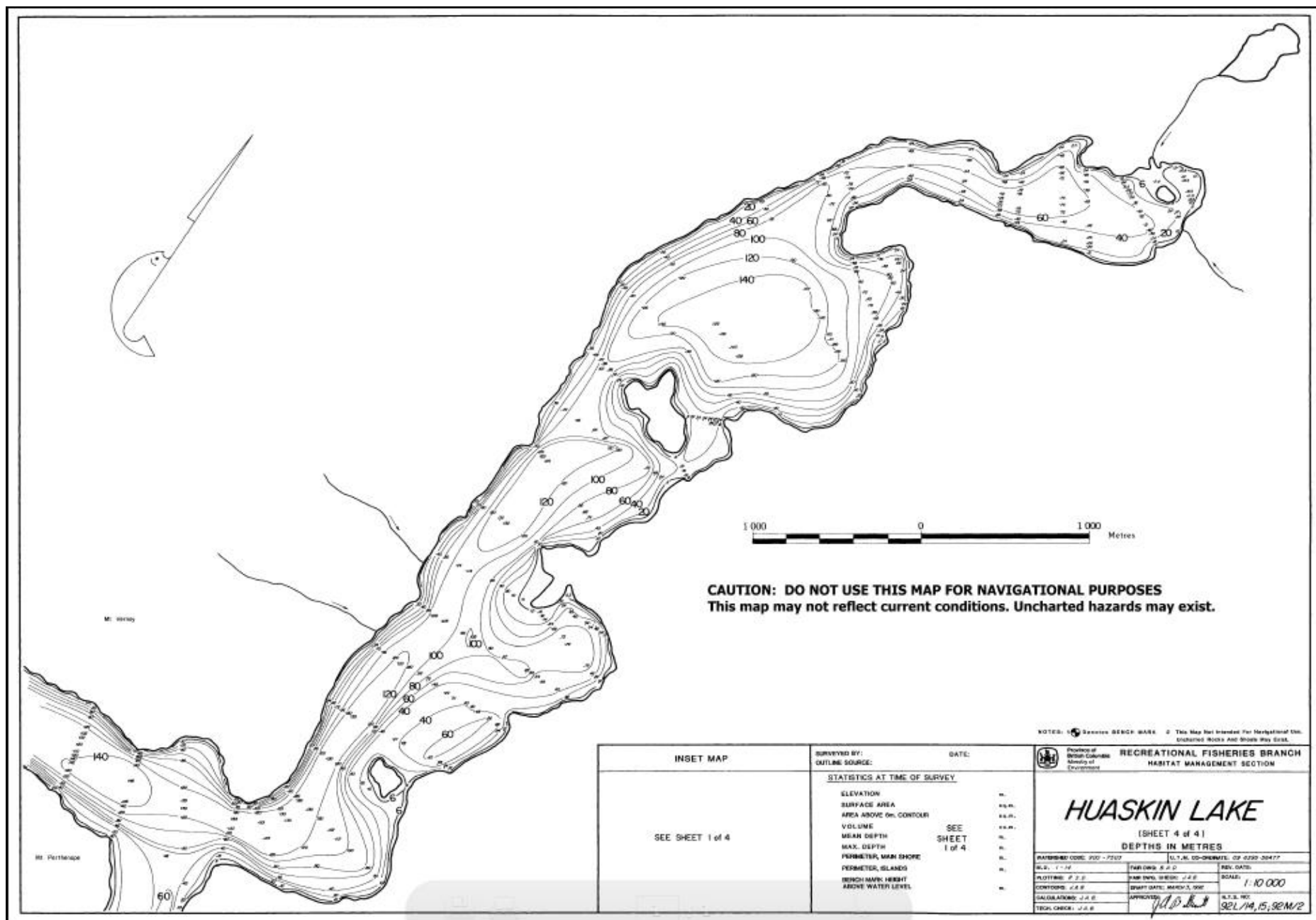


FIGURE 1 (CONTINUED). Bathymetric map of Huaskin Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Stock Status Indicators

Cutthroat Trout

Population Data

The minimum, maximum and mean fork lengths of cutthroat trout captured by gillnet in Huaskin Lake in 1992 is shown in Table 1. Thirty-six cutthroat trout ranged in length from 245 mm - 424 mm. On average, cutthroat trout sampled in Huaskin Lake were 335 mm and 390.6 g.

TABLE 1. Minimum, maximum and average fork length (mm) of cutthroat trout captured in gillnets in Huaskin Lake May 1992 (N=36) (Source: Coombes and Carswell, 1991).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1992	36	245	424	335.4	390.6

Length Frequency Distributions

The modal length of cutthroat trout sampled in 1992 was between 301 mm -350 mm. (Figure 2). This comprised ~40% of the total sample. The next size classes (351 mm – 450 mm) made up 27 % of all cutthroat sampled.

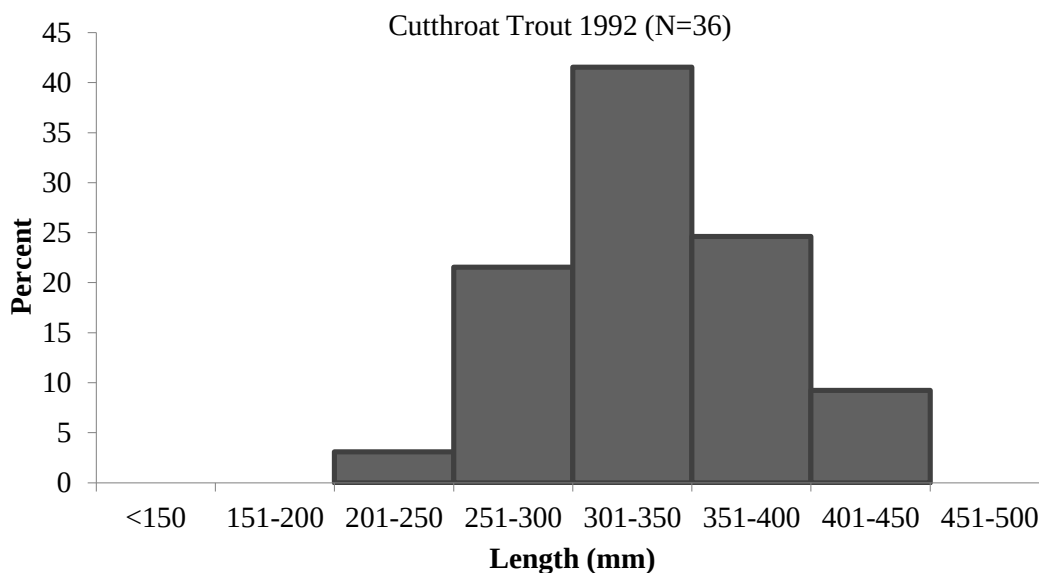


FIGURE 2 Length frequency of cutthroat trout captured in gillnets in Huaskin lake 1992, N=36 (Source: Coombes and Carswell, 1991).

Dolly Varden

Population Data

The minimum, maximum and mean fork lengths of Dolly Varden captured by gillnet in Huaskin Lake in 1991 is shown in Table 2. Thirty-nine Dolly Varden ranged in length from 169 mm - 318 mm. On average, Dolly Varden sampled in Huaskin Lake were 240 mm and 165 g.

TABLE 2. Minimum, maximum and mean fork length (mm) of Dolly Varden captured in gillnets in Huaskin Lake May 1992 (N=39) (Source: Coombes and Carswell, 1991).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1992	39	169	318	240.1	165.0

The modal length of Dolly Varden captured in Huaskin Lake was between 201 mm - 250 mm, representing ~60% of the population (Figure 3).

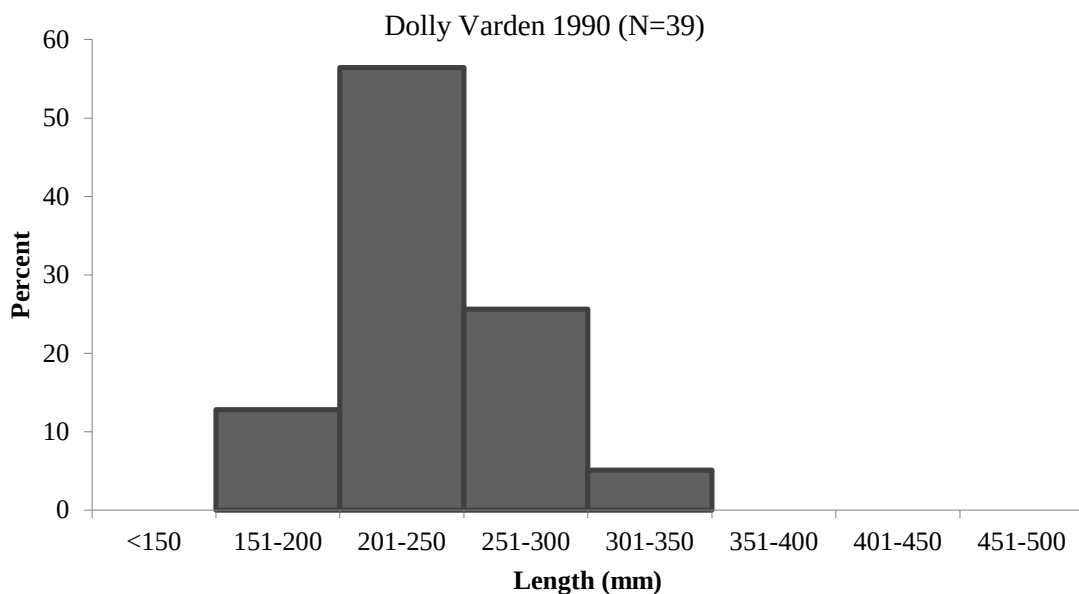


FIGURE 3. Percent length frequency analysis of Dolly Varden captured in Huaskin Lake (N=39) (Source: Coombes and Carswell, 1991).

Maturity

The mean length of female cutthroat trout captured in Huaskin Lake in 1991 was 316 mm while males averaged ~370 mm (Figure 4).

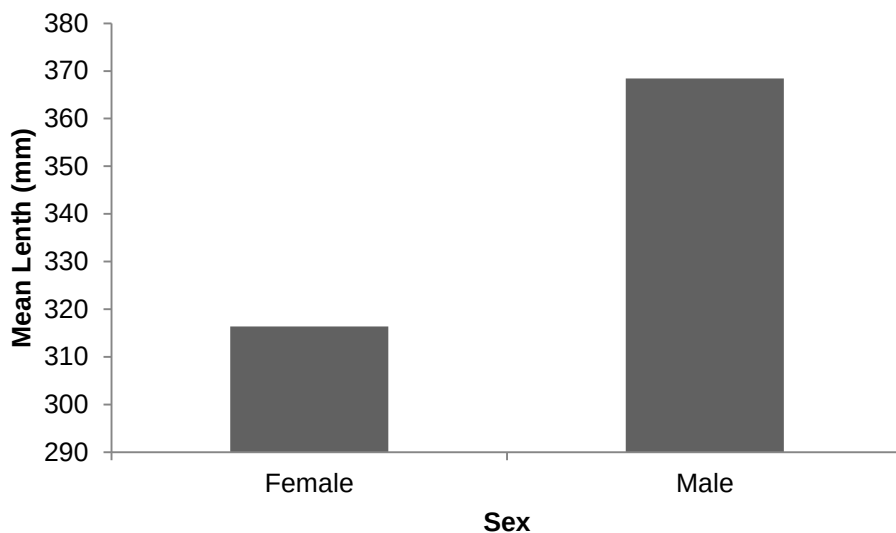


FIGURE 4. Mean length of gillnet caught cutthroat trout in Huaskin Lake, 1991, N=29 (Source: Coombes and Carswell, 1991).

The modal length for female and male cutthroat trout fell between 301 mm - 350 mm. (Figure 5).

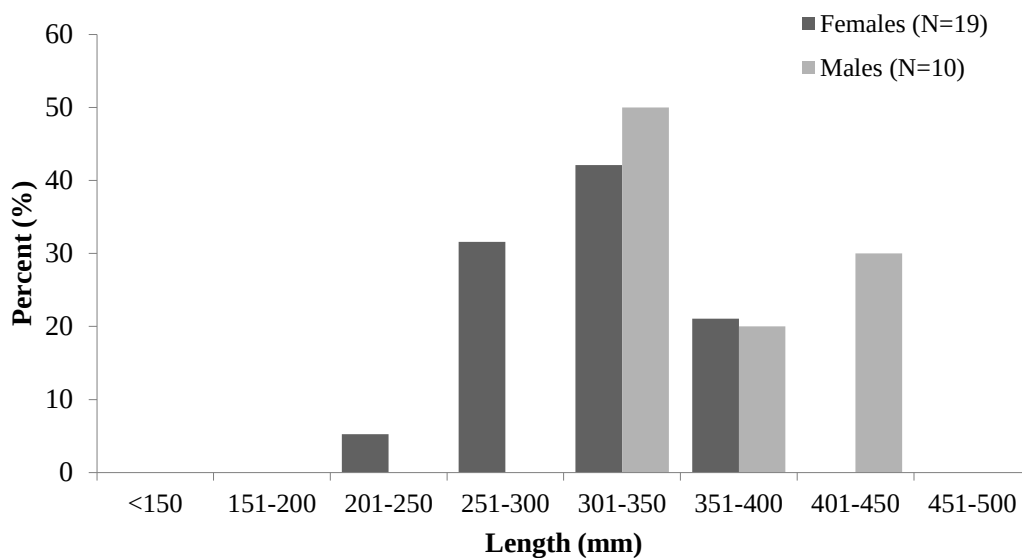


FIGURE 5. Length frequency of female and male cutthroat trout captured in gillnets, Huaskin Lake 1991 (N=29). (Source: Coombes and Carswell, 1991).

Length Weight Relationship

The length and weight relationship for cutthroat trout captured in gillnets in 1991 is shown in Figure 6.

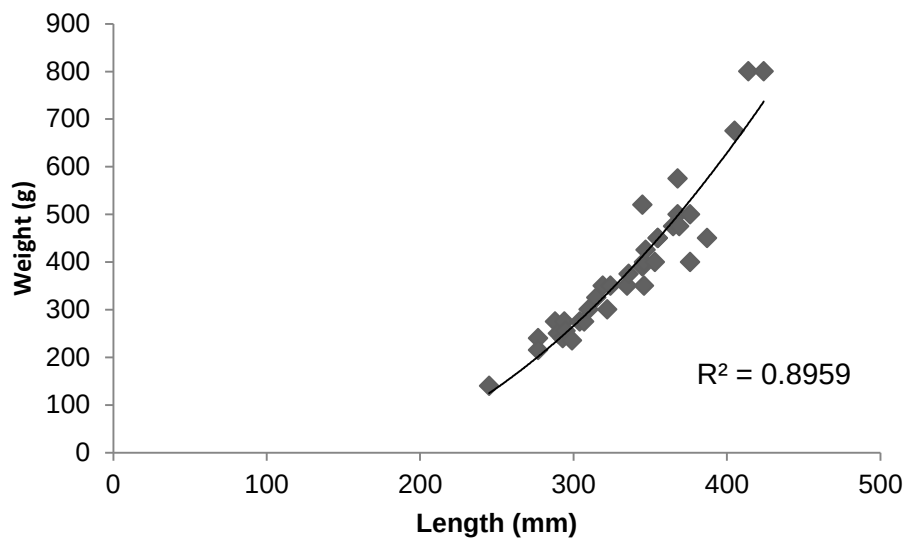


FIGURE 6. Length-weight relationship for cutthroat trout captured in gillnets in Huaskin Lake (N=36) (Source: Coombes and Carswell, 1991).

Maturity

A total of 36 cutthroat trout were captured and of those, only 2 females were mature (Table 3). The length distribution of mature males varied between 304 mm – 424 mm and the females between 245 mm – 376 mm

TABLE 3. Male vs. female cutthroat numbers and size captured in gillnets in Huaskin Lake (N=29) (Source: Coombes and Carswell, 1991).

Factor	Females N=19		Males N=10	
	Immature (n=18)	Mature (n=1)	Immature (n=10)	
Range	245-376	215	304-424	
Mean	316	215	368	

Dolly Varden

Population Data

The mean length of female Dolly Varden captured in Huaskin Lake in 1991 was 241 mm while males averaged 246 mm (Figure 7).

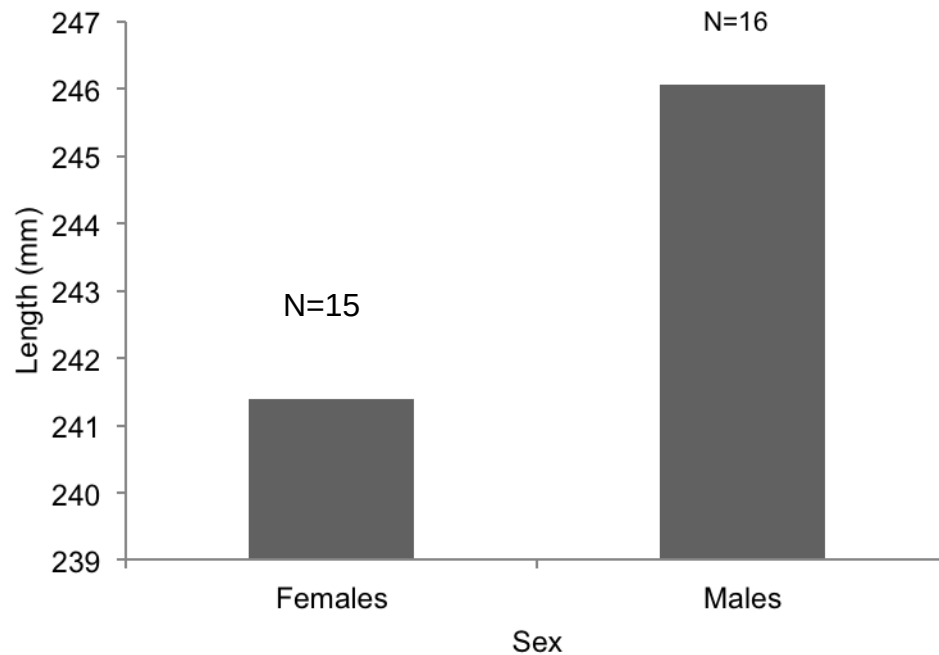


FIGURE 7. Mean length of female and male cutthroat trout caught in gillnets in Huaskin Lake, 1991 (N=31) (Source: Coombes and Carswell, 1991).

Length Frequency Distributions

The modal length for females fell between 251 mm -300 mm representing 40% of the total (Figure 8). The male modal length was 201 mm - 250 mm, however, there were more males > 250 mm representing 27% of the total number captured. The largest Dolly Varden captured was 318 mm.

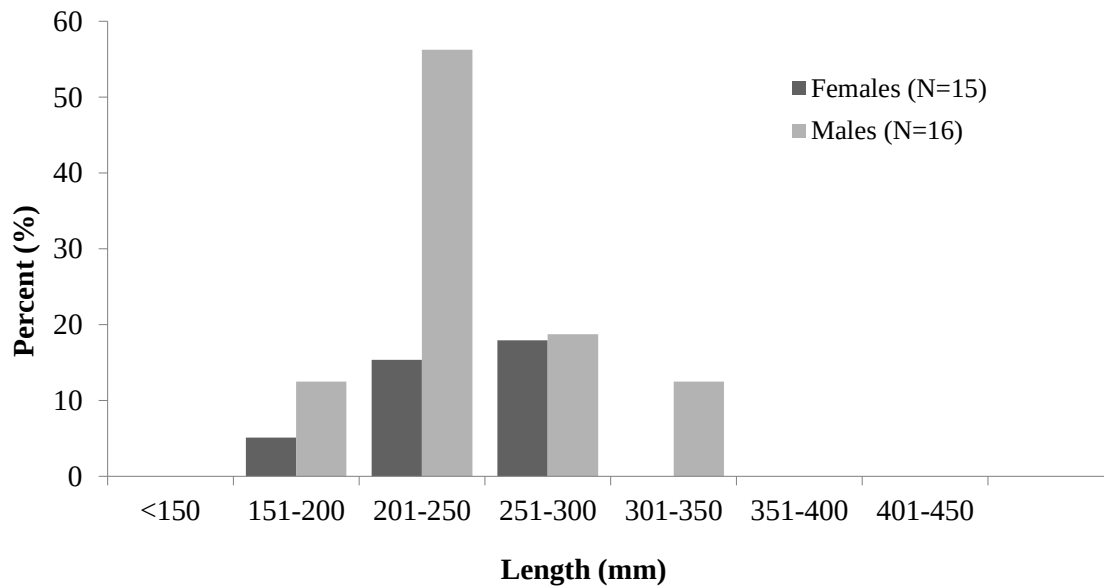


FIGURE 8. Percent length frequency analysis of male (n= 15) and female (n=16) Dolly Varden captured in gillnets in Huaskin Lake in 1991 (N=31) (Source: Coombes and Carswell, 1991).

Length Weight Relationship

The length and weight relationship for Dolly Varden captured in gillnets in 1991 is presented in Figure 9.

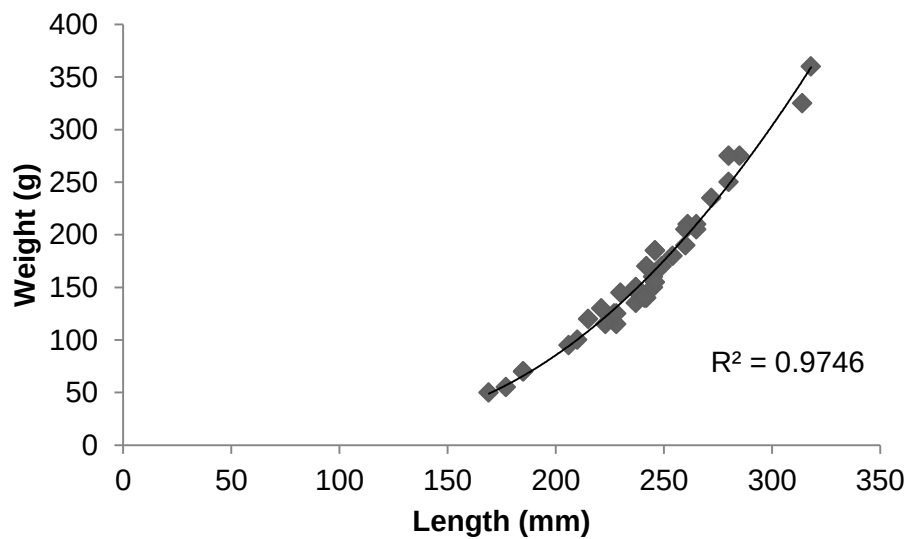


FIGURE 9. Length weight relationship of gillnet caught Dolly Varden captured in Huaskin Lake (N=38) (Source: Coombes and Carswell, 1991).

Maturity

A total of 39 Dolly Varden were captured in gillnets in Huaskin Lake and of that 29 could be sexed and evaluated for maturity (Table 4). The mean length of mature female Dolly Varden captured in Huaskin Lake in 1991 was 252 mm while mature males averaged 268 mm. Mature female Dolly Varden ranged between 215 mm - 265 mm and mature males between 221 mm - 314 mm.

TABLE 4. Male vs. female Dolly Varden numbers and size captured in gillnets in Huaskin Lake (N=29) (Source: Coombes and Carswell, 1991).

Factor	Females N=19		Males N=10	
	Immature (N=8)	Mature (N=7)	Immature (N=14)	Mature (N=2)
Range	169-285	215-265	185-318	221-314
Mean	232	252	243	268

Kokanee Salmon

Population Data

The minimum, maximum and mean fork lengths of kokanee captured by gillnet in Huaskin Lake in 1992 is shown in Table 5. Eighty-five kokanee ranged in length from 106 mm - 230 mm. On average, kokanee sampled in Huaskin Lake were 193 mm and 92 g.

TABLE 5. Minimum, maximum and mean fork length (mm) of kokanee captured in gillnets in Huaskin Lake May 1992 (N=85) (Source: Coombes and Carswell, 1991).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1992	85	106	230	193.6	92.4

Length Frequency

Eighty percent or 75 out of the 85 kokanee captured in Huaskin lake were between 151-250 mm. (Figure 10) Only 1 kokanee was > 225mm. These fish were probably 2+ years old and would have spawned in the fall of 1990.

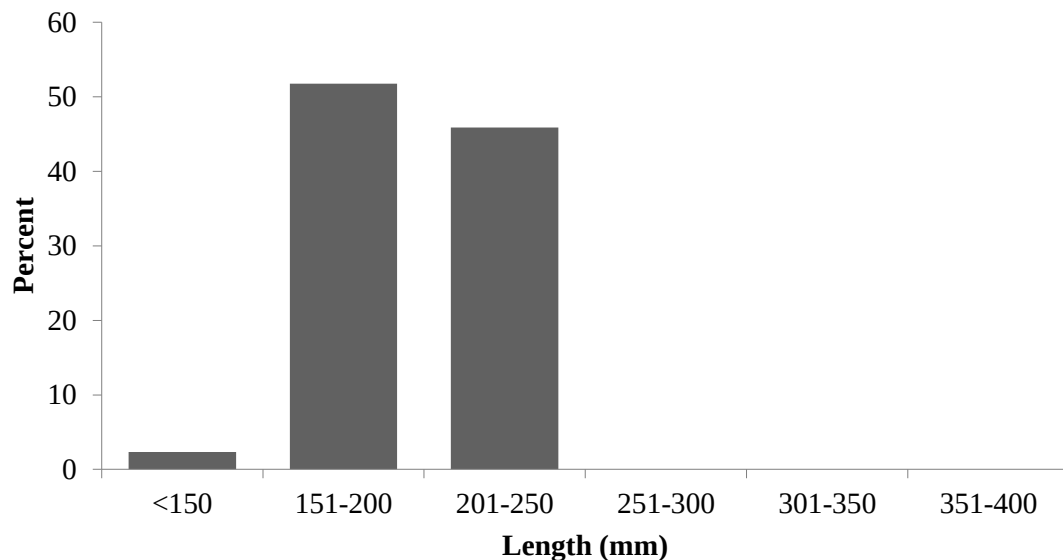


FIGURE 10. Percent length frequency analysis of kokanee captured in Huaskin Lake. 1991 (N=85) (Source Coombes and Carswell, 1991).

Over 60% of female kokanee sampled in 1991 were 151 mm – 200 mm (Figure 11). Male kokanee comprised 2 length classes – 47% were 151 mm – 200 mm and 53% were 201 mm - 250 mm.

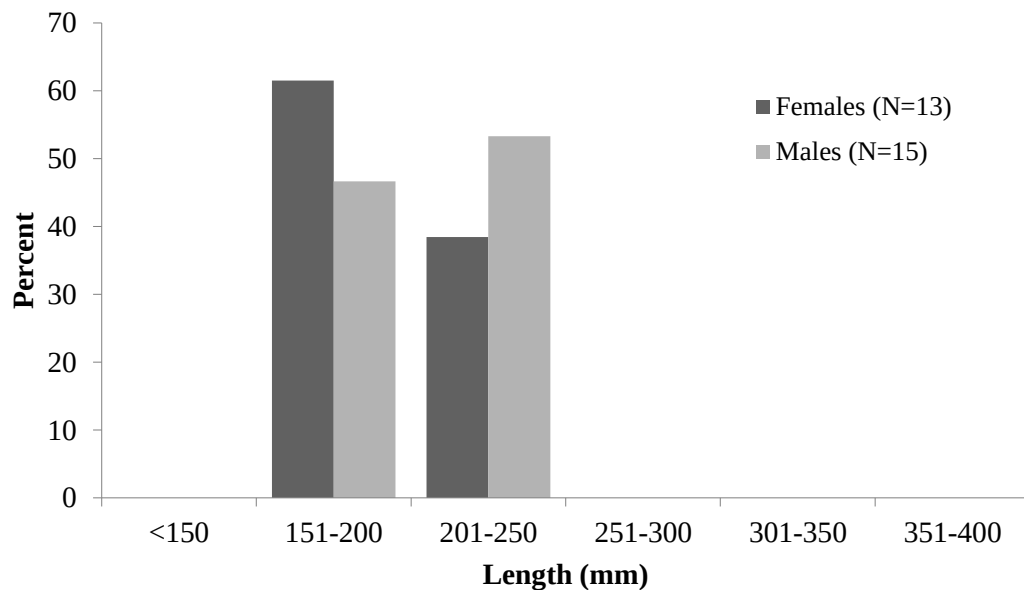


FIGURE 11. Percent length frequency of male and female kokanee captured in Huaskin Lake in 1991 (N=28) (Source: Coombes and Carswell, 1991).

Length Weight Relationship

The length and weight relationship for kokanee captured in gillnets by Coombs and Carswell in 1991 is presented in Figure 12. A total of 85 kokanee were captured and of those 85, 10 females and 9 males were mature. The weights of the captured kokanee ranged between 15 – 135 g. The largest kokanee collected was 230 mm and 135 g. Very few of these fish would be available to anglers.

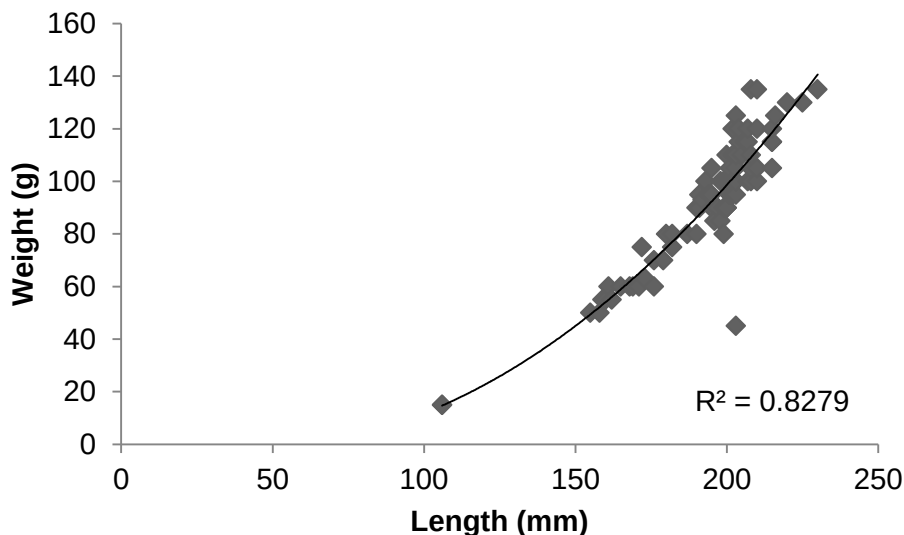


FIGURE 12. Length weight relationship of gillnet caught kokanee captured in Huaskin Lake in 1991 (N=85) (Source: Coombes and Carswell, 1991).

Maturity

Twenty-eight kokanee captured in gillnets in Huaskin Lake could be sexed and evaluated for maturity (Table 6). The mean length of mature female kokanee captured in Huaskin Lake in 1991 was 197 mm while mature males averaged 196 mm. Mature female kokanee ranged between 168 mm - 208 mm and mature males between 195 mm - 197 mm. Note that only 2 mature male kokanee were captured.

TABLE 6. Numbers, size and maturity of male vs. female kokanee captured in gillnets in Huaskin Lake (N=28) (Source: Coombes and Carswell, 1991).

Factor	Females N=13		Males N=15	
	Immature (N=5)	Mature (N=8)	Immature (N=13)	Mature (N=2)
Range	168-208	182-216	187-225	195-197
Mean	192	197	203	196

Both male and female kokanee in Huaskin Lake mature between 180 mm - 200 mm (Table 6). The mean length of mature female kokanee was 197 mm and 196 mm for males.

Appendix 17. Lower Campbell Lake

Angling Data

TABLE 1. Raw data from aerial angler counts and angler creel surveys conducted at Lower Campbell Lake and associated small lakes and flooded areas in the Lower Campbell Lake watershed 1977 – 1980 (Source: FLNRO files, Nanaimo).

	Year	Fisheries Statistic			Species (%)		
		Harvest	Use (angler days)	Success (fish/day)	Cutthroat	Rainbow	Dolly Varden
Lower Campbell Lake	1977	0	9	0	----	----	----
	1978	2,389	143	0.56	48	49	3
	1979	1,331	190	0.23	100		
	1980	2,975	136	0.73	24	73	2
Fry Lake	1976	1,404	81	0.58	47	53	
	1977	186	26	0.24	60	40	
	1978	720	34	0.72	44	56	
	1979	0	41	0	----	----	----
John Hart Lake	1980	208	32	0.21	81	10	10
	1977	224	46	0.16	30	67	3
	1978	42	20	0.07	----	100	----
	1979	1,696	56	1	100	----	----
McIvor Lake	1980	0	30	0	----	----	----
	1978	0	9	0	----	----	----
	1979	337	21	0.53	100	----	----
Strathcona Dam	1978	33	15	0.08	43	14	43

TABLE 2. Total catch, angler hours, catch/hour, total angler days and catch/angler day determined from box angler creel surveys July 2010 – June 2011 at Lower Campbell Lake. Note an average angler day at Lower Campbell Lake is ~6.3 hours (Source: FLNRO files, Nanaimo).

Month and Year	Total Catch	Angler Hours	Catch/Hour	Angler Days	Catch/Day
10-Jul	33	126	0.3	20	1.65
10-Aug	17	53	0.3	8.4	2.02
10-Sep	25	62.5	0.4	9.9	2.52
10-Oct	2	0	0	0	0
10-Nov	7	9	0.8	1.4	4.9
11-Feb	0	12	0	1.9	0
11-Mar	0	0	0	0	0
11-Apr	0	3	0	0.5	0
11-May	2	9	0.2	1.4	1.4
11-Jun	0	8	0	1.3	0
Total	86	282.5	0.3	44.8	1.92

Stock Status Indicators

Cutthroat Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of cutthroat trout captured in gillnets in Fry Lake in 1978 and 2004 is shown in Table 3. Minimum fork length was 175 mm in both sample years, while maximum fork length ranged from 375 mm in 1978 to 470 mm in 2004. Mean fork length of cutthroat captured Fry Lake was in 252 mm in 1978 and 290 mm in 2004. Mean weight of cutthroat caught varied from 187 g in 1978 to 320 g in 2004.

TABLE 3. Total numbers and minimum, maximum and mean fork length of cutthroat trout captured by gillnet in Fry Lake in 1978 and 2004 (Source: FISS; FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1978	25	175	375	252.6	187.1
2004	31	175	470	290.6	320.3

Cutthroat trout were sampled in Lower Campbell Lake in 1951, 1953, and 1957, however the method of sampling is unknown (Table 4). Eleven cutthroat trout ranging in length from 225 mm – 380 mm were sampled 1951. A single cutthroat was sampled in 1953 with a fork length of 571 mm and a weight of 2270 g. Two cutthroat trout were sampled in 1957 ranging in length from 362 mm – 457 mm and a weight of 510 g – 907 g. Cutthroat trout were sampled in gillnets set in Lower Campbell Lake in 1960 (n=32), 1961 (n=21) and 1962 (n=6), however no length and weight data was recorded.

TABLE 4. Total numbers and minimum, maximum and mean fork length of cutthroat trout captured in Lower Campbell Lake in September 1951, July 1953, and April 1957. Note the method of capture is unknown (Source: FISS; FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1951	11	225	380	283	207
1953	1	571	571	571	2270
1957	2	362	457	410	510 - 907

Length Frequency Distributions

We've presented the length-frequency distributions of cutthroat trout sampled in 1951, 1978 and 2004 in Figures 1, 2 and 3. In 1951, the modal length was 226 mm – 250 mm with 45% of the catch in this length class. In 2004, the mode was 201 mm – 225 mm. Only 25% of the catch was within this length class, however, with ~5% of the catch in length classes ranging from 226 mm – 400 mm. Note that 2004 was the only year when cutthroat >400 mm were captured and almost 15% of the catch was within that size class.

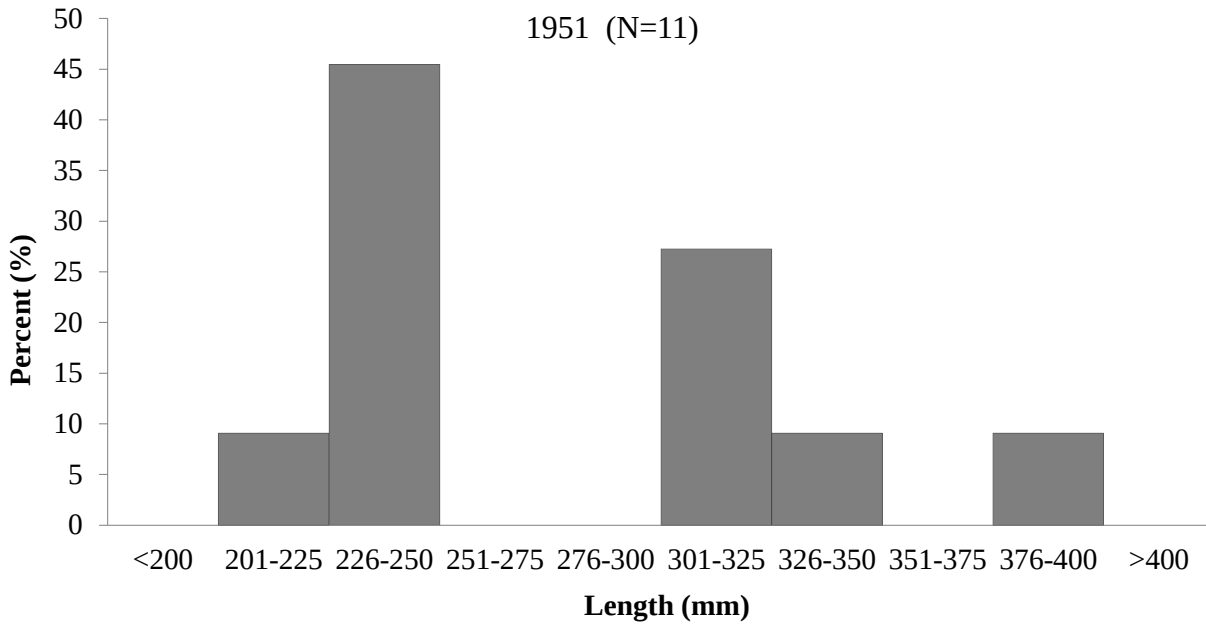


FIGURE 1. Length frequency of cutthroat trout captured in Lower Campbell Lake, September, 1951 (N=11) (Note: sample method is unknown) (Source: FLNRO files, Nanaimo).

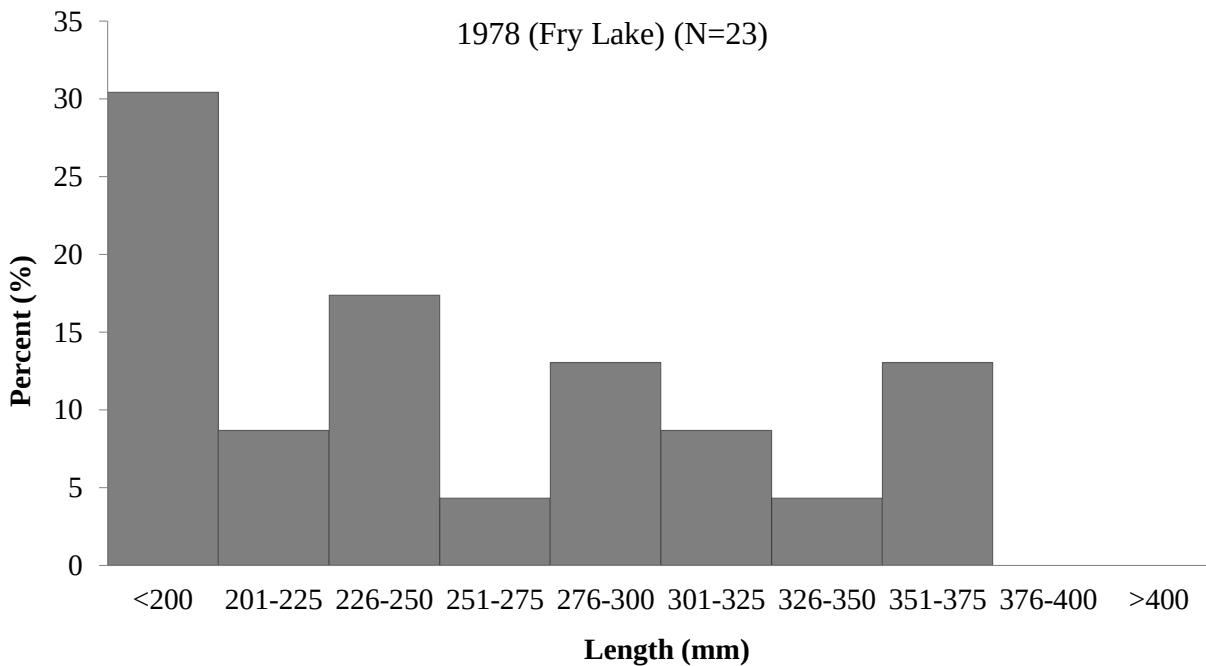


FIGURE 2. Length frequency of cutthroat trout captured by gillnetting in Lower Campbell Lake, July, 1978 (N=23) (Source: FLNRO files, Nanaimo).

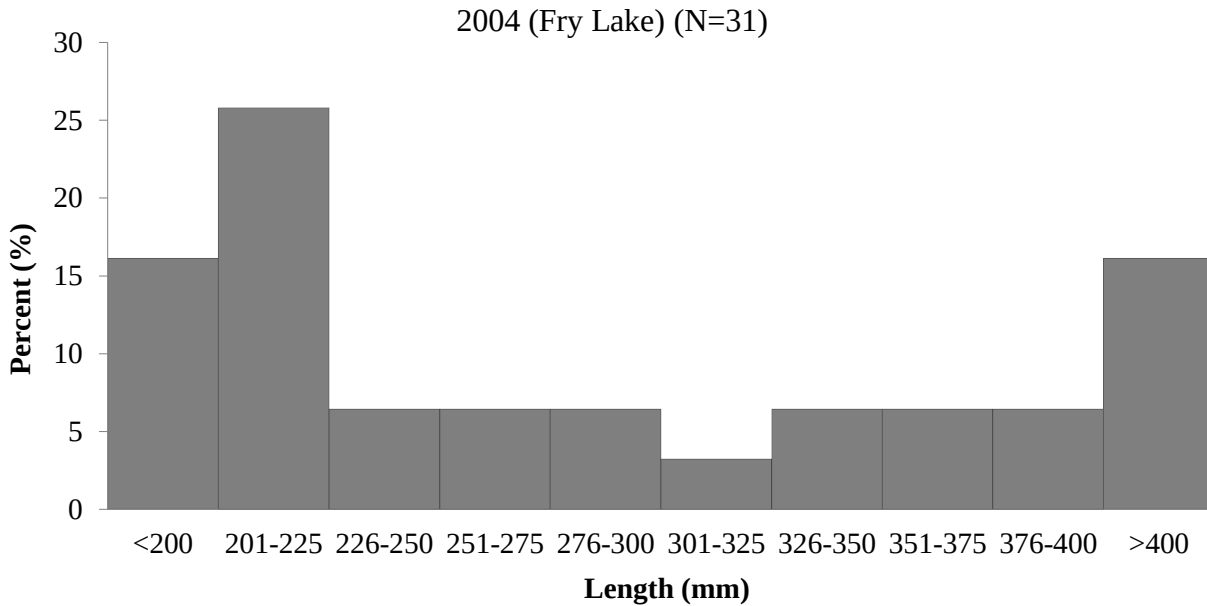


FIGURE 3. Length frequency of cutthroat trout captured by gillnetting in Lower Campbell Lake September, 2004 (N=31) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

The length-weight relationship of cutthroat trout captured in Lower Campbell Lake is presented in Figure 4. Most cutthroat sampled have been <400 mm and <500 g. The smallest fish captured was 225 mm and 120 g, while the largest was 571 mm and 2,270 g (~5 lb.)

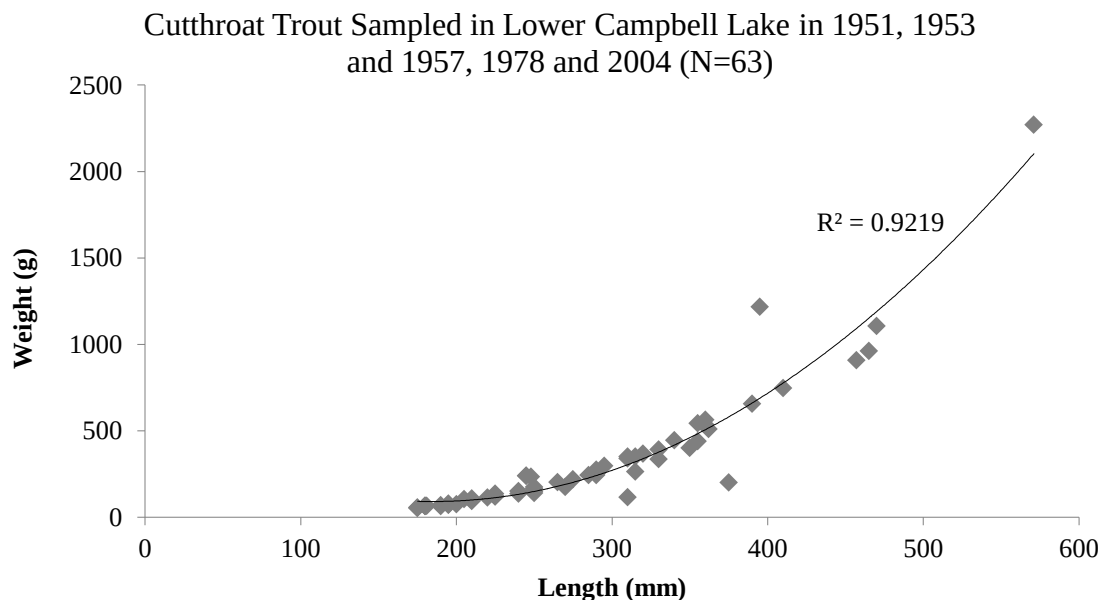


FIGURE 4. Length-weight relationship for cutthroat trout captured in gillnets in Lower Campbell Lake in 1951 (N=11); 1953 (N=1); 1957 (N=2); 1978 (N=23); 2004 (N=31) (Source: FLNRO files, Nanaimo).

Age-at-Length of Cutthroat Trout

Small lakes and streams within the Lower Campbell Watershed were sampled by electrofishing in December 1996, March 1997 and from August to October 1998 (Lough, Hay, Rutherford, 2000) (Figure 5). Cutthroat trout sampled in the three years ranged from 37 mm to 405 mm and age 0+ to age 6+. Mean length of age 0+ cutthroat was 95 mm, mean length of age 1+ was 167 mm, mean length of age 2+ was 208 mm, mean length of age 3+ was 260 mm, mean length of age 4+ was 305 mm, mean length of age 5+ was 379 mm and mean length of age 6+ was 385 mm.

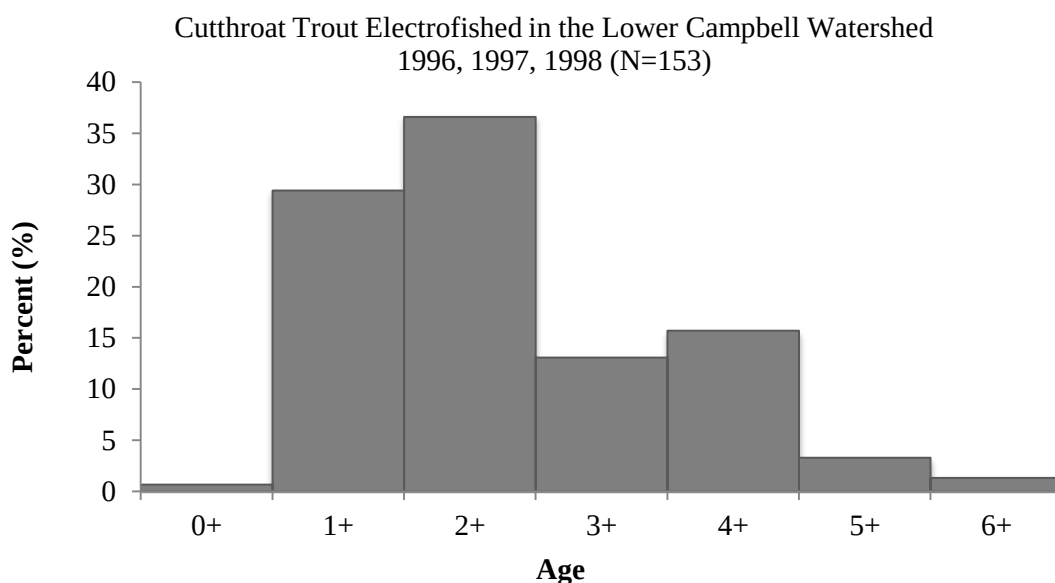


FIGURE 5. Age frequency of cutthroat trout captured by electrofishing in the Campbell Watershed Area between December 1996; March 1997; and August to October 1998 (N=153) (Source: Lough, et al, 2000).

Maturity and Size of Male and Female Cutthroat Trout

Immature cutthroat were captured in 1951 and 1957 (Table 5). Only 3 females were captured and those were in 1951. These fish ranged from 120 mm – 350 mm and averaged 260 mm. One immature male cutthroat was captured in 1951 and it was 250 mm, and 2 immature males were captured in 1957 and they were 260 mm and 457 mm and together these fish averaged 261.9 mm. In 2004, 10 immature females ranging from 225 mm – 465 mm and averaging 339 mm were captured while 18 immature and 1 mature male were captured. Immature males ranged from 190 mm – 470 mm and averaged 248.5 mm while the mature cutthroat was 315 mm.

TABLE 5. Range of lengths and mean sizes of male and female cutthroat trout captured in gillnets in Lower Campbell Lake in 1951 (N=4); 1957 (N=2); 2004 (N=29) (Source: FLNRO files, Nanaimo).

Length (mm)	1951	1957	2004
	Female (n=3) Immature	Male (n=1) Immature	Male (n=2) Immature
			Female (n=10) Immature (n=10)
			Male (n=19) Immature (n=18)
			Mature (n=1)
Range	120-350	250	361-457
Mean	260	250	361.9
			339
			248.5
			315.0

Cutthroat Trout Observed in Snorkel Surveys

Adult cutthroat trout have been observed in two tributaries to Lower Campbell Lake, Fry and Greenstone Creeks in snorkel surveys conducted between 1998 and 2004 (Figure 6). The highest numbers of adult cutthroat have been counted in these tributaries between March 11 and May 21. Cutthroat have been noted throughout the spring and summer period in these creeks, including a large peak observed on July 10, 2003 however these were juvenile cutthroat.

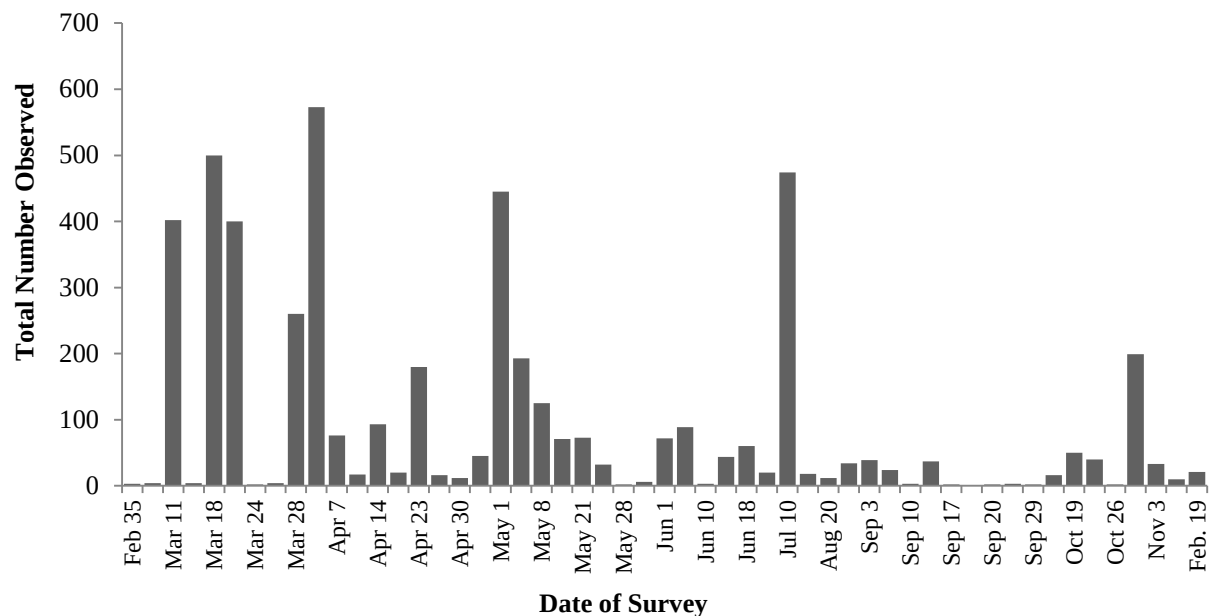


FIGURE 6. Total number of cutthroat trout observed in snorkel counts of Fry and Greenstone Creeks between 1998 and 2004. This graph includes adult and fry counts (Source: FLNRO files, Nanaimo).

Snorkel surveys have also been conducted below Strathcona Dam and the results are presented in Figure 7. Although numbers of cutthroat have been observed throughout the year, the highest counts have been in May, September and October. We suspect that cutthroat trout may use this area for various reasons – in the spring for spawning, in the summer to escape high temperatures in Lower Campbell Lake and in October/November when Dolly Varden are spawning.

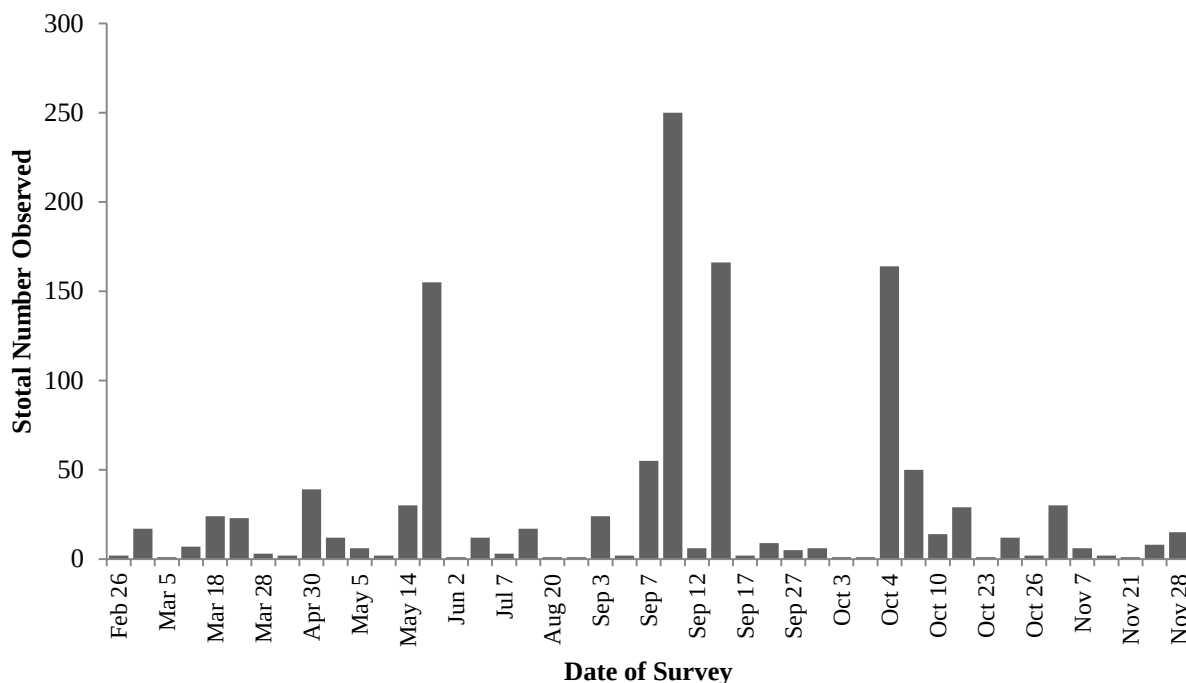


FIGURE 7. Total number of cutthroat trout observed in snorkel counts below Strathcona Dam 1998 and 2002 – 2004; graph includes adult and fry counts (Source: FLNRO files, Nanaimo).

Rainbow Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of rainbow trout captured in gillnets in Fry Lake in 1978 and 2004 is shown in Table 6. Minimum fork length was 140 mm in 1978 and 185 mm in 2004, while maximum fork length ranged from 277 mm in 1978 to 300 mm in 2004. Mean fork length of rainbow trout captured in Fry Lake was 188 mm in 1978 and 222 mm in 2004. Mean weight of rainbow trout caught varied from 81 g in 1978 to 122 g in 2004.

TABLE 6. Total numbers and minimum, maximum and mean fork length of rainbow trout captured by gillnet in Fry Lake in 1978 and 2004 (Source: FISS; FLNRO files, Nanaimo.).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1978	16	140	277	188	81
2004	10	185	300	222	122

Rainbow trout were also sampled in Lower Campbell Lake in 1951, 1953, and 1957, however the method of capture is unknown (Table 7). A total of 34 rainbow trout ranging from 220 mm – 430 mm were sampled 1951. Six rainbow trout were sampled in 1953 ranging from 245 mm – 325 mm, and four rainbow trout were sampled in 1957 ranging in length from 171 mm - 318 mm. Rainbow trout were sampled in gillnets set in Lower Campbell Lake in 1960 (n=31), 1961 (n=10) and 1962 (n=10), however no length and weight data was recorded.

TABLE 7. Total numbers and minimum, maximum and mean fork length of rainbow trout captured in Lower Campbell Lake in 1951, 1953 and 1957; method of capture unknown. (Source: FISS; FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1951	34	220	430	272	216.8
1953	6	245	325	282	202.5
1957	4	171	318	246	196.7

Length Frequency Distributions

Length frequency distributions for rainbow trout sampled in 1951 and 2004 are presented in Figure 8 and Figure 9. Length frequency distributions were not prepared for sample years where <10 fish were collected. In 1951, the modal frequency was 276 mm – 300 mm (Figure 8). Forty percent of the sample was within this length class while 30% of the sample was 226 mm – 250 mm. Fish >400 mm were captured, however, they represent <5% of the sample. Note that fish sampling methods are not known for 1951.

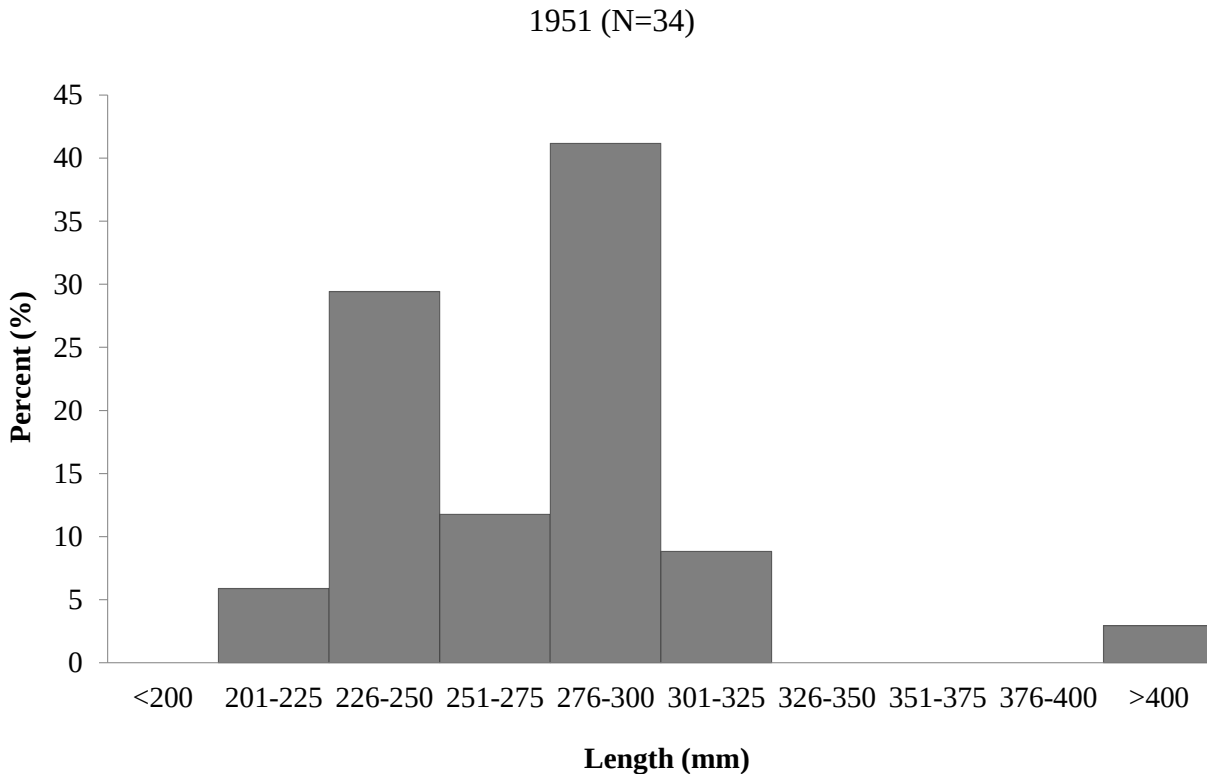


FIGURE 8. Length frequency of rainbow trout captured in gillnets in Lower Campbell Lake, September, 1951 (N=34); method of capture is unknown (Source: FLNRO files, Nanaimo).

No rainbow >300 mm were captured in Fry Lake in 2004 (Figure 9). There was a bi-modal distribution of this sample as 40% of rainbow captured were <200 mm and 40% were 226 mm – 250 mm.

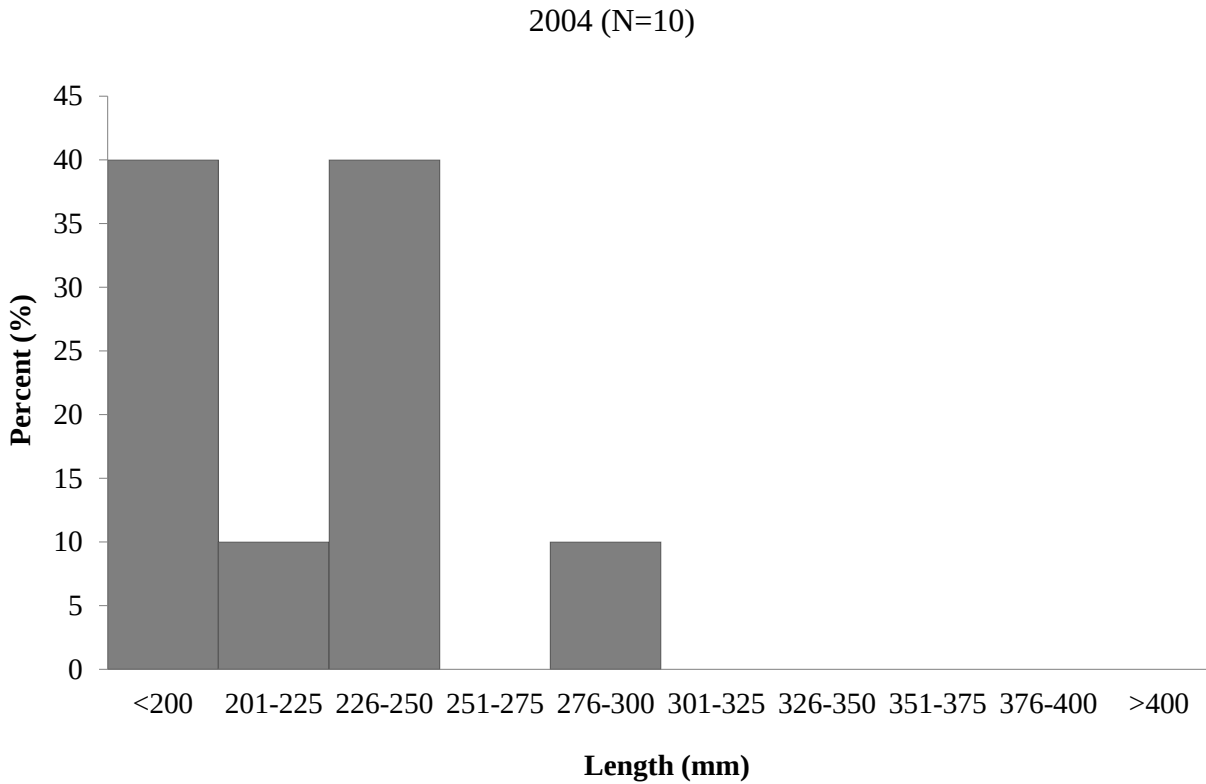


FIGURE 9. Length frequency of rainbow trout captured in gillnets in Lower Campbell Lake, August 2004 (N=10)
(Source: FLNRO files, Nanaimo).

Length-Weight Relationship

The length-weight relationship for rainbow trout in Lower Campbell Lake is presented in Figure 10. Rainbow trout sampled in this lake, which includes Fry Lake, ranged from ~150 mm and <50 g, to ~350 mm and ~375 g. Most fish sampled have been ~300 mm and 300 g.

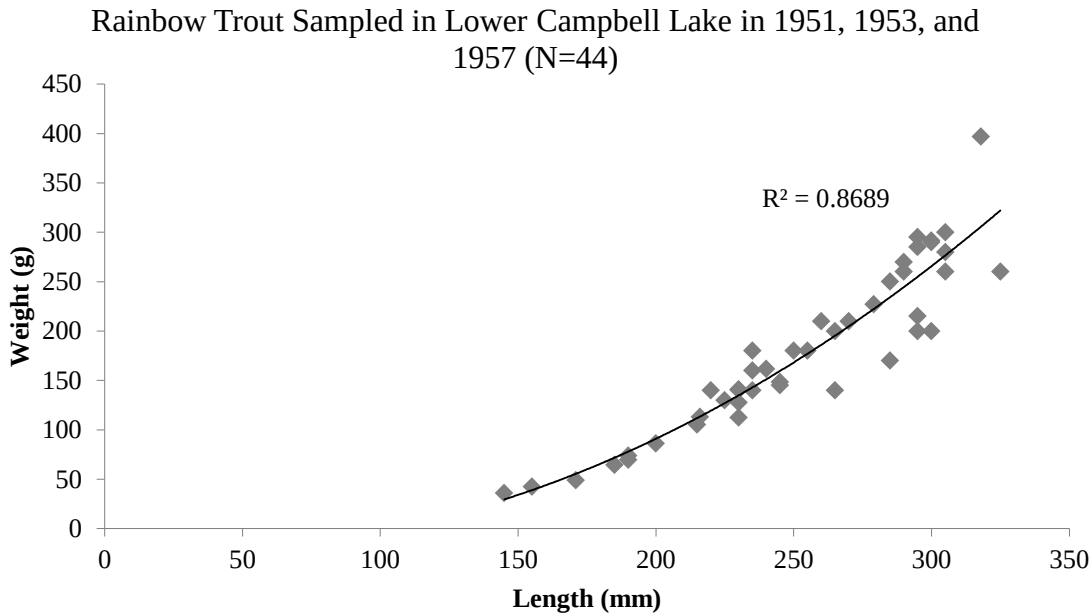


FIGURE 10. Length-weight relationship for rainbow trout captured in Lower Campbell Lake in 1951 (N=20), 1953 (N=6), 1957 (N=4), 1978 (N=4) and 2004 (N=10). Note that the sampling method is unknown for fish collected in the 1950's and samples in 1978 and 2004 are from Fry Lake (Source: FLNRO files, Nanaimo).

Age-at-Length of Rainbow Trout

Ages were determined for 16 cutthroat captured in 1951 and 2 captured in 1957. In 1951, 2 fish aged 2+ were captured and these averaged 227.5 mm. This age class accounted for ~20% of the sample. Six rainbow accounting for >50% of the sample were aged 2+ and averaged 253 mm. Three rainbow (~30% of the sample) aged 3+ fish averaging 273 mm were sampled. In 1957, 1 fish aged 2+ was captured and it was ~215 mm while 2 fish 3+ years old and averaging 225 mm were sampled. That year, 1 age 5+ fish was caught and it was 317 mm.

Maturity and Size of Male and Female Rainbow Trout

One immature and 12 mature female rainbow trout were captured in 1951. The mature fish ranged from 225 mm – 305 mm and averaged 274 mm (Table 8). Only mature males were captured that year and these ranged from 235 mm – 305 mm and averaged 281 mm.

TABLE 8. Range of lengths (mm) and mean sizes (mm) of male and female cutthroat trout captured in gillnets in Lower Campbell Lake in 1951 (N=19); 1953 (N=6); 1957 (N=4); 2004 (N=9) (Source: FLNRO files, Nanaimo).

1951		1953		1957		2004	
Female (n=13)		Male (n=6)	Female (n=5)	Male (n=1)	Female (n=2)	Male (n=2)	Female (n=3)
Immature (n=1)	Mature (n=12)	Mature (n=6)	Immature (n=4)	Mature (n=1)	Immature (n=1)	Mature (n=1)	Immature (n=3)
-----	225-305	235-305	145-260	-----	-----	-----	215-279
235	274.6	281.7	196.2	290	140	171.4	247.6
							230
							185-300
							129.9

Immature and mature females were captured in 1953, however, only one mature female was found that year. Immature females ranged from 145 – 260 mm and averaged 196 mm while the only immature male was 140 mm.

In 1957, 1 immature female (171 mm) and 1 mature female (317 mm) were captured. Two immature males were also sampled and these ranged from 215 – 279 mm and averaged 247 mm. Only immature rainbow were sampled in 2004. Females ranged from 215 – 345 mm and averaged 230 mm, while males ranged from 185 – 300 mm and averaged ~130 mm.

Snorkel Surveys

Observers have counted rainbow trout in Fry and Greenstone creeks primarily through the summer and early fall months (Figure 11). Peak counts of rainbow trout have been noted in August; however, this peak, as well as the smaller counts throughout the summer were of juvenile trout. Adult rainbow were observed in May and June counts and again in October and November counts.

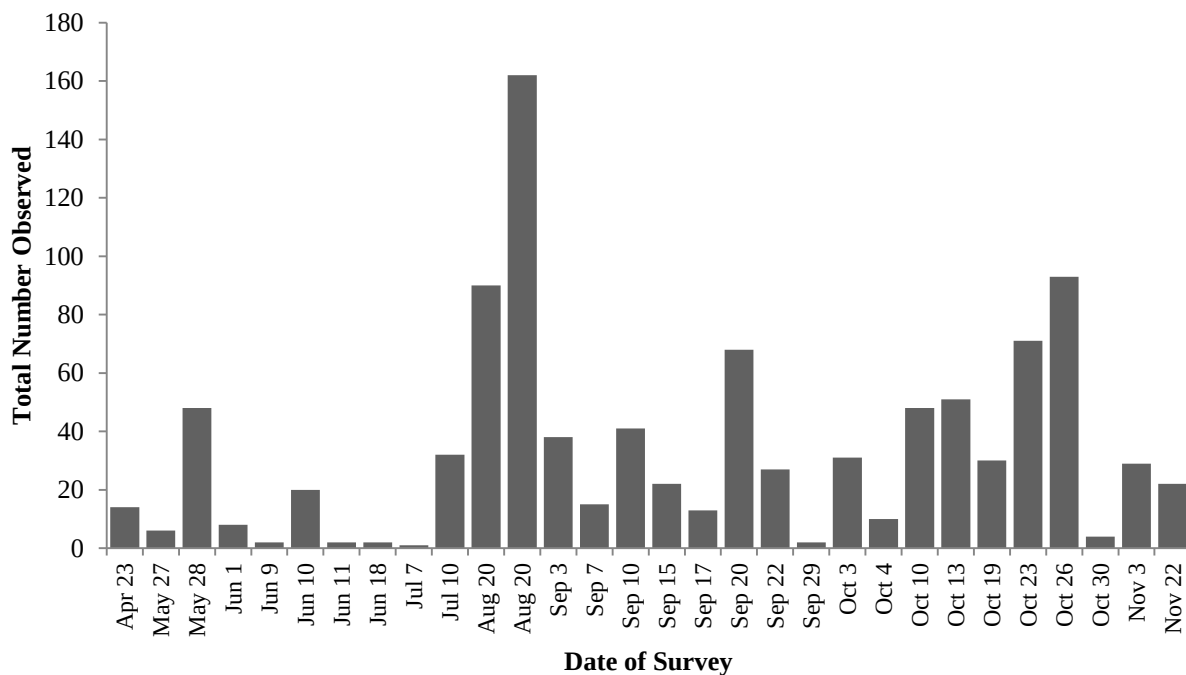


FIGURE 11. Total number of rainbow trout observed in snorkel counts of Fry and Greenstone Creeks between 1998 and 2004 (Source: FLNRO files, Nanaimo).

Rainbow trout have also been observed below Strathcona Dam throughout the year, however, the highest numbers of this species have been seen in June during the spawning period and again in October during Dolly Varden spawning (Figure 12). This species may also use the area when temperatures rise in Lower Campbell Lake during summer months.

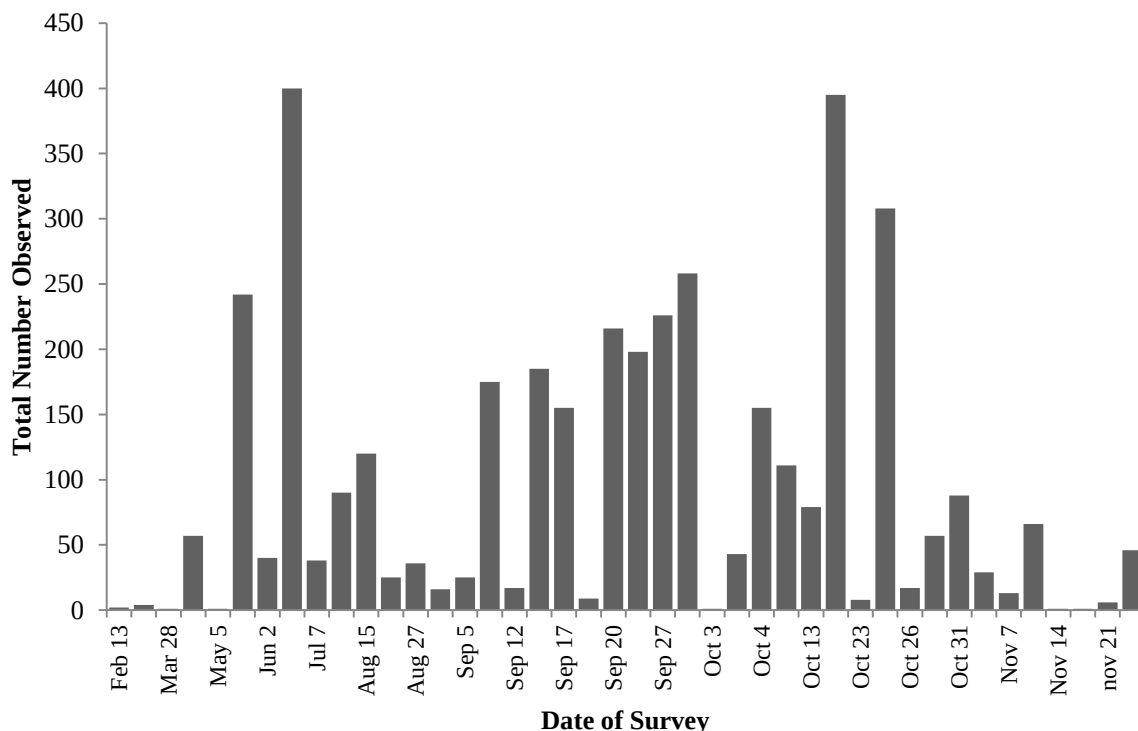


FIGURE 12 Total number of rainbow trout observed in snorkel counts below Strathcona Dam 1998 and 2002 - 2004 (Source: FLNRO files, Nanaimo).

Dolly Varden

Population Data

The minimum, maximum and mean length (mm) and weight (g) of Dolly Varden captured in gillnets in Fry Lake in 1978 and 2004 is shown in Table 9. Minimum fork length was ~170 mm in both sample years, while maximum fork length was ~330 mm. Mean fork length of Dolly Varden captured Fry Lake was in ~240 mm. Mean weight of Dolly Varden caught ranged from 212 g in 1978 to 184 g in 2004.

TABLE 9. Total numbers and minimum, maximum and mean fork length of Dolly Varden captured by gillnet in Fry Lake in 1978 and 2004 (Source: FISS, FLNRO files, Nanaimo.).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1978	8	170	320	246.3	211.8
2004	13	175	340	236.1	184.4

Dolly Varden were sampled in Lower Campbell Lake in 1957, however the method of sampling is unknown (Table 10). Seven Dolly Varden ranging in length from 235 mm – 279 mm were sampled 1957. Dolly Varden were sampled in gillnets set in Lower Campbell Lake in 1960 (n=2), 1961 (n=11) and 1962 (n=4), however no length and weight data was recorded.

TABLE 10. Total numbers and minimum, maximum and mean fork length of Dolly Varden captured in Lower Campbell Lake in April 1957; method of capture is unknown (Source: FISS, FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1957	7	235	279	261	164.7

Length Frequency Distributions

Length frequency distributions for Dolly Varden captured in Lower Campbell Lake in 1957, 1978 and 2004 are presented in Figures 13-15. In 1957, 7 Dolly Varden were captured and the modal length was 251 – 275 mm. Almost 60% of the fish caught were within this length class and a further 30% were in the 226 – 250 mm class. Ten percent of the Dolly Varden sampled that year were 276 mm – 300 mm and no fish larger than 300 mm were captured.

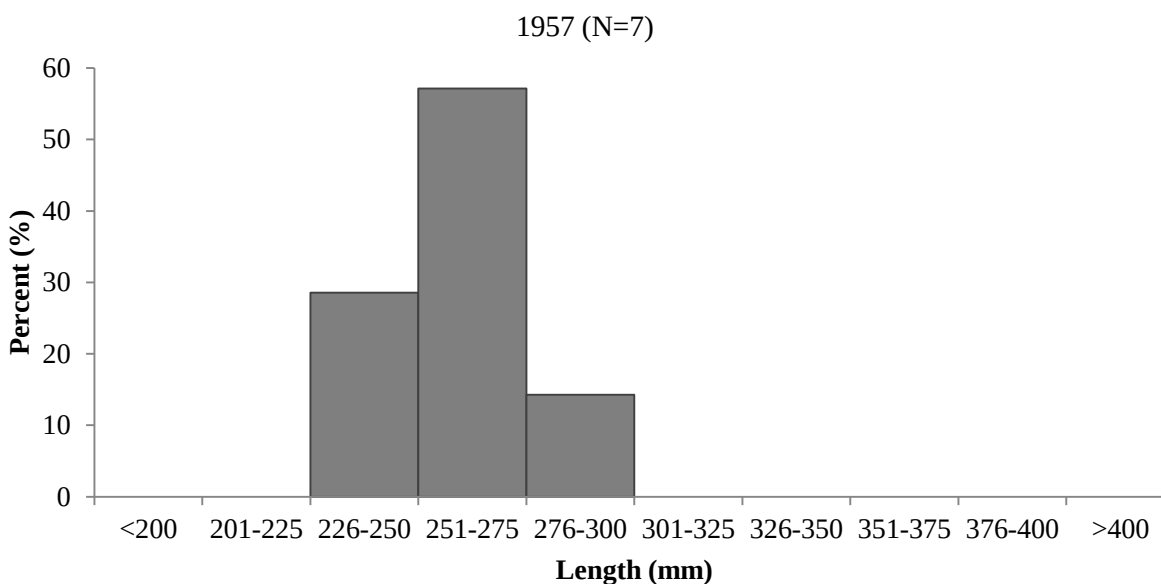


FIGURE 13. Length frequency of Dolly Varden captured in Lower Campbell Lake, 1957 (N=7); method of capture is unknown (Source: FLNRO files, Nanaimo).

In 1978 and 2004, Dolly Varden >300 mm were captured. In 1978, ~25 % of the sample consisted of fish 301 mm – 325 mm although the modal length that year was <200 mm with >35% of the sample within that length class (Figure 14). Fish were also sampled in the 226 mm – 250 mm and 276 mm - 300 size ranges.

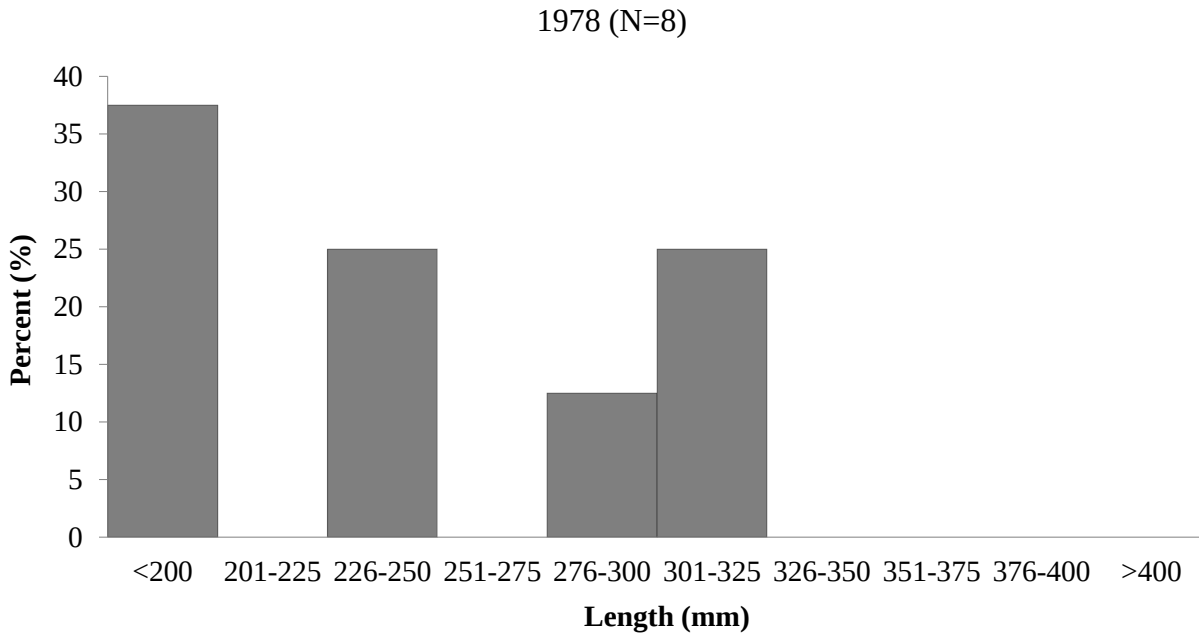


FIGURE 14. Length frequency of Dolly Varden captured with gillnets in Lower Campbell Lake (Fry Lake) July, 1978 (N=8) (Source: FLNRO files, Nanaimo).

In 2004, the modal length class was again <200 mm with more than half of the sample within that length class (Figure 15). Fish >300 mm were also captured; however, they made up a small percentage of the sample with ~5% in the 301 mm – 325 mm length class, and ~10% in the 326 mm – 350 mm length class.

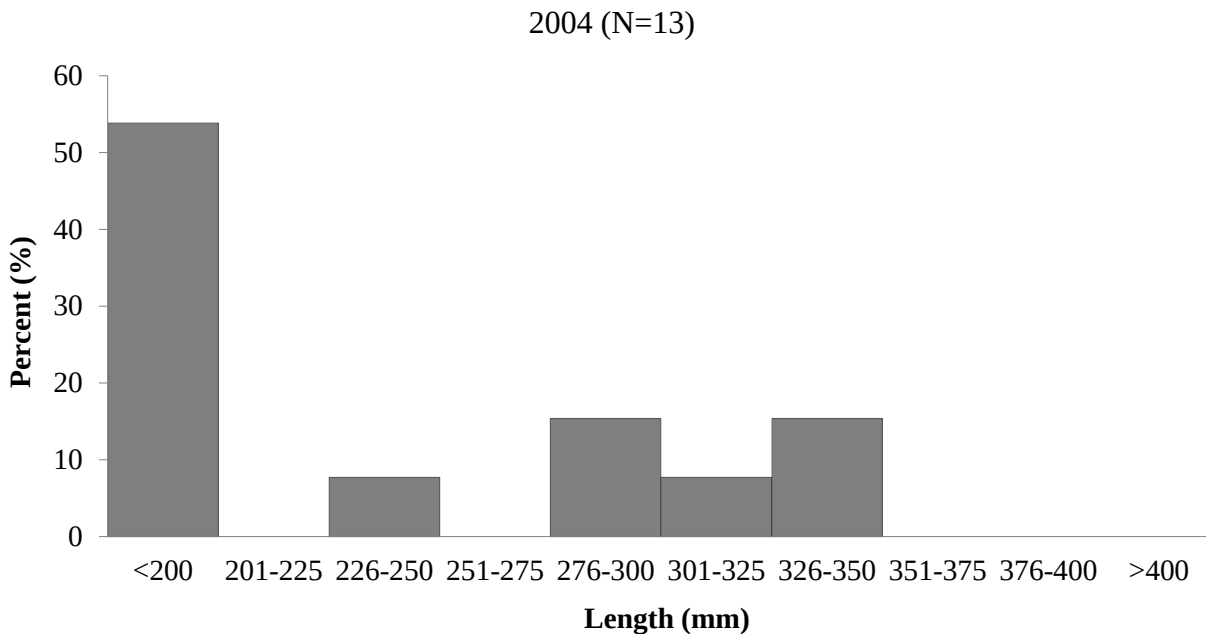


FIGURE 15. Length frequency of Dolly Varden captured with gillnets in Lower Campbell Lake (Fry Lake) August, 2004 (N=13) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

The length-weight relationship for Dolly Varden captured from 1957 – 2004 in Lower Campbell Lake (including Fry Lake) is presented in Figure 16. The smallest fish have been ~175 mm and 50 g, while the largest have been <350 mm and ~450 g. Most Dolly Varden sampled have been <200 mm and <100 g and 275 mm and ~200 g.

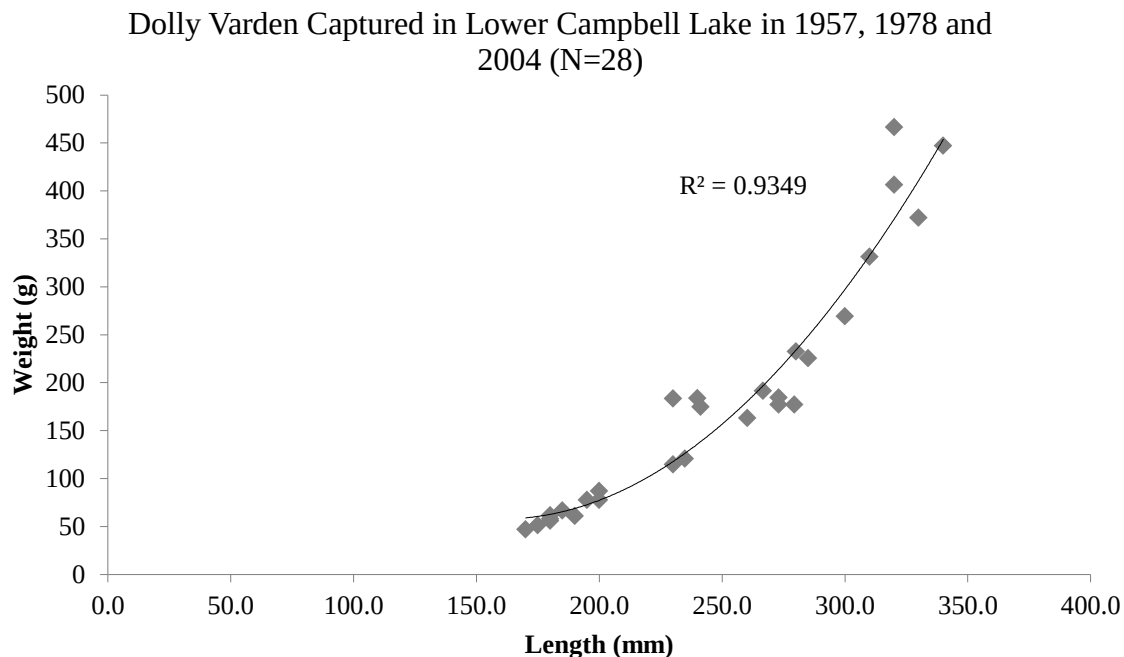


FIGURE 16. Length-weight relationship for Dolly Varden captured in Lower Campbell Lake in 1957 (n=7), 1978 (n=8) and 2004 (n=13). Note: capture method for 1957 is unknown; samples from 1978 and 2004 are from Fry Lake (Source: FLNRO files, Nanaimo).

Maturity and Size of Male and Female Dolly Varden

Five immature females were sampled from Fry Lake in 2004 and these fish ranged in size from 180 mm – 280 mm and averaged 208 mm (Table 11). Seven immature males were also captured and they ranged from 175 mm – 330 mm and averaged 241 mm. One mature male, 340 mm was also captured that year.

TABLE 11. Range of lengths and mean sizes of male and female Dolly Varden captured in gillnets in Lower Campbell Lake (Fry Lake) 2004 (N=13) (Source: FLNRO files, Nanaimo).

Factor	Female (n=5)	Male (n=8)	
	Immature (n=5)	Immature (n=7)	Mature (n=1)
Range	180 – 280	175-330	-----
Mean	208.0	241.4	340

Dolly Varden Observed in Snorkel Surveys

Small numbers of adult Dolly Varden (e.g. 2) have been observed in snorkel surveys of Fry and Greenstone Creeks in 1998, 2003 and 2004 (Figure 17). High numbers of juvenile Dolly Varden have been found in these creeks in the May – June period prior to migration into lake habitats.

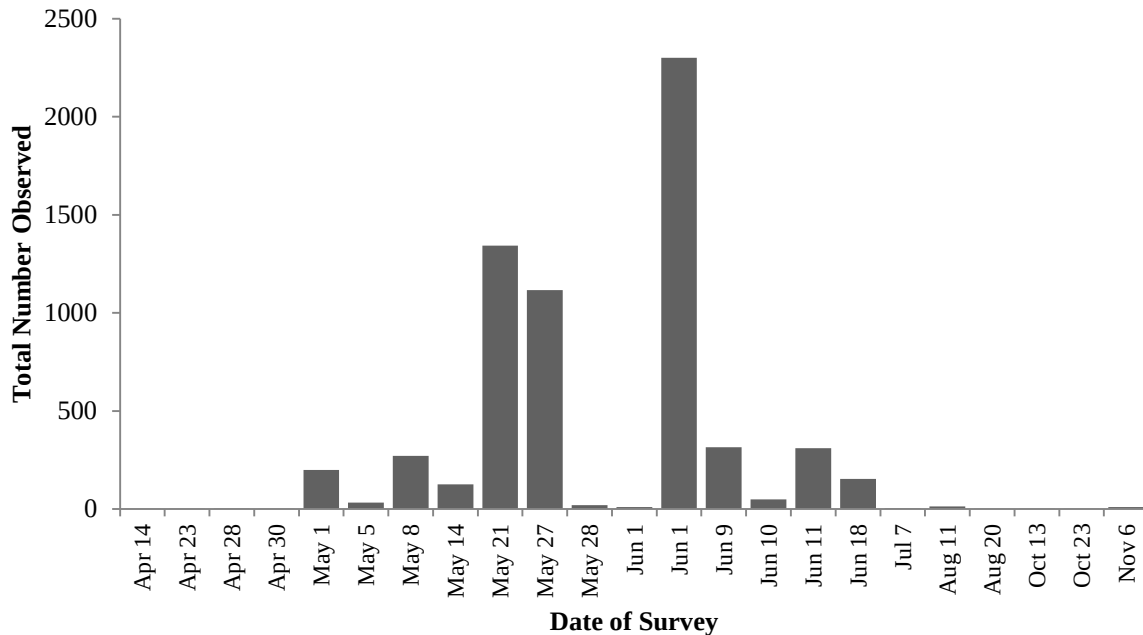
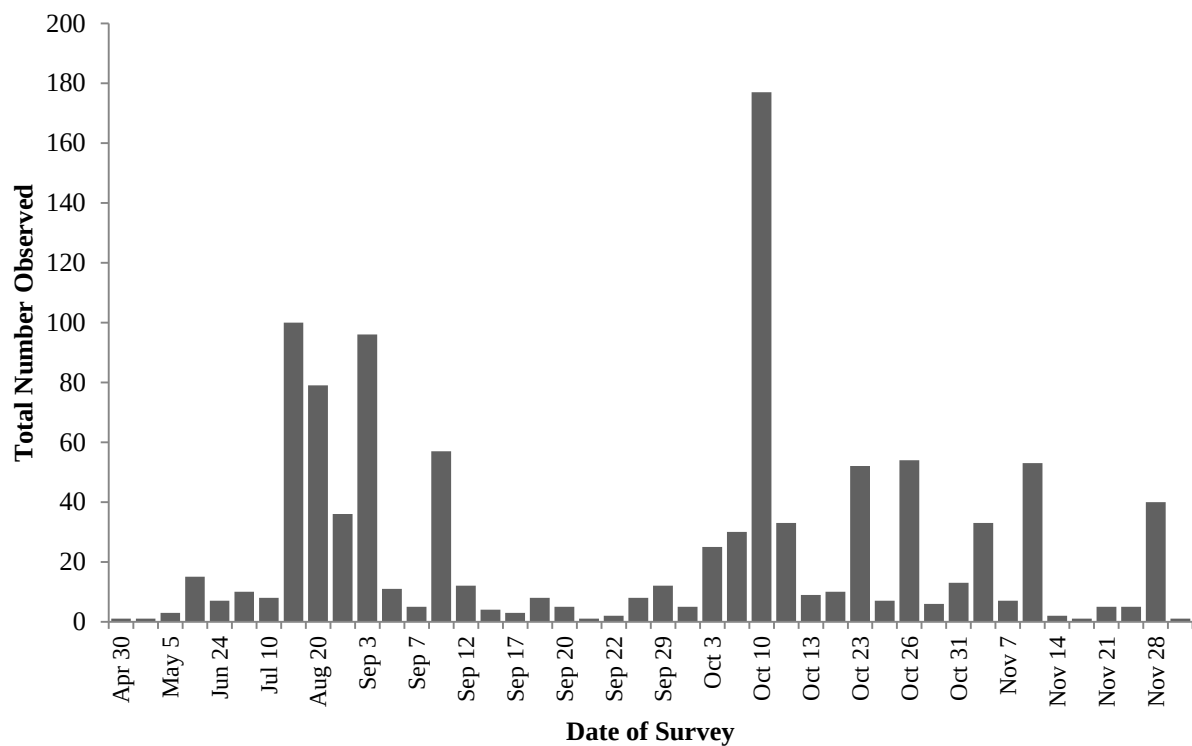


FIGURE 17. Total number of Dolly Varden observed in snorkel counts of Fry and Greenstone Creeks 1998, 2003 and 2004 (Source: FLNRO files, Nanaimo).

Adult Dolly Varden have been observed in snorkel surveys below Strathcona Dam, particularly throughout October and November during spawning (Figure 18). Adults and juveniles have also been observed earlier in the year, especially during August, however, and it is suspected that Dolly Varden use the area below Strathcona Dam when temperatures in Lower Campbell Lake warm during summer months.



Fisheries Objectives and Management Strategies

TABLE 12. Number of responses and percent of total responses by anglers regarding the quality of fishing, reasons for fishing, preferred species, and suggestions for regulations to improve angling at Lower Campbell Lake determined from box angler creel surveys conducted July, 2010 – September, 2011 (Source: FLNRO files, Nanaimo).

Survey Question and Responses	Number of Responses	Percent
1. How do you rate fishing in this lake?		
Excellent	2	8.3
Good	8	33.3
Poor	14	58.3
2. Why do you fish this lake?		
Catch fish to eat	14	70.0
Catch large fish	4	20.0
Catch many fish	2	10.0
3. Which species do you prefer to catch?		
Cutthroat trout	8	38.1
Rainbow trout	9	42.9
Dolly Varden	1	4.8
Does not matter	3	14.3
4. If new regulations were implemented to improve the fishery and conserve fish stocks, which regulation would be acceptable to you?		
Size limits	6	37.5
Reduction on the number of fish killed	5	31.3
Season or area closure	1	6.3
Catch-and-Release regulation	4	25.0
Total Responses	81	

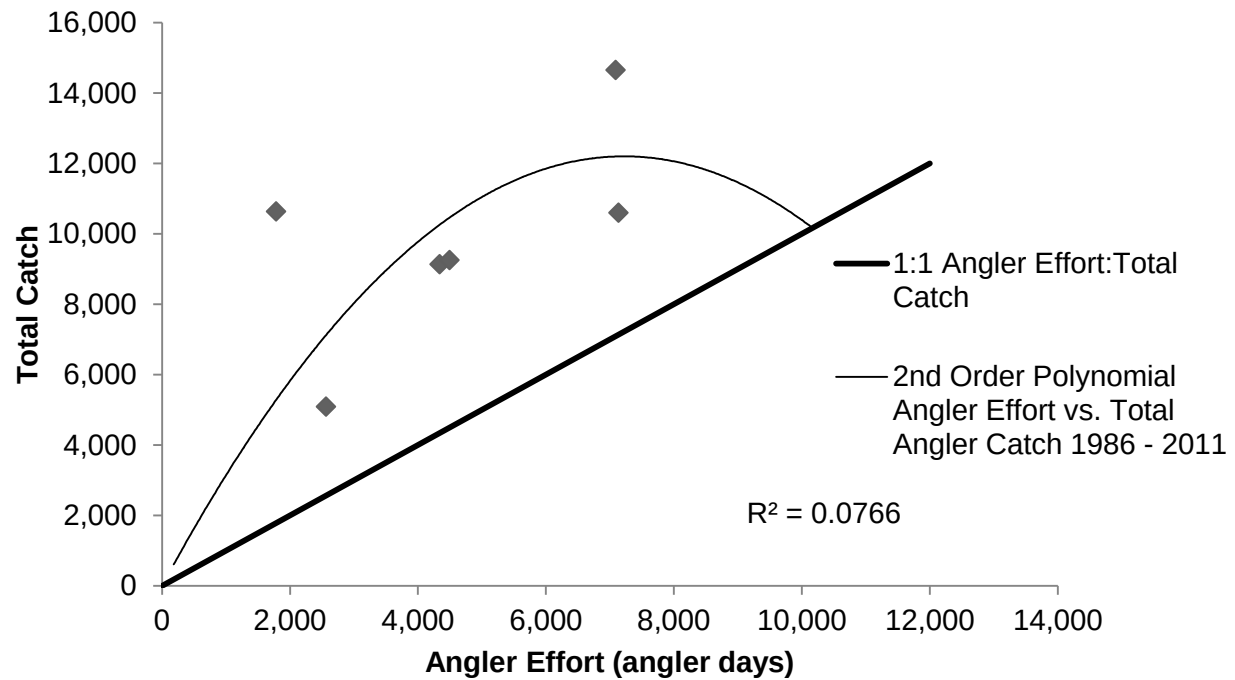


FIGURE 19. Relationship between angler effort (angler days) vs. total catch and 45 degree equilibrium line at Lower Campbell 1986 – 2011 Note; the point at which the 2nd degree polynomial curve diverges furthest from the 45 degree equilibrium line is where the optimum angler effort produces the highest sustained catch (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Appendix 18. Nimpkish Lake

Fisheries Objectives and Management Strategies

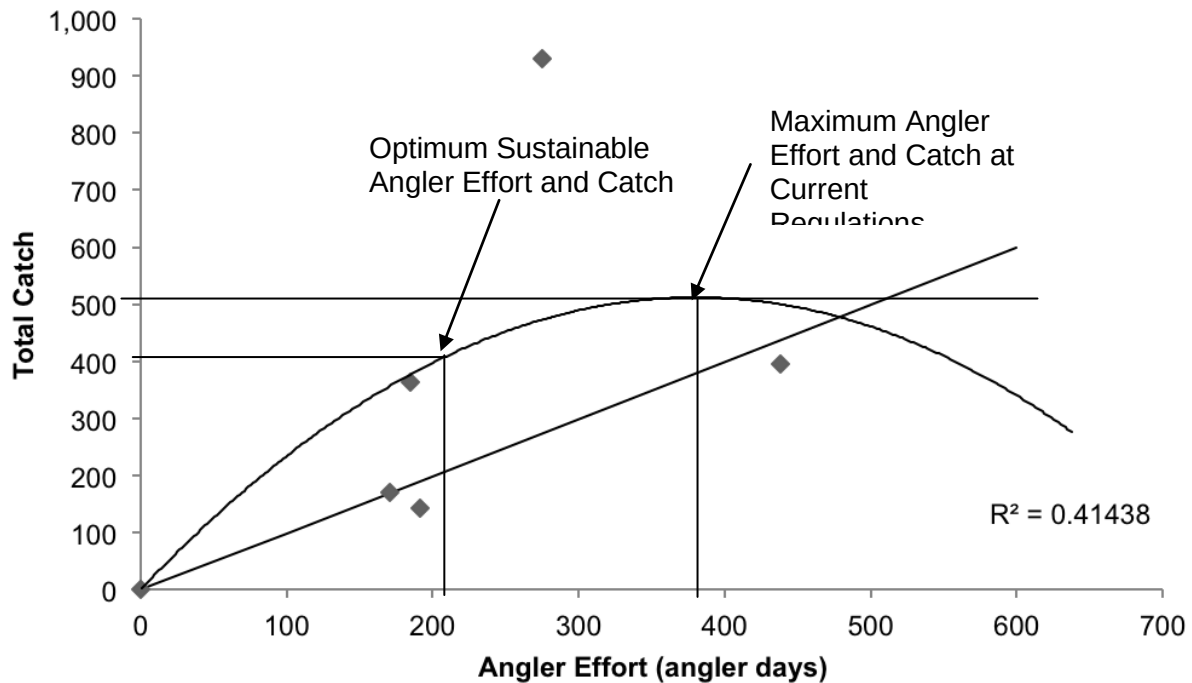


FIGURE 1. Angler effort (angler days) vs. total catch and maximum angler effort and catch at the current regulations at Nimpkish Lake 1986 – 2011 Note; the point at which the 2nd degree polynomial curve diverges furthest from the 1:1 equilibrium line is where the optimum angler effort produces the highest sustained catch. In this case, 200 angler days would result in an optimal catch of ~400 fish and a success rate of 2 fish/angler day. However, we chose not to use this relationship to determine optimum and maximum levels at Nimpkish Lake because of the low R^2 value (0.3723) (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Appendix 19. Nitinat Lake

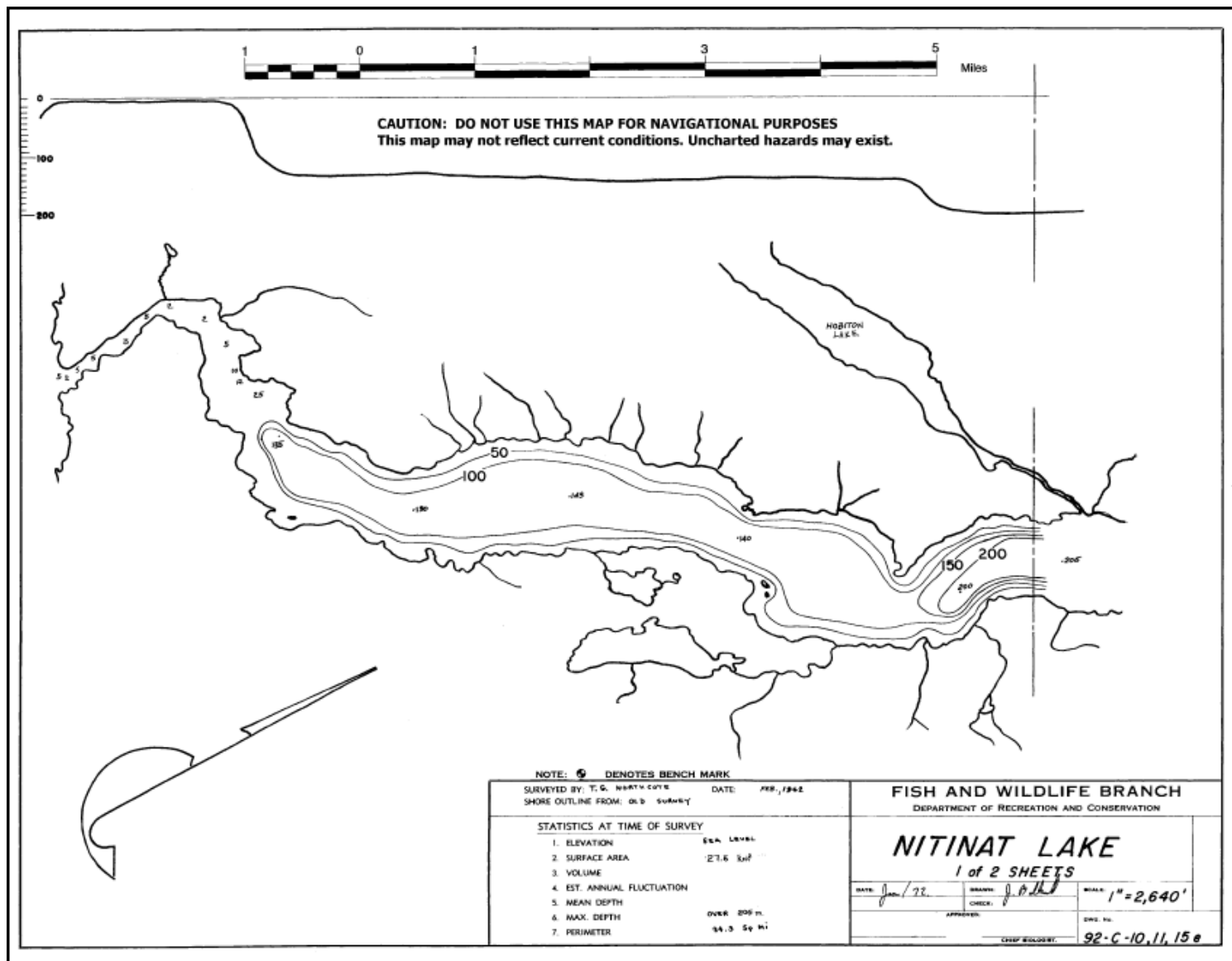


FIGURE 1. Bathymetric map of Nitinat Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

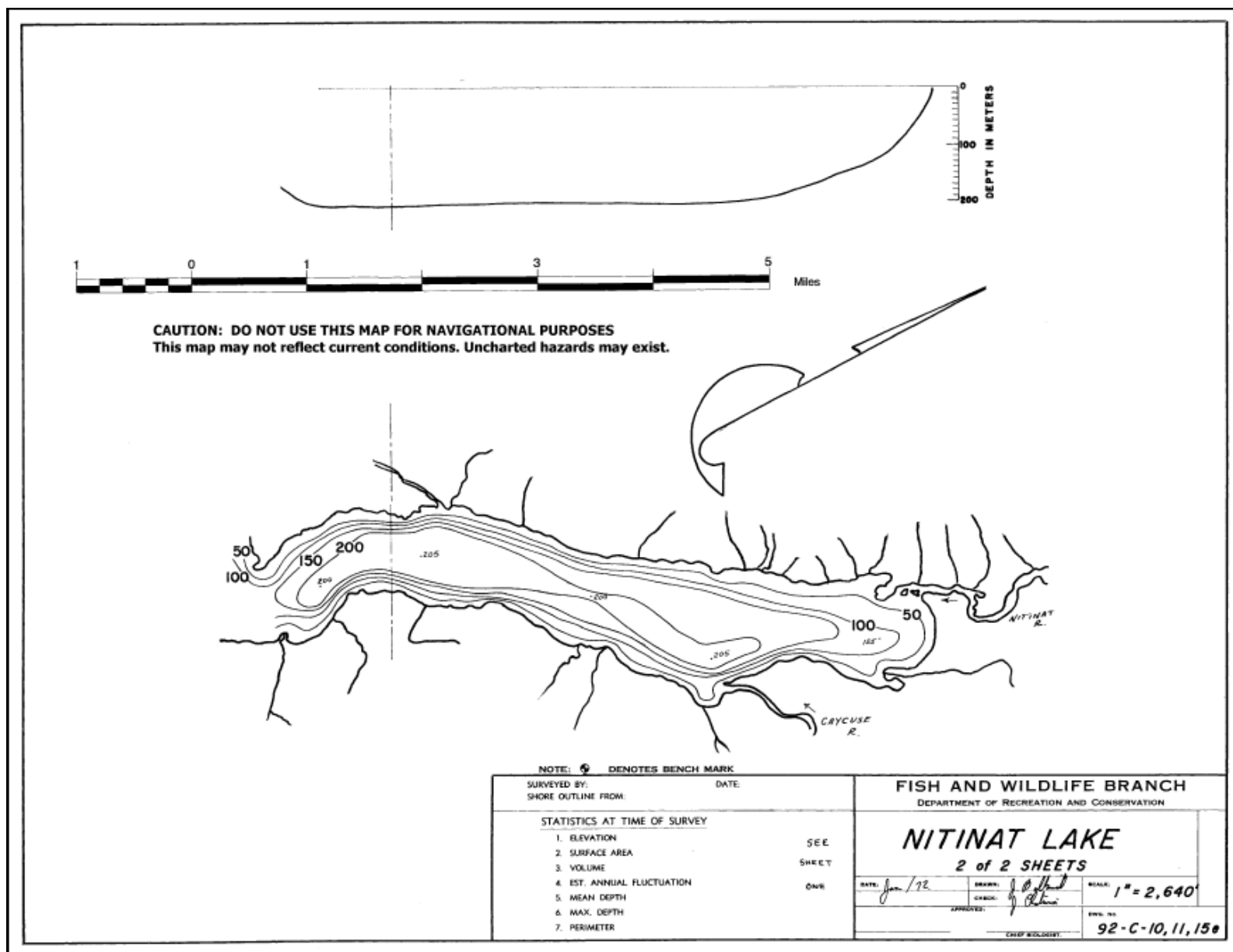


FIGURE 1 (CONTINUED). Bathymetric map of Nitinat Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Appendix 20. Sproat Lake

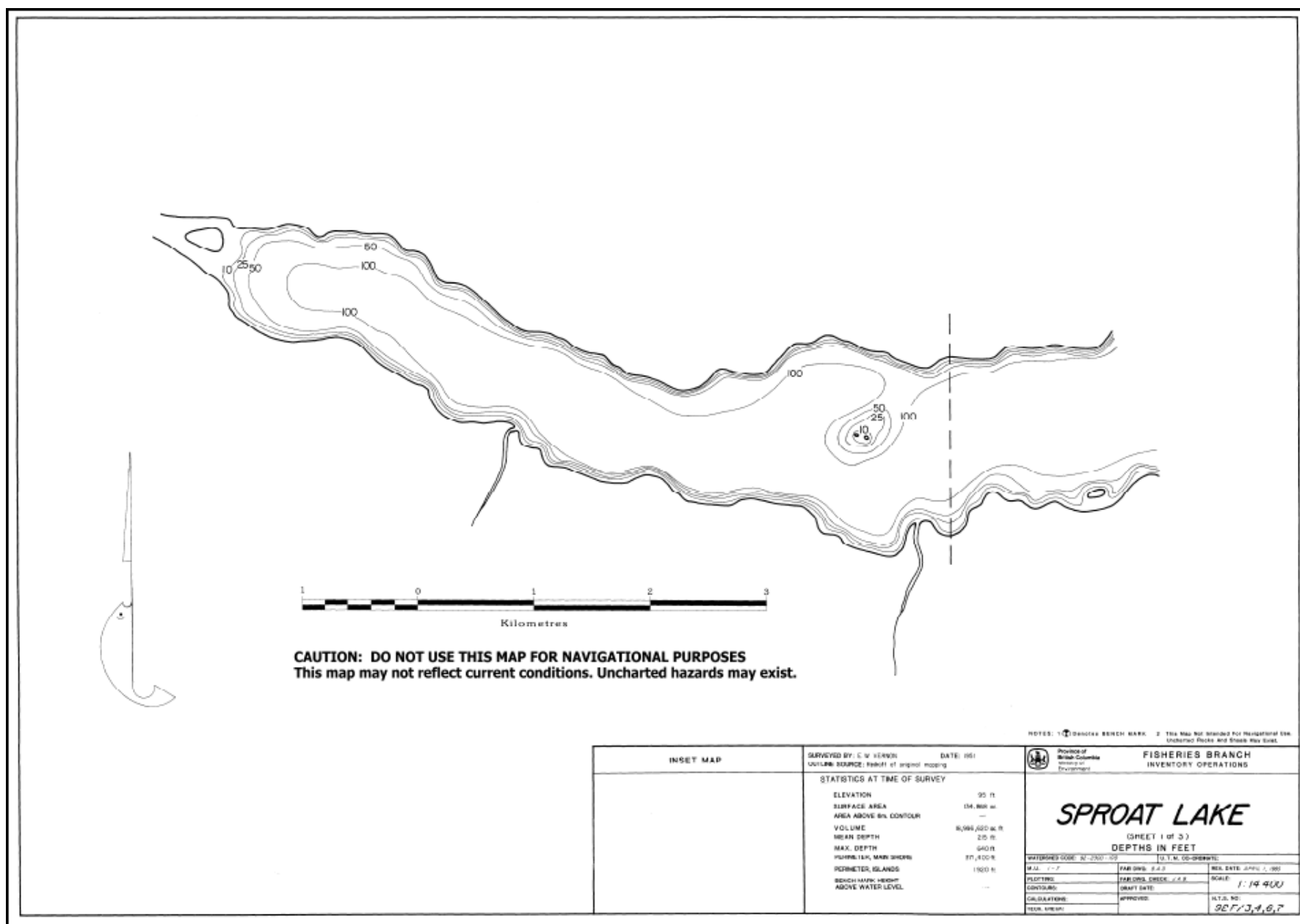


FIGURE 1. Bathymetric map of Sproat Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

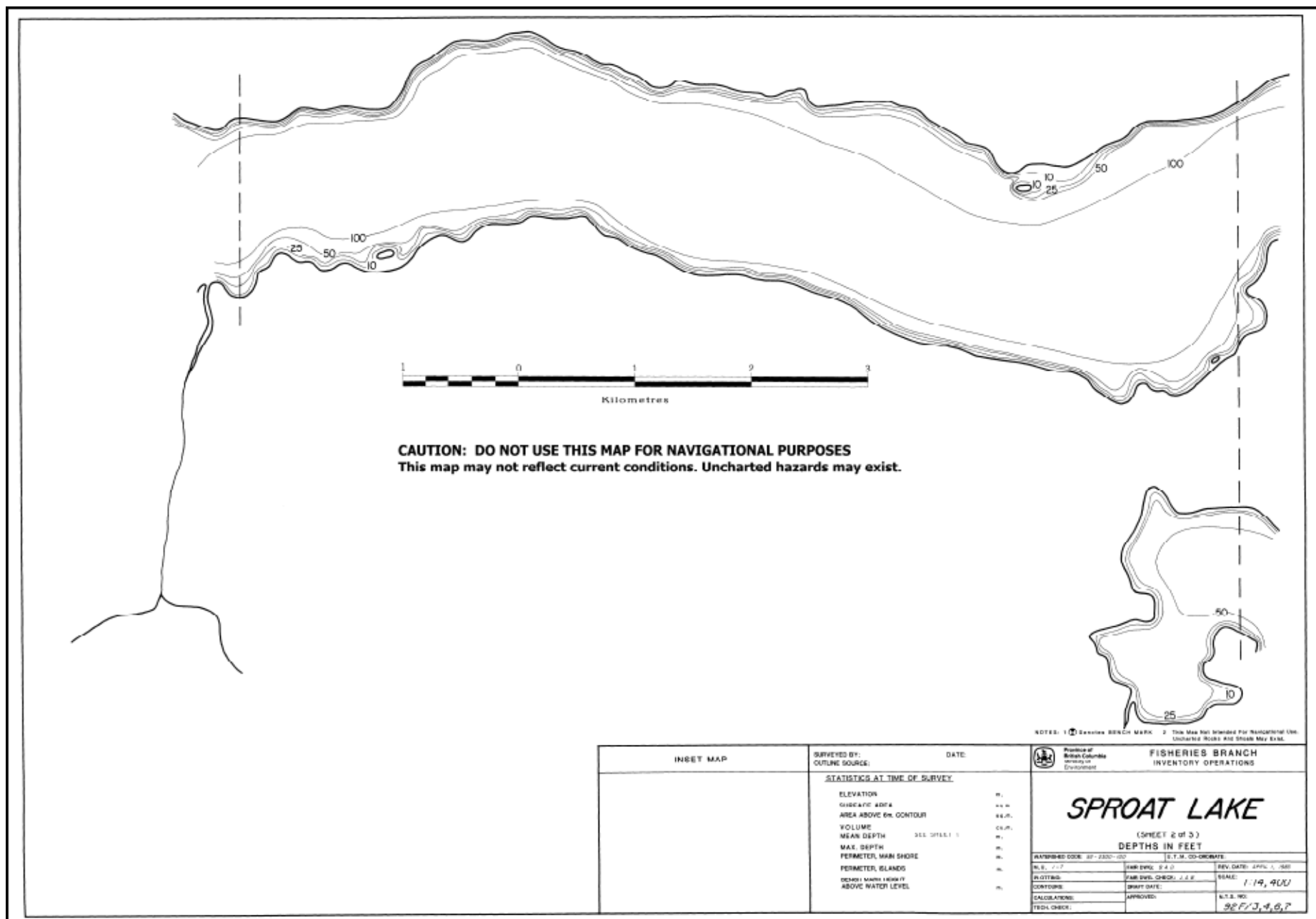


FIGURE 1 (CONTINUED). Bathymetric map of Sproat Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

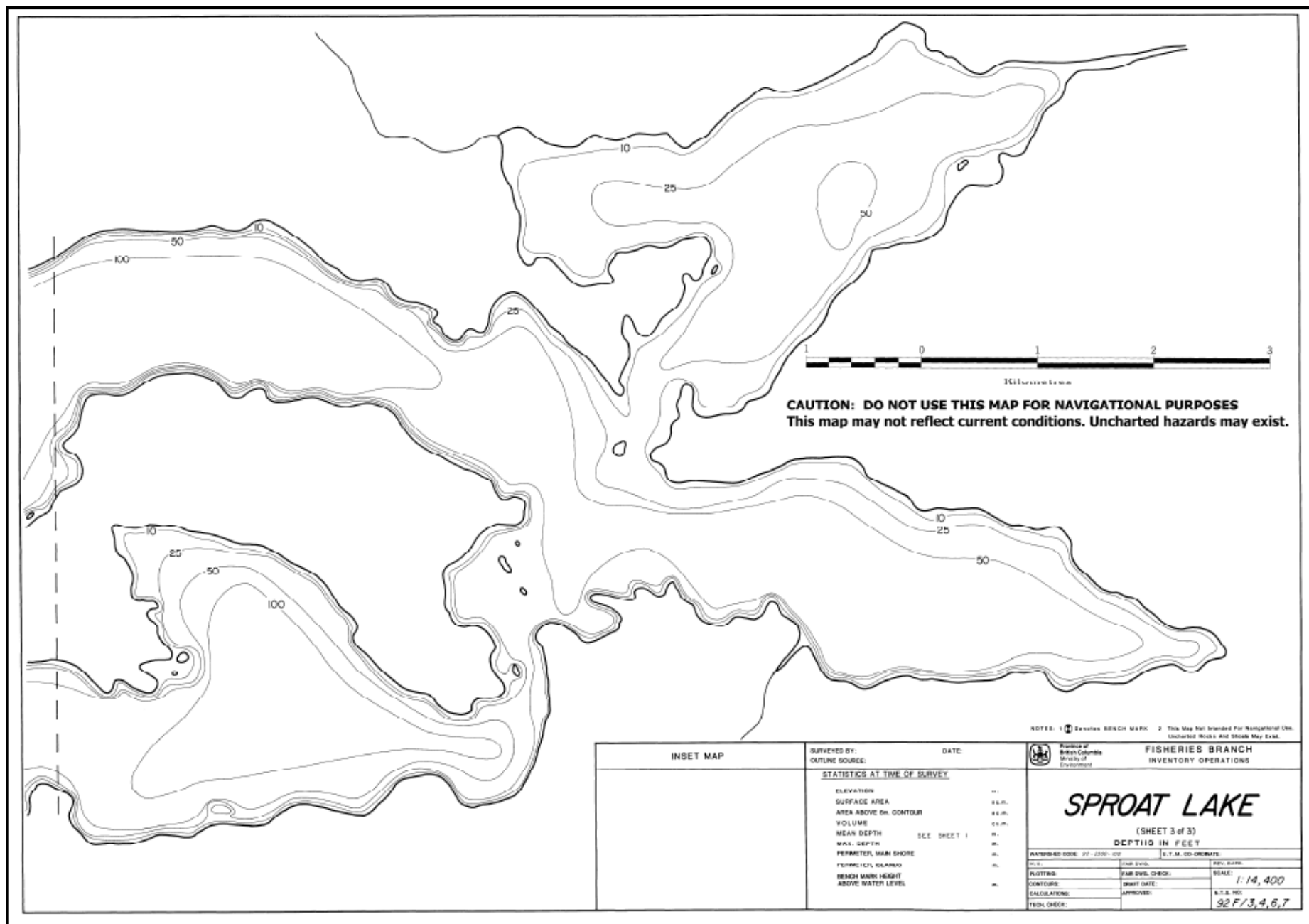


FIGURE 1 (CONTINUED). Bathymetric map of Sproat Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Stock Status Indicators

Cutthroat Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of cutthroat trout captured in gillnets in Sproat Lake, from 1951-2012 is shown in Table 1. Minimum fork length has ranged between 125 mm – 260 mm, while maximum fork length has ranged between 520 mm – 724 mm, except in 1977 when the maximum fork length was only 285 mm. Mean fork length of cutthroat captured in gillnets has stayed somewhat consistent at ~400 mm. Most recently in September 2012, two cutthroat trout were captured in a single gillnet set near the centre of Sproat Lake with a fork length of ~500 mm.

TABLE 1. Total numbers, and minimum, maximum and mean fork length of cutthroat trout captured in gillnets in Sproat Lake from 1951-2012 (Source: FISS; FLNRO files, Nanaimo; Lough, 1990)

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1951-53*	35	125	724	433	---
1951	12	180	620	368	908
1952	26	180	720	442	1846
1953	8	260	609	404	1115
1977	8	146	285	197	---
2012	2	500	520	510	---

*Lough (1990) combined data from 1951-53. Method of capture reported in Lough (1990) was creel, troll, gillnet. It is unknown whether some of Lough's data is the same data reported in FISS so both data sets are shown.

Maturity

In 1951-53, mature female cutthroat trout ranged from 585 mm to 630 mm, while mature males ranged from 480 mm - 720 mm (Table 2). Sampling during those years also included immature females from 180 mm – 355 mm and immature males between 185 mm and 245 mm.

TABLE 2. Range of lengths and mean sizes of male and female cutthroat trout captured in gillnets in Sprout Lake in 1951, 1952 and 1953 (Source: FLNRO files, Nanaimo).

Factor	Female cutthroat N=11		Male cutthroat N=8	
	Immature (n=4)	Mature (n=7)	Immature (n=3)	Mature (n=5)
Range	180-355	585-630	185-245	480-720
Mean	236	612	217	622

Taylor River Snorkel Surveys

Fisheries personnel from the BC Ministry of Environment and BC Conservation Foundation have conducted snorkel surveys of the Taylor River almost annually since 1970 (Figure 2). The area snorkelled is approximately 5.5 km in length from Sutton Creek confluence to lower logging bridge. Most swims were conducted in May while some swims were in April, June and September. No fish were observed in February or October surveys. Spot checks were performed in 1976, 1977 and 1982 therefore numbers observed are lower in those years. No

surveys were conducted in 2006-07. The 2010 survey was cancelled due to high water conditions.

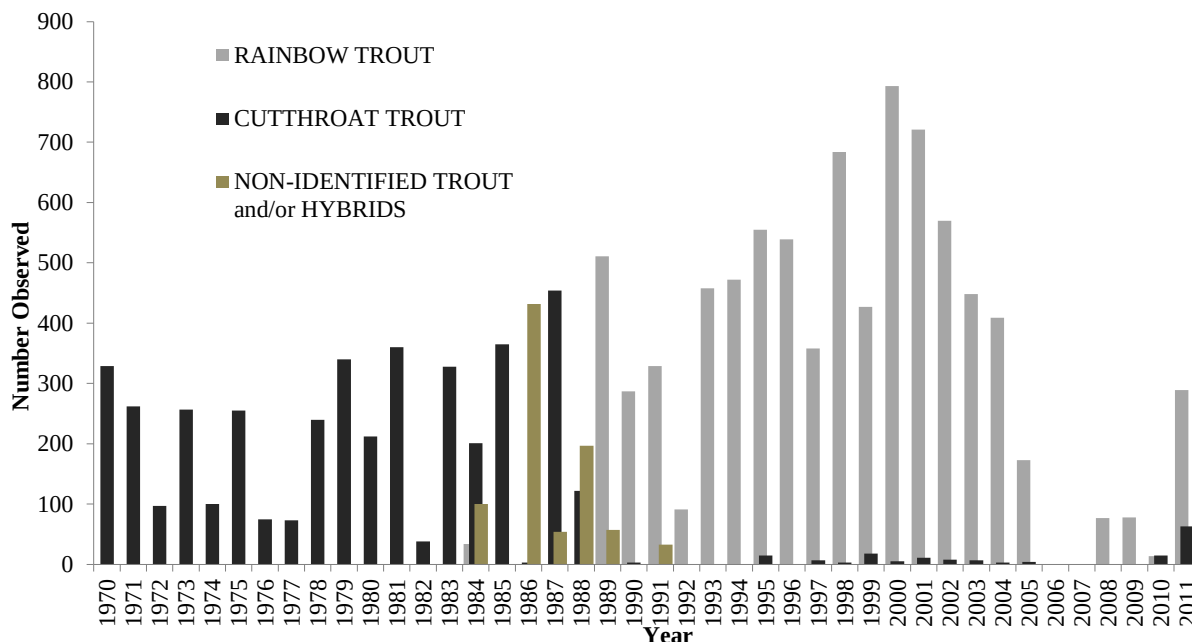


FIGURE 2. Total number of cutthroat trout, rainbow trout, hybrids and non-identified trout observed in snorkel counts of the Taylor River from 1970 – 2011 (N=13463). Note: No swims were conducted in 2006-07. The 2010 survey was cancelled due to high water conditions (Source: FLNRO files, Nanaimo).

Swims conducted in the 1970-1980's had higher numbers of cutthroat compared to the 1990-2000's. Hybrid (rainbow/cutthroat) trout were noted in the mid 1980's and represented 30% of the total count in 1984, while cutthroat trout comprised 60% and rainbow trout 10%. In 1986, only three fish were positively identified as cutthroat with the remaining 432 considered hybrids. A shift to rainbow trout was observed in the late 1980's where greater than 90% of the 568 trout observed in 1989 were rainbow. It was noted in the 1989 survey that larger cutthroat migrate earlier between April 15 and May 15, while smaller rainbow are migrating between May 1 and June 1. Dolly Varden were observed during swims in 1998 (n=1) and 2000 (n=4) and the presence of Dolly Varden juveniles was confirmed in the upper reaches of Taylor River during a September 2005 survey.

Due to some uncertainty of species identification, we have combined all trout species to show total number of trout observed in snorkel swims of the Taylor River by year and month in Figure 3 and Figure 4.

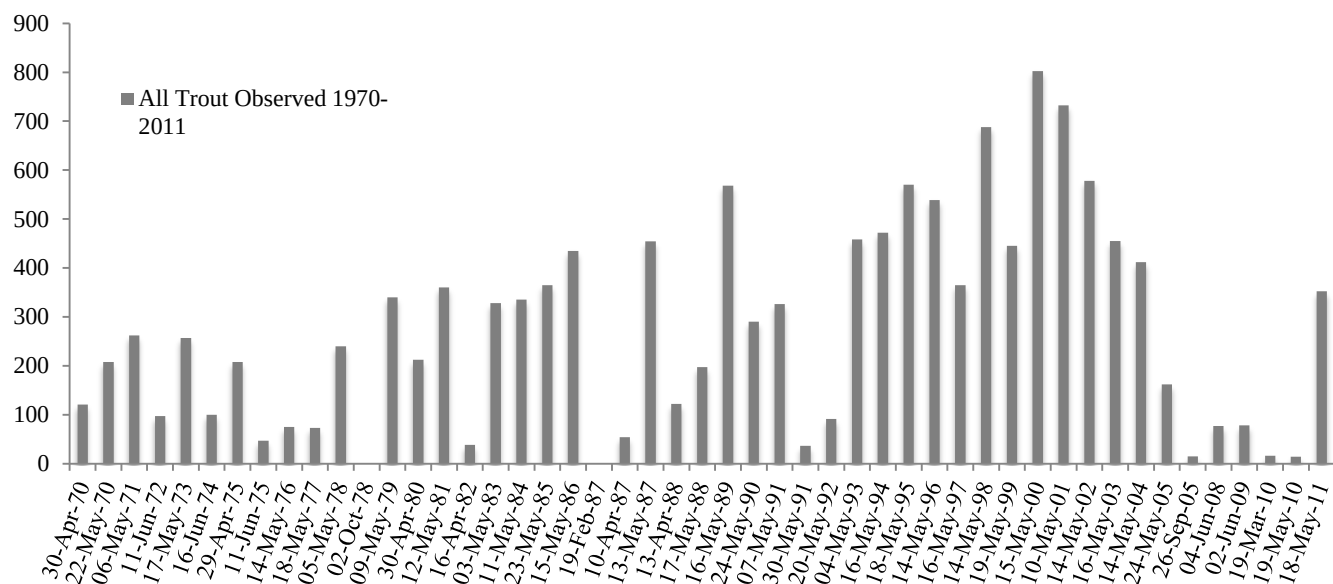


FIGURE 3. Total number of trout observed in snorkel counts of the Taylor River from 1970 – 2011 (N=13469). Note: No swims were conducted in 2006-07. The 2010 survey was cancelled due to high water conditions (Source: FLNRO files, Nanaimo).

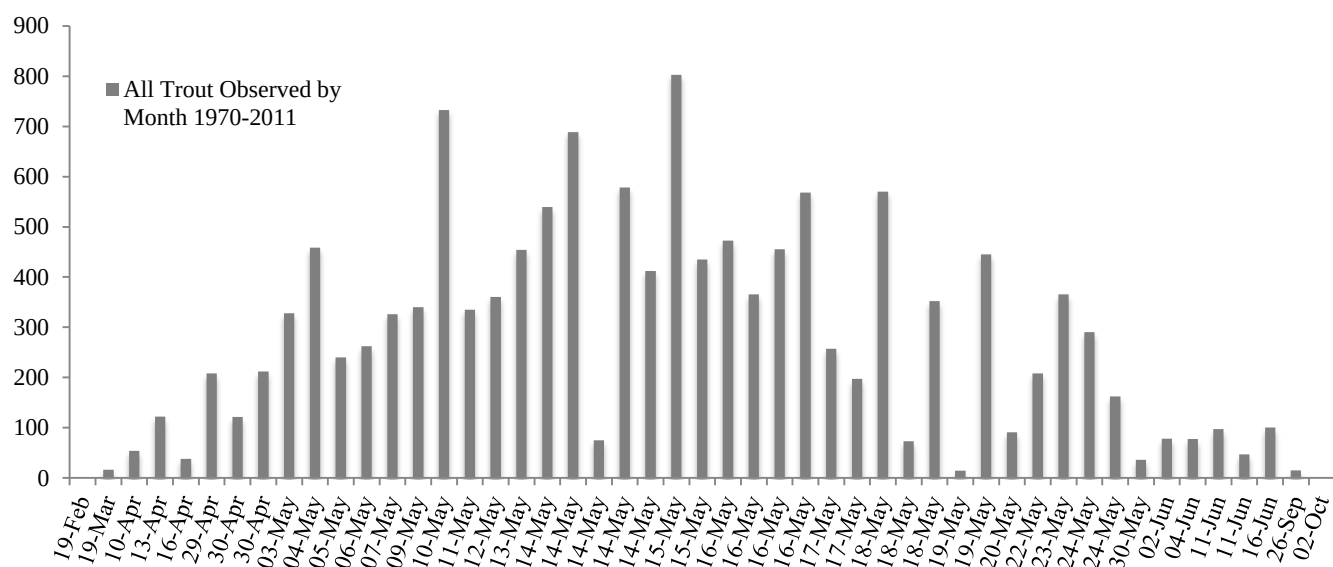


FIGURE 4. Total number of trout observed in snorkel counts of the Taylor River from 1970 – 2011 by month (N=13469). Note: No swims were conducted in 2006-07. The 2010 survey was cancelled due to high water conditions (Source: FLNRO files, Nanaimo).

The total number of adult cutthroat trout observed in snorkel surveys of the Taylor River between 1970 and 2011 is shown in Figure 5. No cutthroat trout were observed in surveys conducted in 1991-94, 1996 and 2008-09. No surveys were conducted in 2006-07. The 2010 survey was cancelled due to high water conditions. Note, however, that the objective of this snorkel survey is focused on monitoring numbers of rainbow trout and as such observations should be viewed as incidental and not be considered as representing total escapement numbers or timing of cutthroat trout. A cutthroat trout snorkel survey study is in progress for 2011 to determine run timing. During the 1970-1980's, technicians observed on average 274

adult cutthroat during the May swim which covers ~5 km of the Taylor River. Between 1990-2000's, the average declined to only 11 adult cutthroat observed. An increase in cutthroat from previous years occurred in 2011, where 63 adult cutthroat trout were observed. Cutthroat trout observed in the 2011 survey were generally over 400 mm in length and many larger fish were noted.

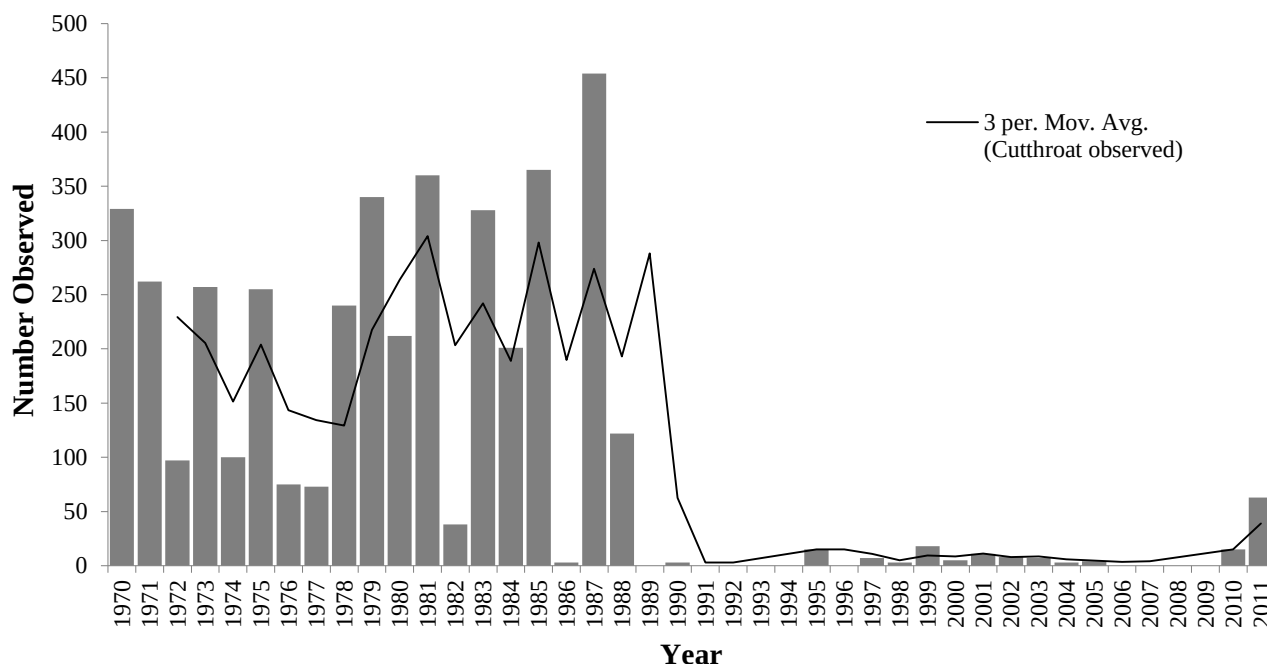


FIGURE 5. Total number and 3-year moving average of cutthroat trout observed in April/May/June snorkel counts of the Taylor River from 1970 – 2011 (N=4273). Note: No cutthroat trout were observed in the 1991-94, 1996 and 2008-09 surveys. No swims were conducted in 2006-07. The 2010 survey was cancelled due to high water conditions (Source: FLNRO files, Nanaimo).

The total number of cutthroat trout observed by day in May snorkel counts of the Taylor River from 1970 – 1990 is shown in Figure 6. Note that this graph represents historical counts and does not reflect recent counts of cutthroat trout observed in the Taylor River

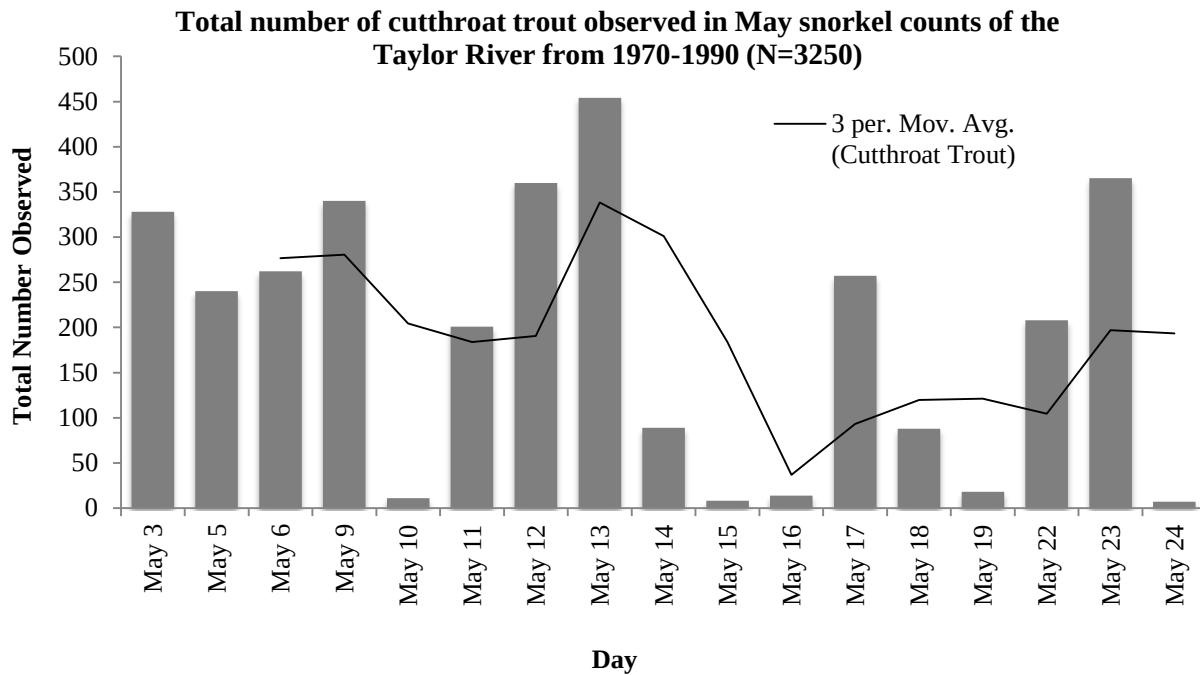


FIGURE 6. Total number of cutthroat trout observed by day in May snorkel counts of the Taylor River from 1970 – 1990 (N=3250, Mean=191). Note that this graph represents historical counts and does not reflect recent counts of cutthroat trout observed in the Taylor River (Source: FLNRO files, Nanaimo).

Twelve snorkel surveys completed by MJ Lough Environmental Consultants between February 27 and June 4, 2012 to identify spawning time of cutthroat trout in the Taylor River is shown in Figure 7. Surveys were conducted weekly in standard historical section of the lower Taylor River between Sutton Creek confluence and the old logging bridge and extended to the mouth of Sproat Lake for one survey on May 11, 2012 (Lough 2012). At the start of the survey on February 27, a total of six cutthroat trout were counted. Numbers of cutthroat observed increased during the weeks that followed as spawners moved into the Taylor River from Sproat Lake. On March 27, following an increase in flow from heavy rainfall, a total of 150 cutthroat trout was observed. A peak count of 347 cutthroat trout occurred on April 14 and 19, 2012. Which is similar to the highest historical counts of 300 to 450 cutthroat observed from 1970 – 1987. Lough (2012) noted that while cutthroat trout tend to spawn from mid April to late May, there was some overlap in spawning period with rainbow trout. Rainbow trout typically spawn starting in the second week of May and continue into early June. Lough (2012) noted the May 11 survey in particular contained both cutthroat and rainbow populations spawning.

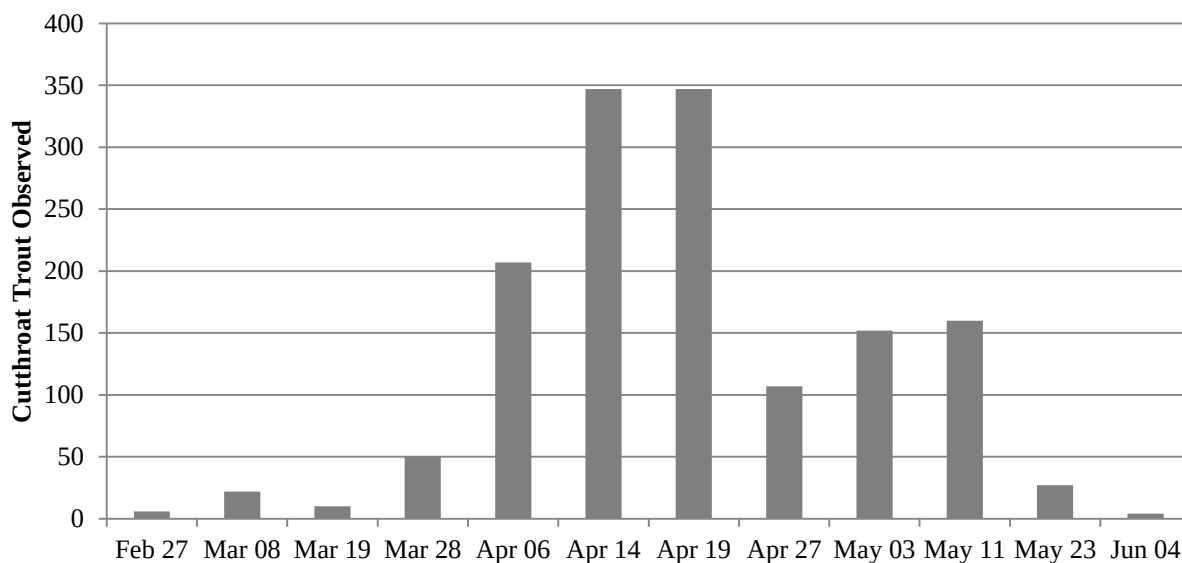


FIGURE 7. Cutthroat trout counts during snorkel surveys in the Taylor River study section, February 27 – June 4, 2012 (Reprinted from: Lough and Hay, 2012)

The total number of redds counted in the Taylor River study section from February 27 – June 4, 2012 is shown in Figure 8. Lough (2012) reported redds for all species. Lough commented that the increase in number of redds at the end of the study was due to the ongoing rainbow trout spawning that was still near peak activity.

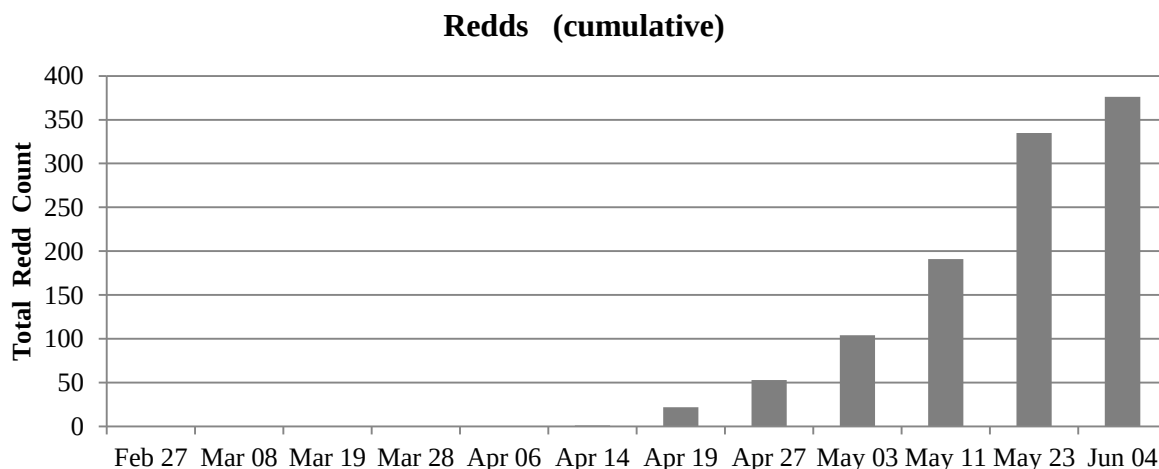


FIGURE 8. Total number of redds (all species combined) during snorkel surveys in the Taylor River study section February 27 – June 4, 2012 (Reprinted from: Lough and Hay, 2012).

Lough and Hay (2012) compared their results from the Taylor River to results of snorkel surveys they've conducted in Comox and Cowichan Lake and found that the estimated size of sexual maturity as indicated by the minimum and maximum size of the spawning population is larger for the Taylor River cutthroat spawning population than Comox Lake and Cowichan Lake cutthroat spawners (Table 3).

TABLE 3. Visually estimated size range of spawning cutthroat trout observed during snorkel surveys at Sproat Lake; Comox Lake and Cowichan Lake (Reprinted from: Lough and Hay, 2012).

Lake Population	Spawning Tributaries Surveyed	Size Range of Spawners	n
Sproat Lake	Taylor River	40 cm to 80 cm	137
Comox Lake	Upper Puntledge Reese Creek Comox Creek	30 cm to 55 cm	31
Cowichan Lake	Robertson River Sutton Creek Nixon Creek Shaw Creek	30 cm to 65 cm	142

Cutthroat-rainbow hybrids observed during the 2012 snorkel survey of the Taylor River is shown in Figure 9. A peak count of cutthroat-rainbow hybrids was observed on May 3, 2012 with a total number of 72 hybrids counted. Lough (2012) observed that some hybrids appeared to be mostly cutthroat or rainbow with only a slight indication of hybridization. For example, Lough noted some trout appeared to be pure cutthroat except for a faint stripe along the lateral line.

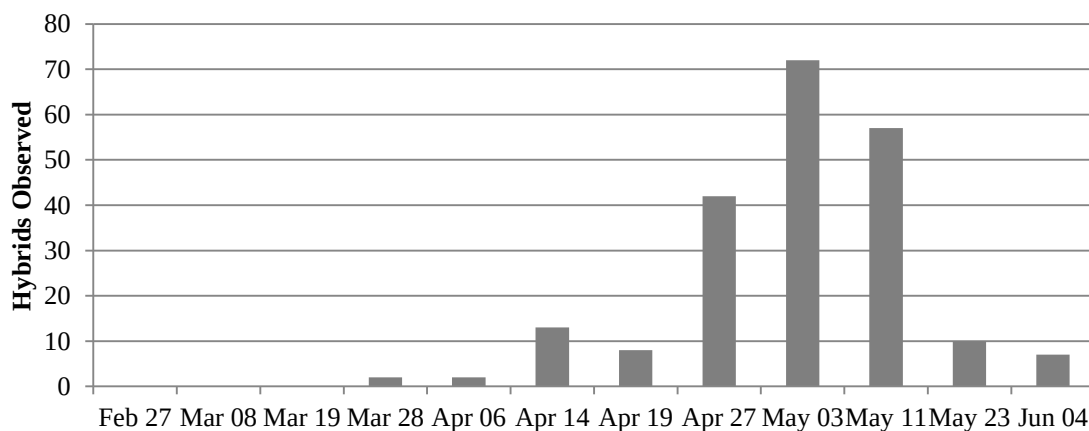


FIGURE 9. Cutthroat-Rainbow Hybrids counted during snorkel surveys in the Taylor River study section February 27 – June 4, 2012 (Reprinted from: Lough and Hay, 2012).

Growth and Migration of Juvenile Cutthroat Trout

Lough (1990) collected juvenile cutthroat trout by electrofishing the lower Taylor River in October, 1989 and to determine life history characteristics of both trout species. In summary, he found most of the sample (57%) was 0+ fry with the remainder composed of 1+ (23%) and 2+ (20%) parr (Table 4).

TABLE 4. Range and mean fork lengths of cutthroat trout juveniles sampled in the Taylor River, October 5 1989 (Reprinted from: Lough, 1990).

Factor	Age		
	0+	1+	2+
Number (% of sample)	30 (57%)	12 (23%)	11 (20%)
Mean Fork Length (mm)	52	100	142
Range (mm)	38 - 86	73 - 160	110 – 179

By comparing scale samples taken from juveniles and adults captured in Sproat Lake, Lough estimated the time of lake entry by examining the spacing on the annuli and found a marked difference between the size of 1 and 2 year migrants of both species (Table 5). Cutthroat had a greater mean length and range of lengths at age 2 than rainbow, and for cutthroat, the optimum size of lake migrants (i.e. the size overlap between 1 and 2 year lake migrants was 100 mm – 110 mm (Lough, 1991). Lough concluded that most cutthroat recruited to the lake as 1+ parr when they reached a size of ~100mm. The slow growth of juvenile fish is reflective of the very low Taylor River water temperatures and the fact that they spawn 3-5 months before rainbow trout.

TABLE 5. Age and range and mean fork lengths of cutthroat trout lake migrants determined from electrofishing samples taken in the Taylor River in 1989 and from fish collected by anglers in 1951-53; 1972; 979 and seines of the Taylor River 1980; 1987 and 1989 (Reprinted from: Lough, 1991).

Age of Lake Migrant Cutthroat Trout	N (%)	Fork Length (mm)	
		Range	Mean
1	7 (64)	44.7-110.5	65.5
2	4 (36)	97.4-165.8	141.4

Rainbow Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of rainbow trout captured in gillnets in Sproat Lake, from 1951-1977 is shown in Table 6.

TABLE 6. Total numbers, and minimum, maximum and mean fork length of rainbow trout captured in gillnets in Sproat Lake from 1951-1977 (Source: FISS; FLNRO files, Nanaimo; Lough, 1990).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1951-53*	10	279	490	407	---
1951	6	120	555	387	794
1952	7	180	533	383	964
1953	1	430	430	430	1134
1977	2	197	229	213	---

*Lough (1990) combined data from 1951-53. Method of capture reported in Lough (1990) was creel, troll, gillnet. It is unknown whether some of Lough's data is the same data reported in FISS so both data sets are shown.

Length Frequency Distributions

We've presented the length-frequency analyses of rainbow trout sampled during 1951-53, 1972 and 1989 in Figure 10.

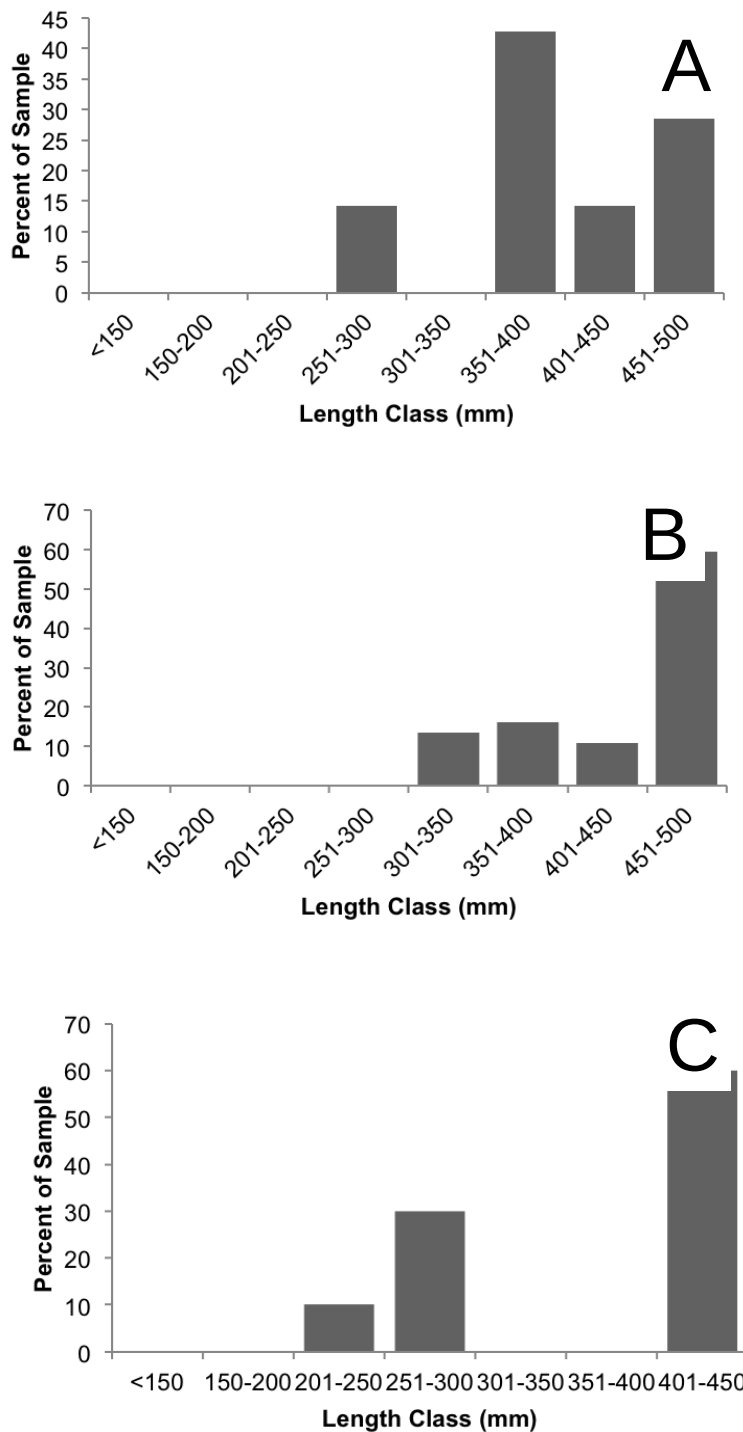


FIGURE 10. Length frequency distributions for rainbow trout sampled by anglers (A) in the 1950's (N=14), (B) the 1970's (N=37) and the 1980's (N=10) in Sprout Lake (Source: FLNRO files, Nanaimo).

Maturity

Investigators determined the sex of 18 rainbow trout captured in Sproat Lake in 1951-53 (Table 7). Of the 9 female rainbow trout sampled, only 4 were identified for maturity. One female was immature with a fork length of 295 mm. Three females were mature with fork length ranging from 400 mm - 490 mm. Of the 9 male rainbow trout sampled, only 2 were identified for maturity. One immature male rainbow had a fork length of 180 mm, while the single mature male had a fork length of 555 mm.

TABLE 7. Range and mean size of male vs. female rainbow trout captured in gillnets in Sprout Lake in 1951, 1952 and 1953. Note: sample sizes (N vs. n) are different because the maturity of only a portion of samples could be determined (Source: FLNRO files, Nanaimo; Lough, 1990).

Factor	Female rainbow N=9		Male rainbow N=9	
	Immature (n=1)	Mature (n=3)	Immature (n=1)	Mature (n=1)
Range	-	400-490	-	-
Mean	295	450	180	555

Age at Spawning

Lough's (1990) examination of rainbow trout scales revealed that most Sproat Lake rainbow trout spawn first at age 4 (24%), 5 (45%) or age 6 (24%) (Table 8). In his examination of spawners, Lough found that >40% were repeat spawners, and of these 31% spawned 2 or more times and 33% had spawned 5 times.

TABLE 8. Sample size, number and percent of repeat spawners and age and percent of sample at first spawning of rainbow trout collected by anglers in Sproat Lake and during a seine of the Taylor River, 1989 (Source: Lough, 1990).

Sample	Total Sample Size (N)	Number Previous Spawners	Percent of Sample	Age at First Spawning	Percent of Sample
Creel (Sproat Lake)	11	2	18	5	100
Seine (Taylor River)	68	28	41	3	4
				4	25
				5	39
				6	29
				7	4

Rainbow Trout Escapement

The total number of adult rainbow trout observed in snorkel surveys of the Taylor River between 1989 and 2011 is shown in Figure 11. No swims were conducted in 2006-07. The 2010 swim was cancelled due to high water conditions. On average 394 adult rainbow trout are observed during the survey, although technicians observed a high of almost 800 rainbow trout in the early 2000 swims. Rainbow trout counts decreased following that period and there has been an overall downward trend in rainbow trout counts in the past several years.

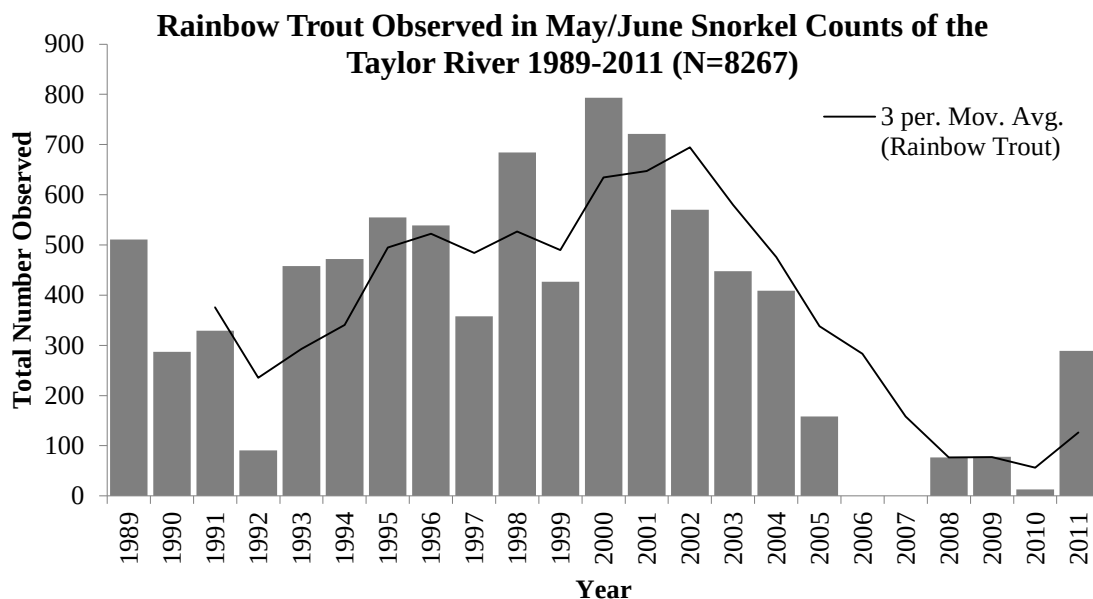


FIGURE 11. Total number and 3-year moving average of rainbow trout observed in May/June snorkel counts of the Taylor River from 1989 – 2011 (N=8267, Mean=394)). No swims in 2006-07. The 2010 swim was cancelled due to high water conditions (Source: FLNRO files, Nanaimo).

The total number and average number of rainbow trout observed by day in May snorkel counts of the Taylor River from 1989 – 2011 is shown in Figure 12 and 13. Note the peak of the run most likely occurs between early May (May 10) and the middle of the month (May 14 – 16) since this is when most fish are observed (Figure 11). As a result, swims conducted in June of 2008 and 2009 are likely missing most of the spawning adults and consequently, the downward trend observed after 2004 should be viewed with caution.

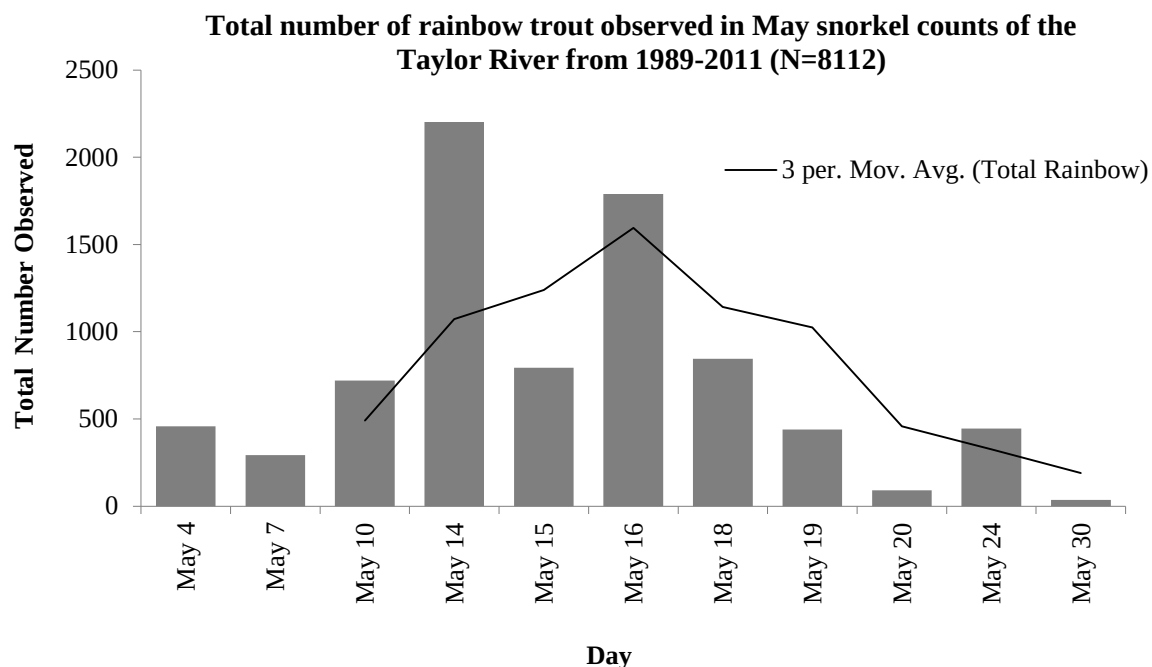


FIGURE 12. Total number of rainbow trout observed by day in May snorkel counts of the Taylor River from 1989 – 2011 (N=8112; mean=737). (Source: FLNRO files, Nanaimo).

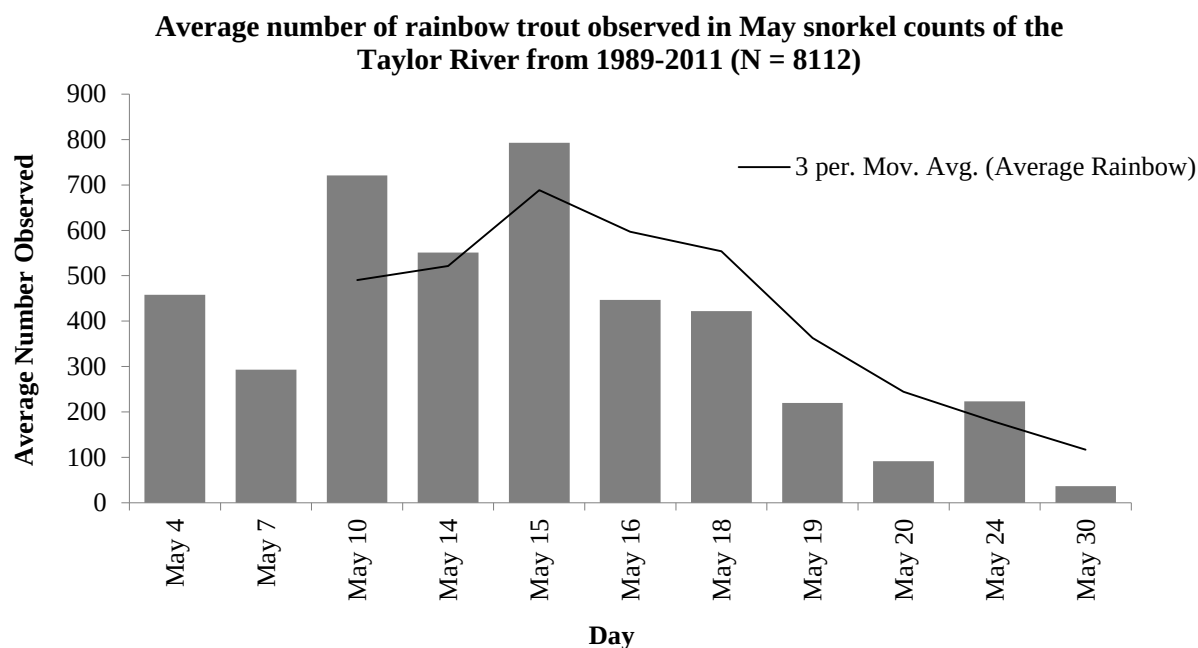


FIGURE 13. Average number of rainbow trout observed by day in May snorkel counts of the Taylor River from 1989 – 2011 (N=8112) (Source: FLNRO files, Nanaimo).

Rainbow trout observed during the snorkel surveys between February 27 and June 4, 2012 in the Taylor River are shown in Figure 14. Lough (2012) noted that rainbow trout began to enter the Taylor River in significant numbers in early May with peak counts in late May and early June. Lough (2012) found that rainbow trout in general tended to utilize the lower sections of the survey area, compared to cutthroat trout that utilize the upper sections. Surveys were conducted weekly in standard historical section of the lower Taylor River between Sutton Creek confluence

and the old logging bridge and extended to the mouth of Sproat Lake for one survey on May 11, 2012 (Lough 2012). A peak count of 421 rainbow trout occurred on May 21, 2012. Lough could not estimate the total run size for rainbow trout since the study ended soon after the peak counts for rainbow trout were observed.

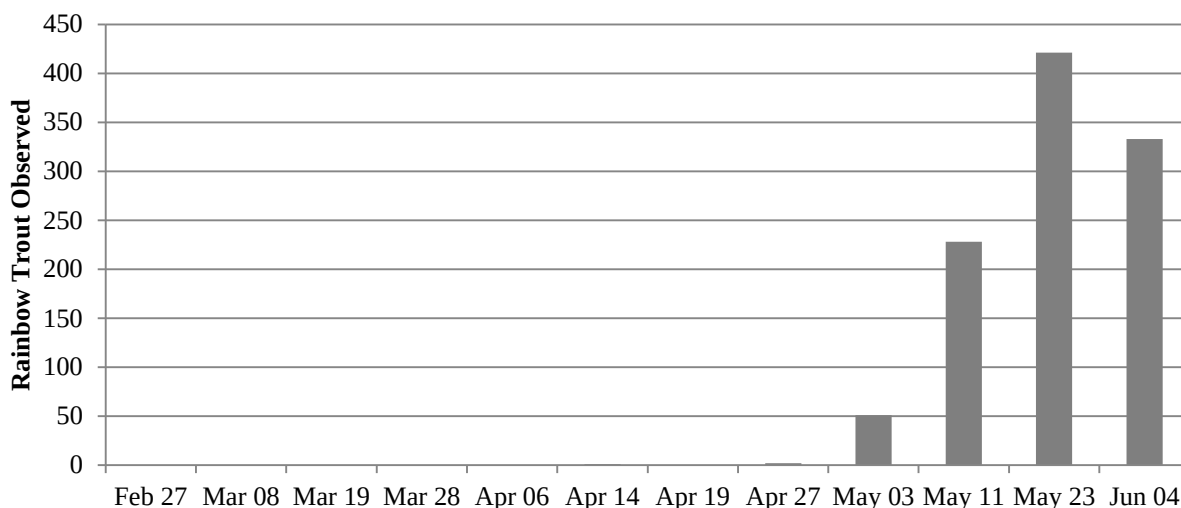


FIGURE 14. Rainbow trout counts during snorkel surveys in the Taylor River study section February 27 – June 4, 2012 (Reprinted from: Lough and Hay, 2012)

During the 2012 snorkel survey counts of the Taylor River, Lough (2012) observed cutthroat-rainbow hybrids (Figure 15). A peak count of cutthroat-rainbow hybrids was observed on May 3, 2012 with a total number of 72 hybrids counted. Lough (2012) observed that some hybrids appeared to be mostly cutthroat or rainbow with only a slight indication of hybridization. For example, Lough noted some trout appeared to be pure cutthroat except for a faint stripe along the lateral line.

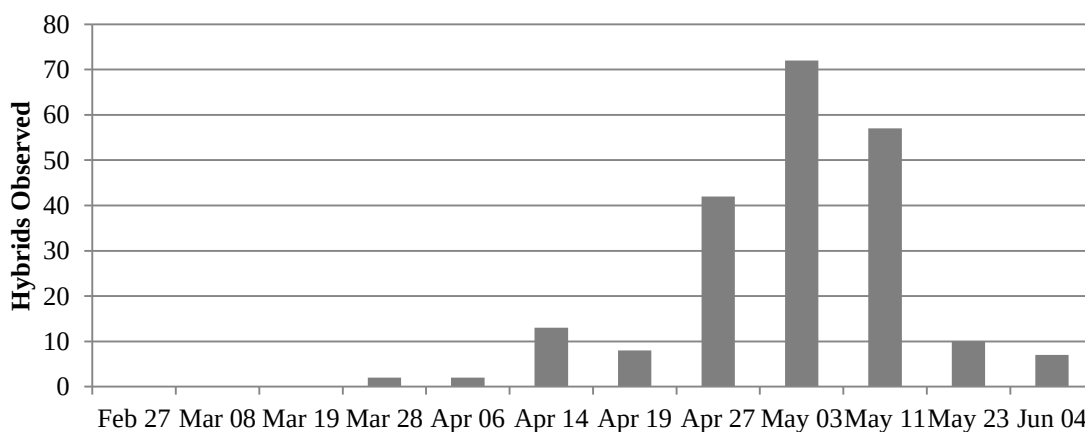


FIGURE 15. Cutthroat-Rainbow Hybrids counted during snorkel surveys in the Taylor River study section February 27 – June 4, 2012 (Source: Lough, 2012).

Growth and Migration of Juvenile Rainbow Trout

Lough (1990) found that rainbow trout recruit to Sproat Lake as 2+ year olds (Table 9). The majority of adult rainbow spawn in mid-May and fry do not reach swim-up until October of the

same year. Growth in the Taylor River where the majority of rainbow spawn is slow because of low water temperatures throughout the year.

TABLE 9. Age and range and mean fork lengths of rainbow trout lake migrants determined from electrofishing samples taken in the Taylor River in 1989 and from fish collected by anglers in 1951-53, 1972, 1979 and seines of the Taylor River 1980, 1987 and 1989 (Reprinted from: Lough, 1990).

Age of Lake Migrant Rainbow Trout	N (%)	Fork Length (mm)	
		Range	Mean
1	7 (37)	56.6-79.9	70.1
2	12 (63)	90.0-128.9	105.7

Juvenile Trout (Cutthroat and Rainbow)

Due to difficulties in discriminating between juvenile cutthroat and rainbow trout, both species were combined and referred to as juvenile trout during the 1989 electrofishing of Taylor River (Lough, 1990). The length frequency distribution of juvenile trout captured by electrofishing in Taylor River in October 1989 is presented in Figure 16. A total of 56 juveniles were captured and of those 53 had lengths and age data noted. Most juvenile trout captured were within the 26 – 50 mm length class (Table 10; Figure 17).

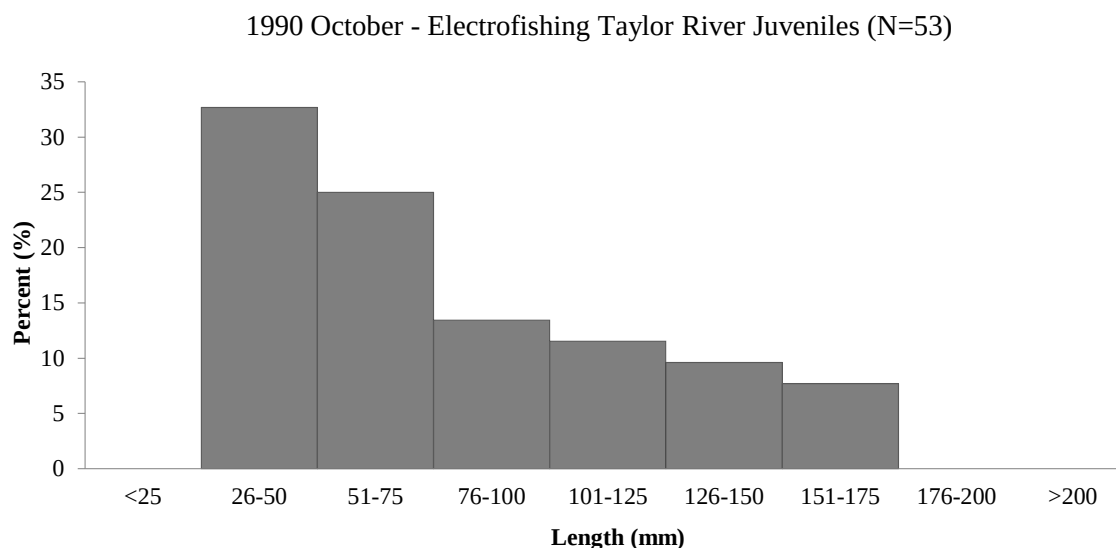


FIGURE 16. Length frequency of juvenile trout captured by electrofishing in Taylor River in October 1989 (N=53) (Source: Lough, 1990).

TABLE 10. Age and range and mean fork lengths of juvenile trout from electrofishing samples taken in the Taylor River in October 1989 (N=53) (Reprinted from: Lough, 1990).

Age of Juvenile Trout (years)	N (%)	Fork Length (mm)	
		Range	Mean
0+	30 (57)	38-73	52
1+	12 (23)	79-113	97
2+	11 (21)	118-179	146

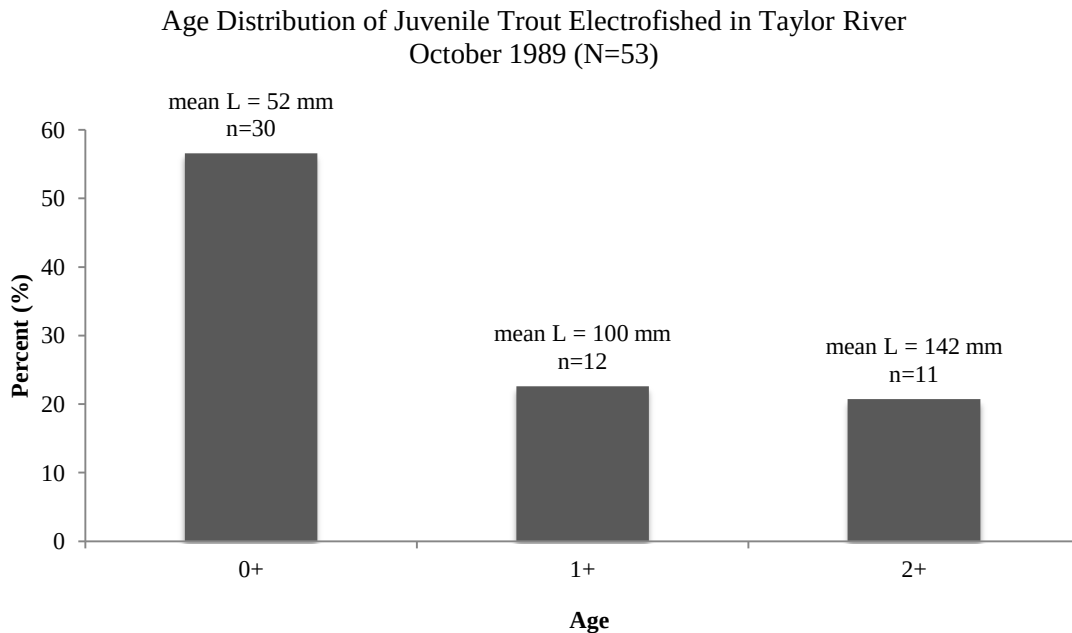


FIGURE 17. Age distribution of juvenile trout captured by electrofishing in Taylor River in October 1989 (N=53) (Reprinted from: Lough, 1990).

TABLE 11. Total number of cutthroat and rainbow trout caught in gillnets 1951, 1952, 1953 and 1977 in Sproat Lake; no information on the number or type of gillnets, the location or the soak time is provided in the files so no comparison of catch/unit effort can be made (Source: FISS; FLNRO files, Nanaimo).

Species	1951	1952	1953	1977
Cutthroat	12	26	8	8
Rainbow	6	7	1	2
Total	18	33	9	10

Sockeye/Kokanee Salmon

Kokanee/sockeye salmon have been observed by Ministry staff during snorkel surveys of the Sproat River. Up to 1,500 were observed in 1993 at the outlet of Sproat Lake and within the reach immediately downstream (Reid, G., 2009, pers. com.). Ministry staff also captured 3 fish identified as kokanee in Sproat Lake between 1952 and 1977. The lengths of these fish were 280 mm (1952); 262 mm (1953) and 184 mm (1977). The ages of the 280 mm and 262 mm kokanee sampled in 1952 and 1953 were age 3+ (Source: FLNRO files, Nanaimo). Lough (1991) notes that up to 80% of the Sproat Lake sockeye are shore spawners, and that sockeye fry emerge in the lake. He estimates that the sockeye pre-smolt population in Sproat Lake ranges from 5 – 30 million and could be a major food source for Sproat Lake cutthroat.

Fisheries and Oceans estimated sockeye escapements between 16,700 in 1966 and 47,000 in 1976 (Pollard and Lindsay, 1977) and in 1979 was 76,446 (Morely, 1981) estimated at a platform below Sproat Lake. Pollard and Lindsay (1977) note that the Taylor River may receive 50 – 70% of these sockeye. The total commercial catch of sockeye in Barkley Sound in 1976 was 680,000 fish of which 20 – 25% came from Taylor River-Sproat Lake.

A detailed assessment of the Taylor River by Pollard and Lindsay (1977) notes that sockeye migration extends from June to October and emergence is April – June depending on water temperatures. Fish spawn in beaches and river mouths through Sproat Lake and especially the mouth and Reach 1 of the Taylor River. Spawning peaks in September and most of these fish spawn at 4-5 years although they may range from 3 – 8 years (Pollard and Lindsay, 1977). These authors also note that emerging fry migrate immediately to Sproat Lake where they rear for 1 or 2 years before moving out to sea.

Lough (1990) compared life history characteristics from 1989 to historical data from 1951 and 1987 in order to detect any changes in population structure or growth patterns that may have occurred during that time. He notes that sampling methods and locations were not always consistent, (e.g. gillnetting vs. angling) which biased samples for some characteristics such as size. Nonetheless, Lough (1990) compared similar data and found that the mean size and age of cutthroat had decreased since 1951-53. The mean fork length of cutthroat in 1951-53 was 52 cm compared to 38.4 cm in 1989. He also found the mean age had decreased from 5.2 years to 4.4 years during that same time (Lough, 1991). In 1951-53, the sample contained fish that were 9 years of age and >70 cm, however, in 1989 the oldest cutthroat was 7 years and the largest was ~46 cm (Lough, 1990).

In his summary of the May 1989 derby at Sproat Lake, Lirette (1989) notes that the mean size of cutthroat spawning in the Taylor River appears to have declined from 1980 when it was 48.4 cm, to 1987 when it was 41.8 cm and that this appears to be due to the loss of older age classes in 1987. Note that derbies are held at the same time as the peak of escapement as determined by snorkel surveys of the Taylor River.

With respect to rainbow trout, Lough (1991) found that although rainbow fork lengths decreased slightly, the mean age in 1989 is older than in 1951-53. He also noted that it is unusual for Sproat Lake rainbow to grow >50 cm, however, the 1951-53 sample contained one fish that was almost 80cm – a size not seen in more recent samples even though 8 or 9 year-old fish were still present (Lough, 1991).

Fisheries Objectives and Management Strategies

Sproat Lake Angler Preference Survey

During the Ministry-implemented angler questionnaire survey in 1972 anglers were asked to provide a comparison between how they fished and the type of fishing they most preferred. Participants were asked to rank their preference for each fishery segment including size preference, possession limits, and restrictions to protect certain fisheries (Table 12). Most people (45%) said they fished Sproat Lake because it is close to their home fish and while 20% said they fished the lake because of the possibility of catching a large fish, most favour restrictions to protect trophy-size fish. Over 50% of anglers surveyed preferred a fishery that allowed them to keep 4 trout up to 30 cm in length.

TABLE 12. Results of an opinion and preference survey of Sproat Lake anglers 1976 (Source: Reid and Hazledine, 1976).

Question	Percent Response	Question	Percent Response
<u>Fishing Preferred</u>		<u>Protection of Trophy-Size Fish</u>	
salmon fishing-ocean	27.4	yes-favour restrictions	72.7
salmon fishing-stream	1.2	no-would not favour restrictions	18.2
steelhead	10.7	no opinion	9.1
trout fishing-lakes	45.2	<u>Bag Limits</u>	
trout fishing-streams	11.9	prefer no restriction	17.5
other	3.6	restrictive angling method	7.2
<u>Reason for Fishing Sproat Lake</u>		restrictive bag limit	43.3
close to home	45.1	restrictive seasons	26.8
surroundings	13.2	no opinion	5.2
good fishing	10.9	<u>Catch and Release (vs. Total Closure)</u>	
possibility of catching a large fish	20.9	yes	10.2
vacation	9.9	no	88.8
<u>Fish Size Preference</u>		no opinion	1.0
8 trout 15-25 cm	25.0	<u>Establish Trophy Fishing Waters</u>	
4 trout 30 cm	53.1	in favour	22.2
1 trout 40 cm	21.9	not in favour	68.7
<u>Present Limits</u>		no opinion	9.1
too many	22.7	<u>Introduce Trophy Fishing Stamp</u>	
just right	77.3	BC residents only	18.3
not enough	0.0	Canadian residents only	63.4
<u>Restrictions on Spawning and Rearing Areas</u>		open to all anglers	18.3
trout fishing should be restricted	83.7	<u>Amount Willing to Pay for Trophy Fishing Stamp</u>	
trout fishing should not be restricted	10.2	nothing	45.8
no opinion	6.1	\$1.00	29.2
		\$2.00	14.6
		more	10.4

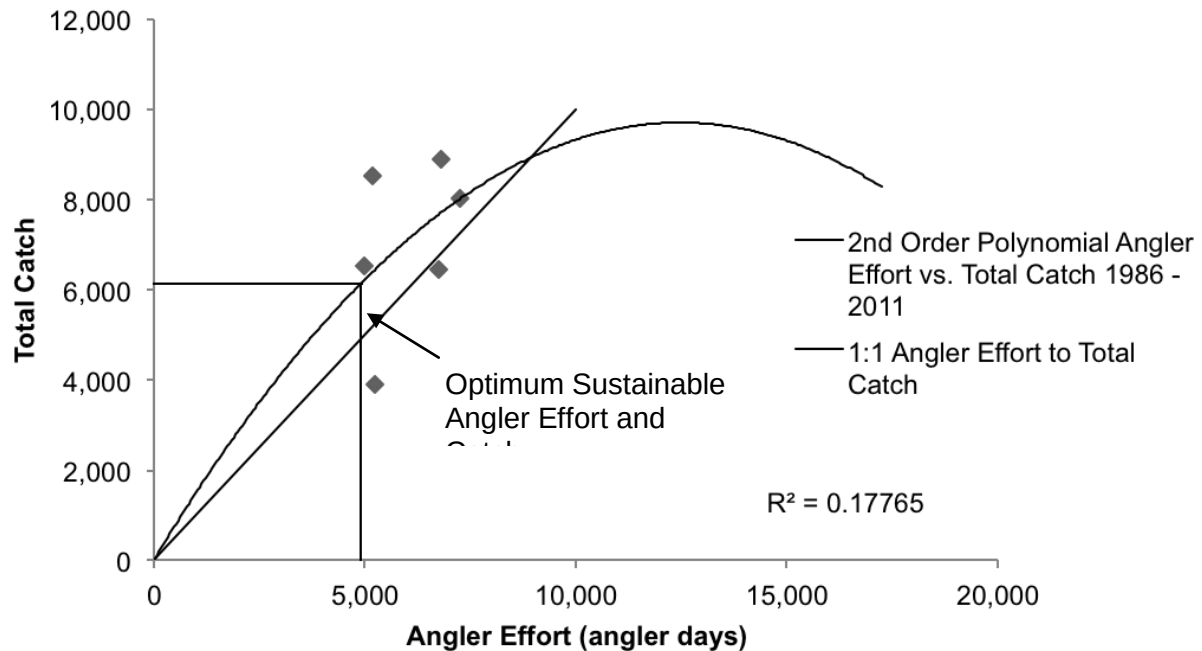


FIGURE 18. Angler effort (angler days) vs. total catch and maximum angler effort and catch at the current regulations at Sproat Lake 1986 – 2011. The point at which the 2nd degree polynomial curve diverges furthest from the 1:1 equilibrium line is where the optimum angler effort produces the highest sustained catch. In this case, 5,000 angler days would result in an optimal catch of ~6,000 fish and a success rate of 1.2 fish/day. However, we chose not to use this relationship to determine optimum and maximum levels at Sproat Lake because of the low R^2 value (0.3723) (Source: Aitzhanova, et al. 2003; Andrews, 2007; Silvestri, 2013 in prep.).

Appendix 21. Upper Campbell Lake

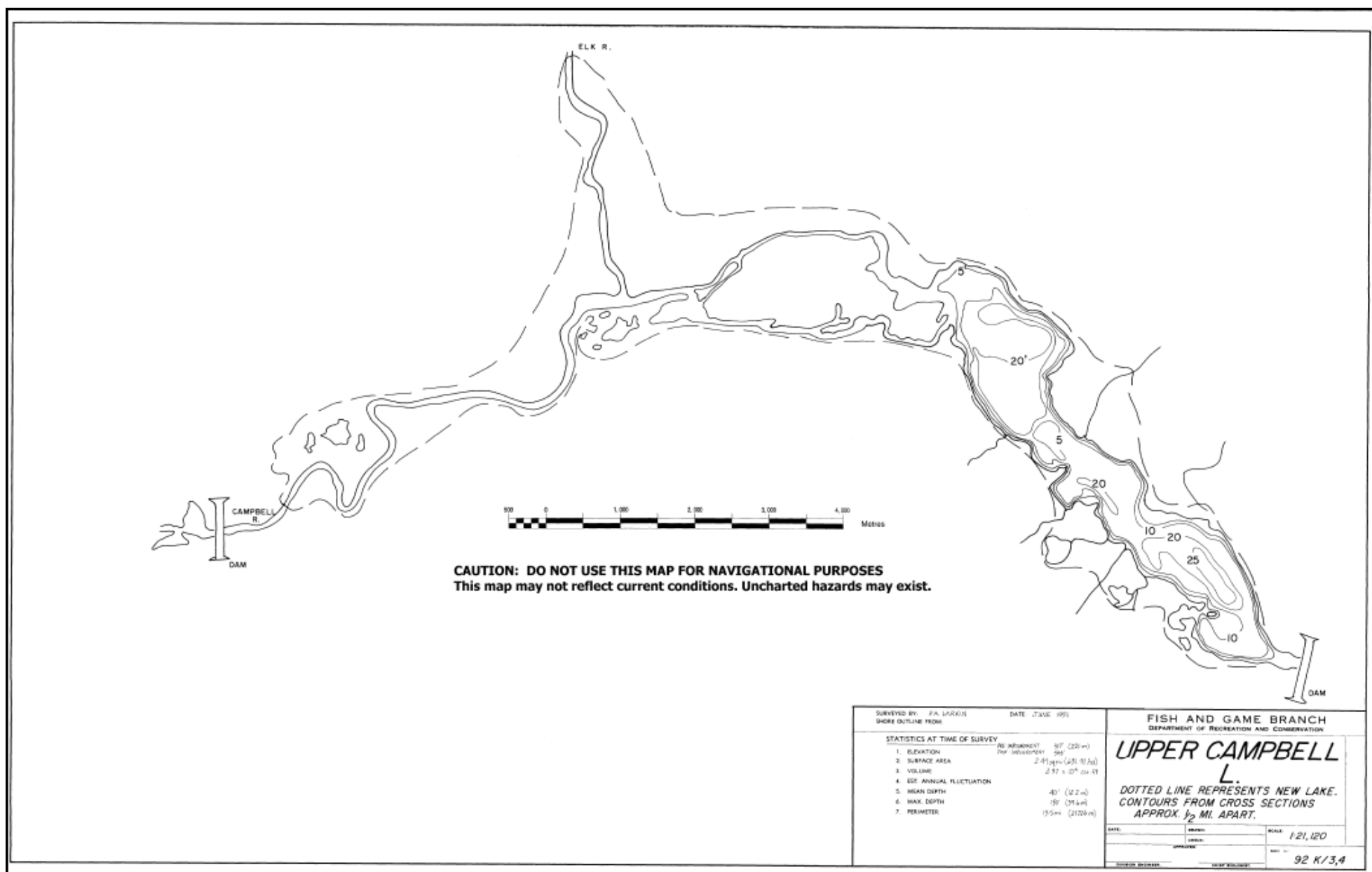


FIGURE 1. Bathymetric map of Upper Campbell Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Angling Data

Angler Creel Surveys

The first documented creel census for Upper Campbell Lake was in 1960 when a success rate of 0.8 fish/rod hour was estimated (Fisheries Branch data files). The total number of anglers and the total harvests were apparently not estimated. Success rates in Upper Campbell Lake have increased since 1978 and most recently (1986) were estimated at about 0.9 fish/rod hour. The species composition of the catches is not documented, except for the 1964 creel in which 62% of the catch was rainbow trout, 37% cutthroat trout and 1% Dolly Varden (Fisheries Branch, Nanaimo, data files). Hatfield (1982b) estimated total angling harvests in May 1982 to be 600-700 fish in Buttle Lake and 1500 in Upper Campbell Lake (Hirst, 1991b).

Stock Status Indicators

Cutthroat Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of 42 cutthroat trout captured in gillnets in Upper Campbell Lake in 2010 is shown in Table 1. Fork length ranged from 120 mm – 454 mm, with a mean fork length of 304 mm and a mean weight of 404 g.

TABLE 1. Total numbers, and minimum, maximum and mean fork length of cutthroat trout captured in gillnets in Upper Campbell Lake in 2010 (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
2010	42	120	454	304	404

Length Frequency Distributions

The length frequency distribution of cutthroat trout captured in gillnets in 2010 is shown in Figure 2. A total of 42 cutthroat trout were captured in 2010 ranging from <200 mm to >500 mm. The highest percentage of fish captured (16%) were <200 mm and 401-425 mm. More than half of the cutthroat captured were >300 mm and almost 10% of the total were 426 mm.

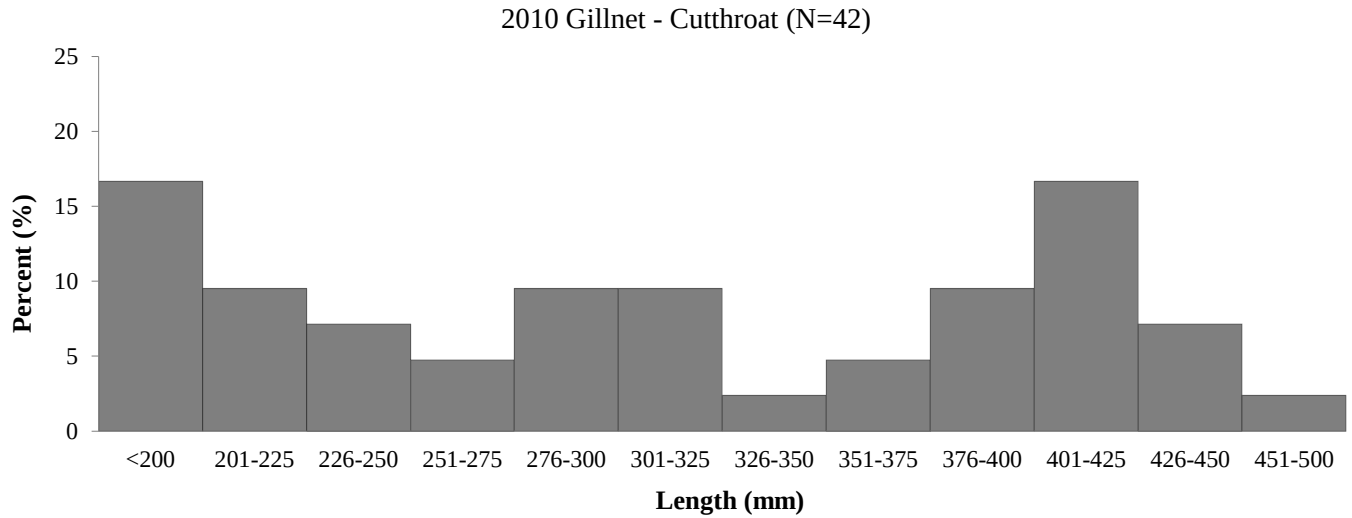


FIGURE 2. Length frequency of cutthroat trout captured by gillnet in Upper Campbell Lake, September 2010 (N=42) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

We've presented the length-weight relationship for Upper Campbell Lake cutthroat trout captured in Upper Campbell Lake and the Elk River in Figure 3. At ~100 mm, cutthroat are <20 g; at 300 mm they are roughly 300 g. Once cutthroat are >400 mm, they reach ~450 g and at 500 mm these fish are >1,000 g (>2 lb).

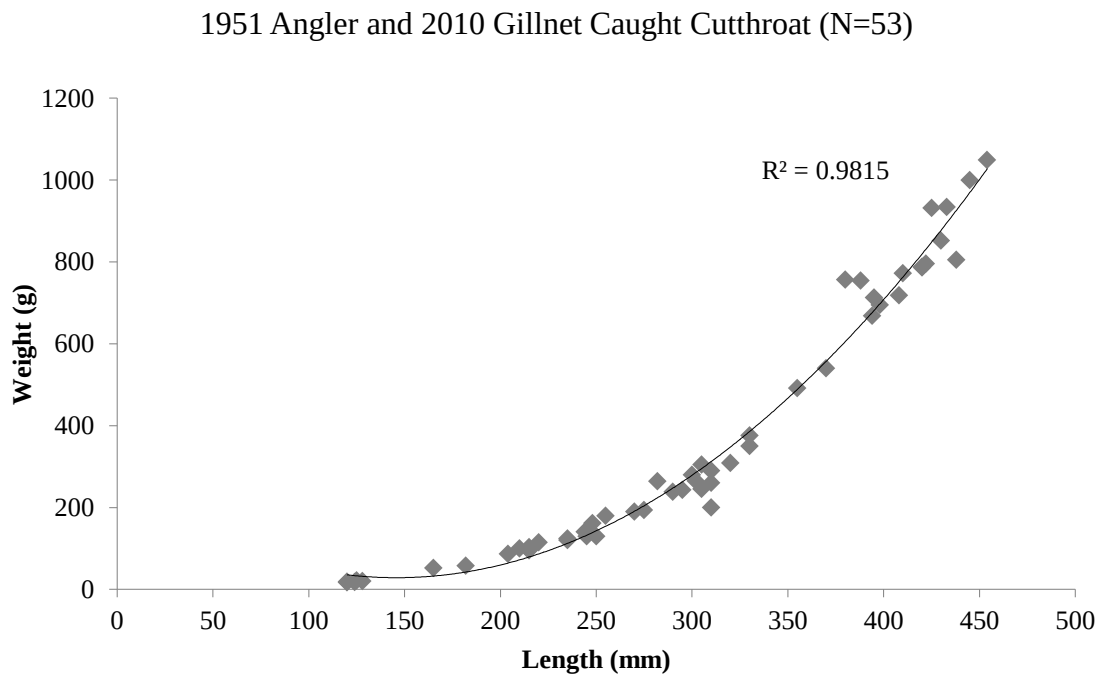


FIGURE 3. Length-weight relationship for cutthroat trout captured by angling in June 1951 and gillnet in September 2010, Upper Campbell Lake (N=53) (Source: FLNRO files, Nanaimo).

Age-at-Length of Cutthroat Trout

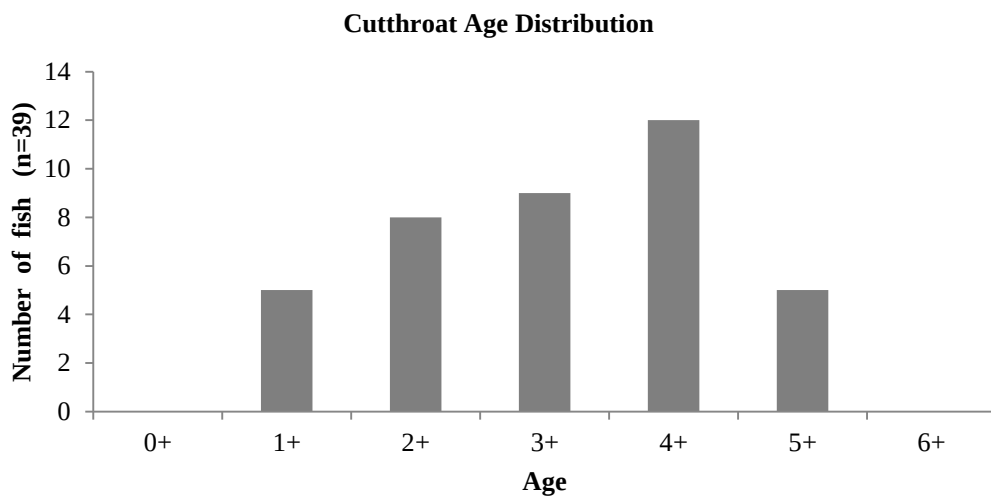


FIGURE 4. Age distribution of cutthroat trout captured by gillnet in Upper Campbell Lake, September 2010 (N=39) (Reprinted from: Lough, 2010).

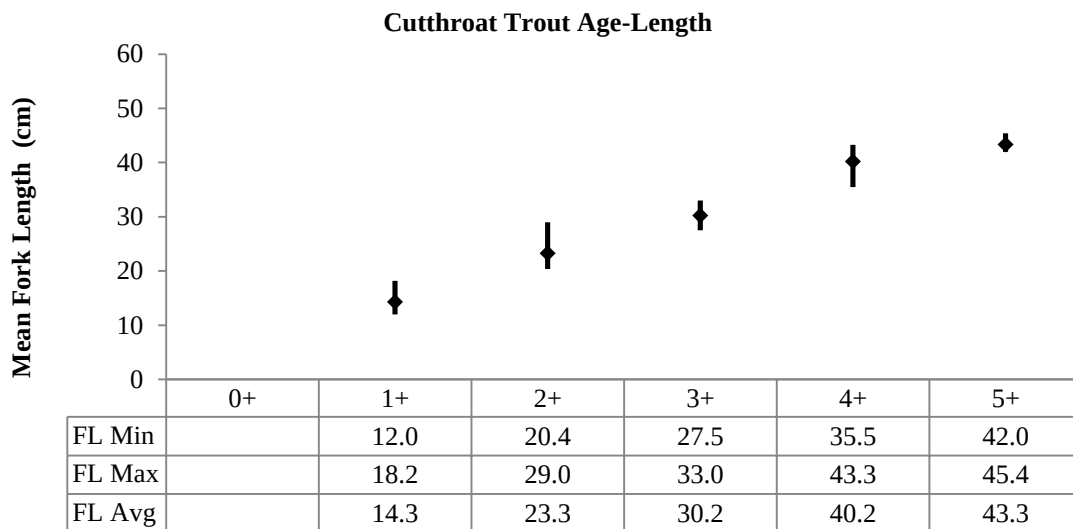


FIGURE 5. Age-length of cutthroat trout captured by gillnet in Upper Campbell Lake, September 2010 (N=39) (Reprinted from: Lough, 2010).

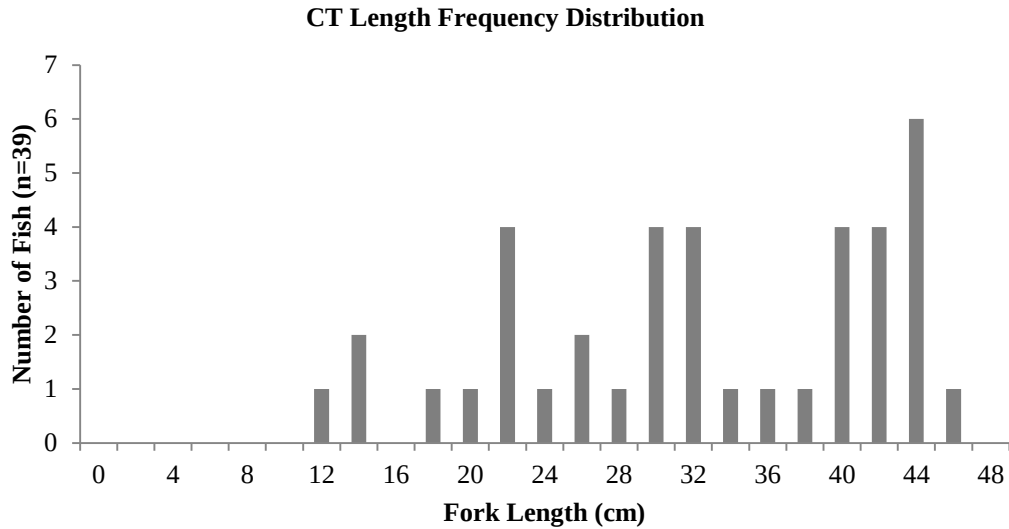


FIGURE 6. Length frequency of cutthroat trout captured by gillnet in Upper Campbell Lake, September 2010 (N=39) (Reprinted from: Lough, 2010).

Tredger (1979) studied the migration patterns of Upper Campbell Lake stocks and found although some fish migrate as fry, most cutthroat trout migrate to the lake in their second year (i.e. age 1+) (Table 2). At this age, cutthroat trout are, on average ~100 mm and 11 g (Table 3).

TABLE 2. Summary of migration patterns of juvenile cutthroat trout to Upper Campbell Lake as determined by scale analysis (Source: Tredger, 1979).

Year of Sample	Number Readable	% Migrating to Upper Campbell Lake		
		Fry	1+	2+
1951	8	50	50	0
1963-64	10	10	80	10
1978	2	0	0	100

TABLE 3. Age, length, weight data of cutthroat trout in tributaries to Upper Campbell Lake, September/October 1978. Tributaries included: Side channels of the Upper Elk River, Upper Mainstem Elk River and an unnamed tributary (Source: Tredger, 1979).

Age	N	Mean Length (mm)	Mean Weight (g)
0+	24	48.4	1.5
1+	17	95.9	11.4

Maturity and Size of Male and Female Cutthroat Trout

Maturity data for male and female cutthroat captured in Upper Campbell Lake are presented in Table 4. In 1951, immature females ranged from 215 mm to 330 mm while in 2010, immature females were ~400 mm. The mean size of immature females in 1951 was ~250 mm while in 2010 it was almost 350 mm. In 2010, mature females ranged from ~400 mm to 450 mm and averaged 425 mm.

In 1951, immature males ranged from 220 to 380 mm and averaged ~290 mm; while in 2010 immature males ranged from 120 to 420 mm and averaged 311 mm. In both 1951 and 2010,

mature male cutthroat were captured. In 1951, these fish averaged 310 mm while in 2010 they averaged 391 mm.

TABLE 4. Range of lengths and mean sizes of male and female cutthroat trout captured by angling in Upper Campbell Lake in 1951 (Source: FLNRO files, Nanaimo).

Factor	1951				2010			
	Female N=5		Male N=8		Female N=15		Male N=16	
	Immature (n=4)	Mature (n=1)	Immature (n=4)	Mature (n=2)	Immature (n=8)	Mature (n=7)	Immature (n=14)	Mature (n=2)
Range	215-330		220-380	310	235-438	398-454	120-420	388-394
Mean	258	305	289	310	346	425	311	391

Adult Cutthroat Trout Observed in Snorkel Surveys

The Vancouver Island Fisheries Section has been monitoring key streams throughout the region to assess the status of key stocks. The Elk River system, a major Upper Campbell Lake spawning stream is one of those key streams monitored annually since 1990 for rainbow trout spawning escapement. The counts are usually done during the month of June.

Data from counts conducted in all sections of the Elk River since 1990 is presented in Figure 7. Data for counts from individual reaches (Upper, Middle and Lower) is presented in Figures 8 and Figure 9. Counts were not completed in 1997, 1999, 2005, 2011 and 2012. In 2010 the number of cutthroat trout observed increased from previous years. In 2009, counts were lower than the previous 3 years but still higher than any year prior to 2005. This pattern has been observed in both the Upper and Lower reaches of this river.

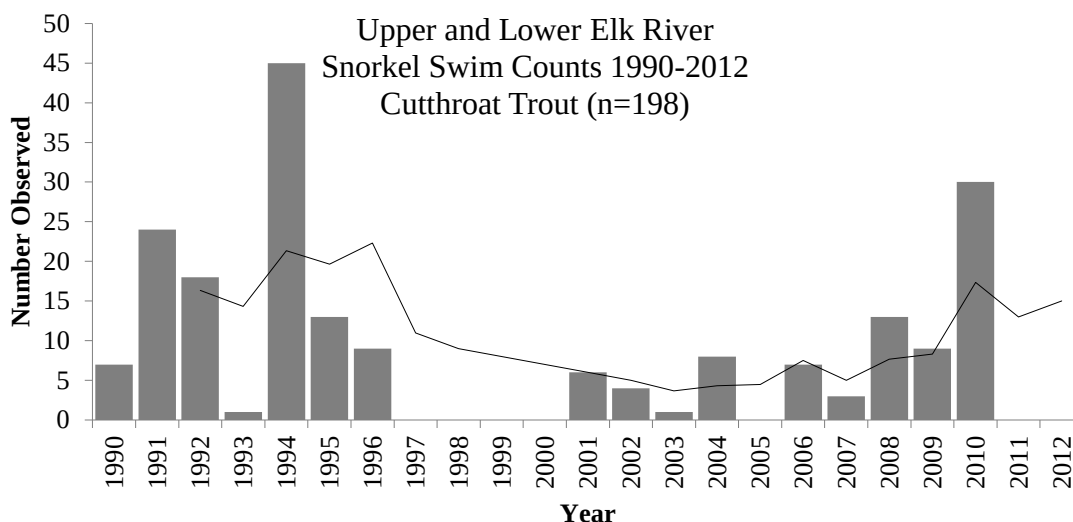


FIGURE 7 Total number and 3-year moving average of cutthroat trout observed in June snorkel counts of the Elk River 1990 – 2012 (N=198; average 11/year) (Source: FLNRO files, Nanaimo).

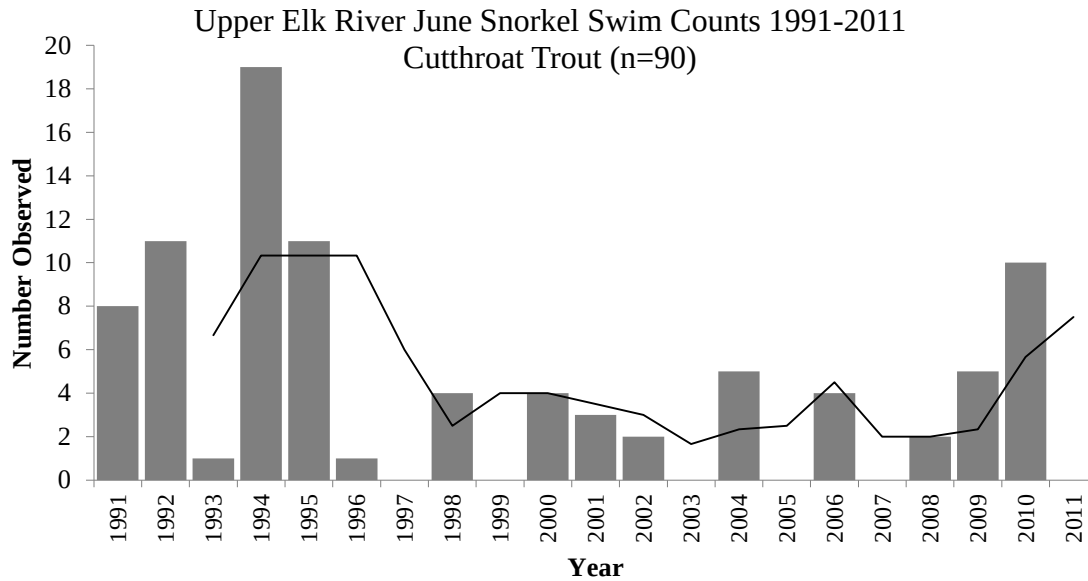


FIGURE 8. Total number and 3- year moving average of cutthroat trout observed in June snorkel counts of the Upper Elk River from 1990 – 2011 (N=90; average 5/year); the Upper Elk River is defined as the confluence of Drum Creek to the highway bridge or pullout (Source: FLNRO files, Nanaimo).

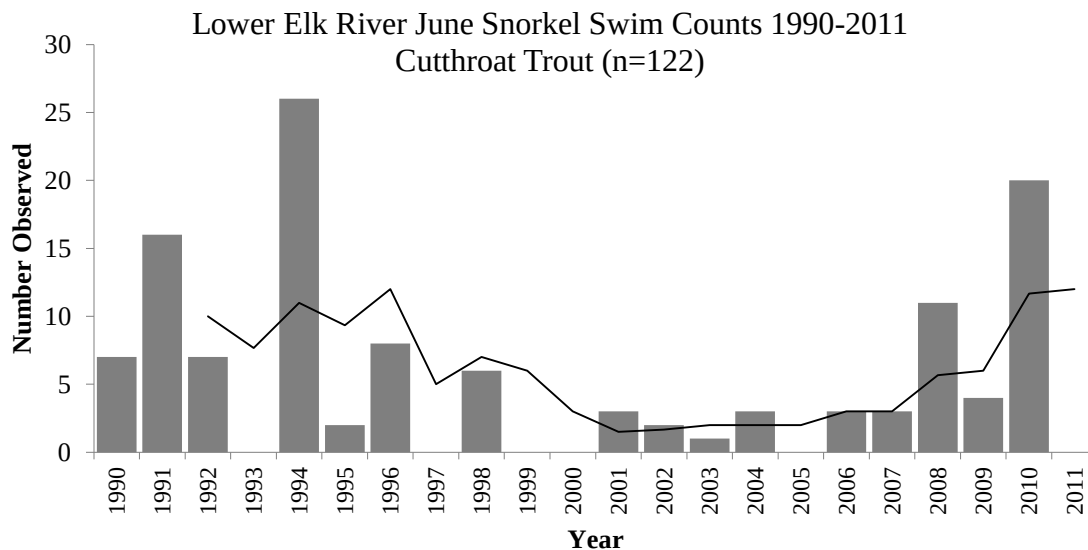


FIGURE 9. Total number and 3-year moving average of cutthroat trout observed in snorkel counts of the Lower Elk River 1990– 2011 (N=122; mean = 7/year); the Lower Elk River is defined as the water gauging station to Upper Campbell Lake (Source: FLNRO files, Nanaimo).

We reviewed number of cutthroat trout observed by date since 1990 in the Elk River to determine the peak spawning time and present this information in Figure 10. Cutthroat begin

arriving in the river in late March and early April and again in mid August.

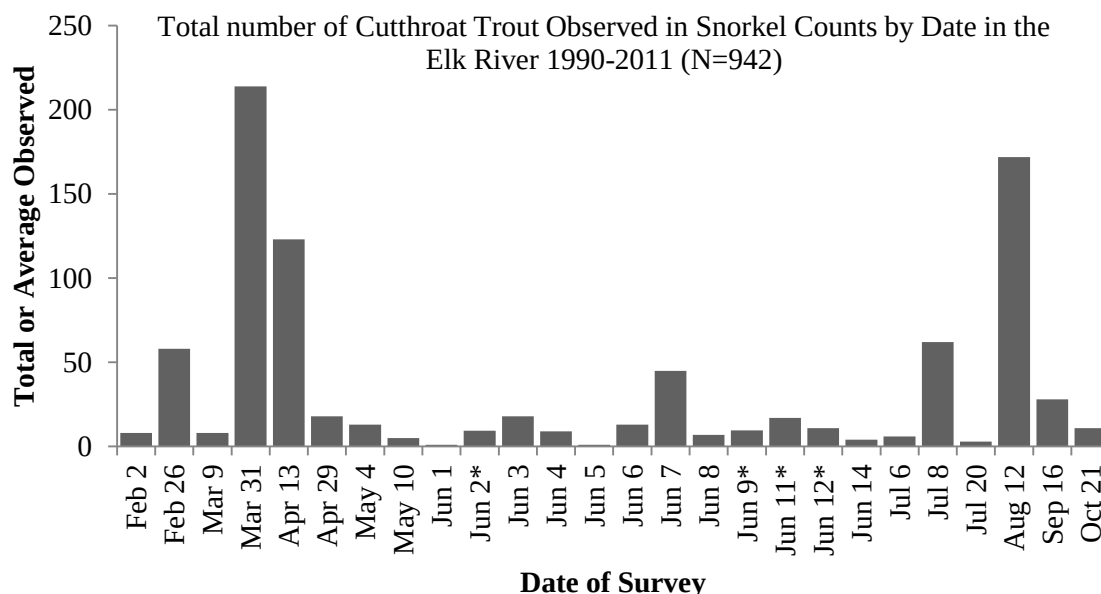


FIGURE 10. Total number of cutthroat trout observed in snorkel counts by date in the Elk River 1990 – 2011 (N=942); counts on June 2; June 9, June 11 and June 12 are average numbers of cutthroat observed as counts were done on those same dates on more than one year. Also, this graph includes adults and juveniles (Source: FLNRO files, Nanaimo).

The total number of cutthroat trout observed by month in the Upper, Middle and Lower Elk River is presented in Figures 11, 12 and 13. Spawning cutthroat move into the Upper and Middle Elk River in March and April (Figures 11 and 12). Cutthroat trout are also observed in the Lower Elk during June and August (Figure 13). It is likely that these fish are following spawning rainbow into the lower reach of the Elk during those months.

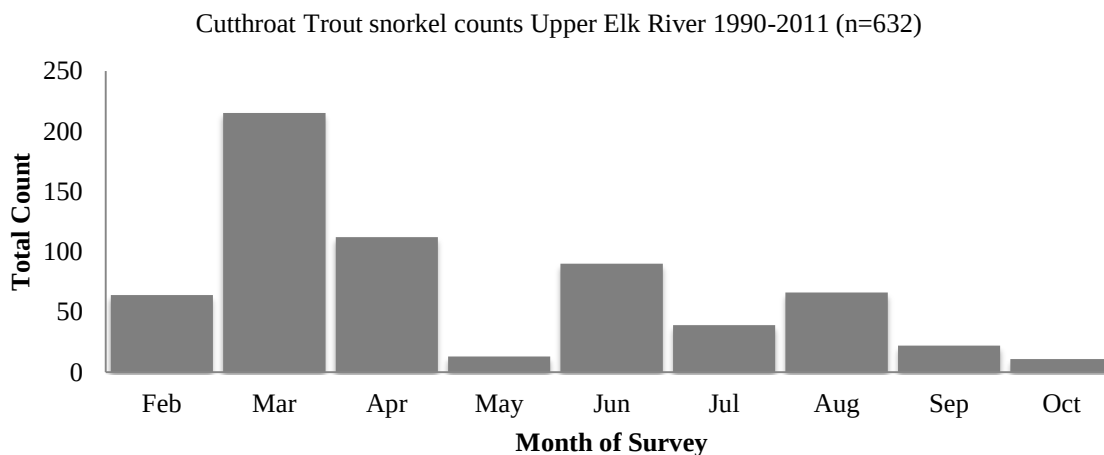


FIGURE 11. Total number of cutthroat trout observed in snorkel counts of the Upper Elk River by month from 1990 – 2011 (N=632); the Upper Elk River is defined as the confluence of Drum Creek to the highway bridge or pullout (Source: FLNRO files, Nanaimo).

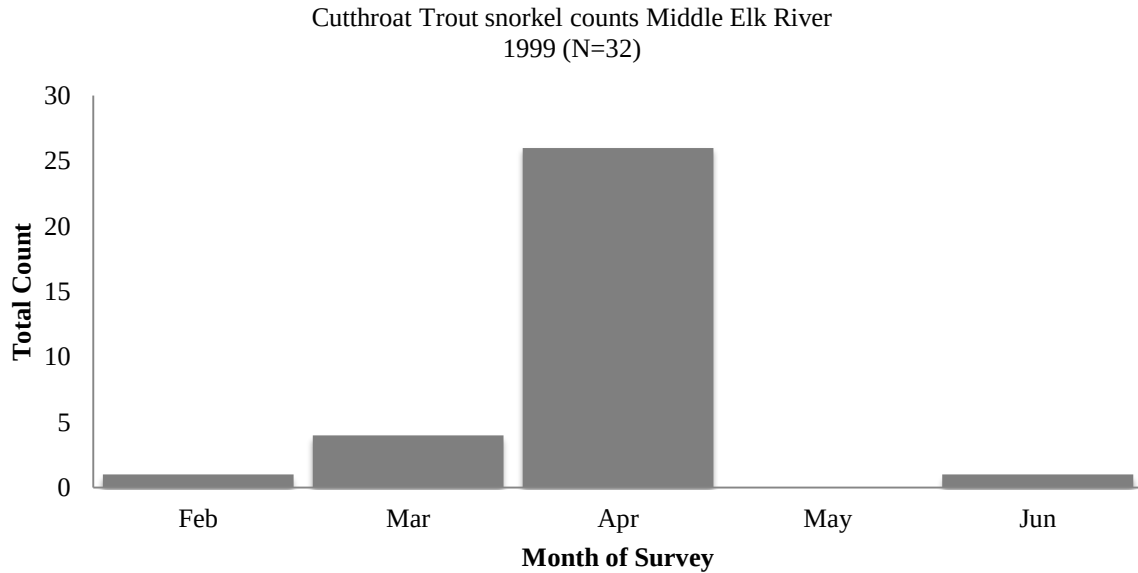


FIGURE 12. Total number of cutthroat trout observed in snorkel counts of the Middle Elk River by month in 1999 (N=32). Note: the Middle Elk River is defined as the highway bridge to the water gauging station to Upper Campbell Lake. In some years, Upper and Middle Elk are combined and defined as Drum Creek to water gauging station (Source: FLNRO files, Nanaimo).

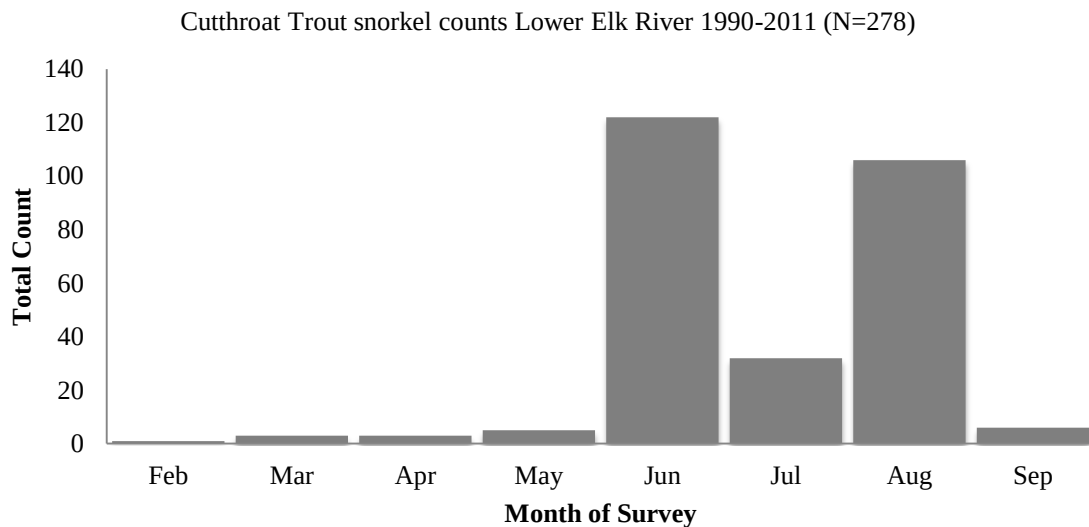


FIGURE 13. Total number of cutthroat trout observed in snorkel counts of the Lower Elk River by month from 1990 – 2011 (N=278); the Lower Elk River is defined as the water gauging station to Upper Campbell Lake (Source: FLNRO files, Nanaimo).

Snorkel surveys to count spawning cutthroat in tributaries to Upper Campbell Lake were conducted by the Ministry in 1998 and 1999 and the data is presented in Figure 14. Most fish were seen in Drum creek during 2 peaks – one at the end of March and a second at the end of April.

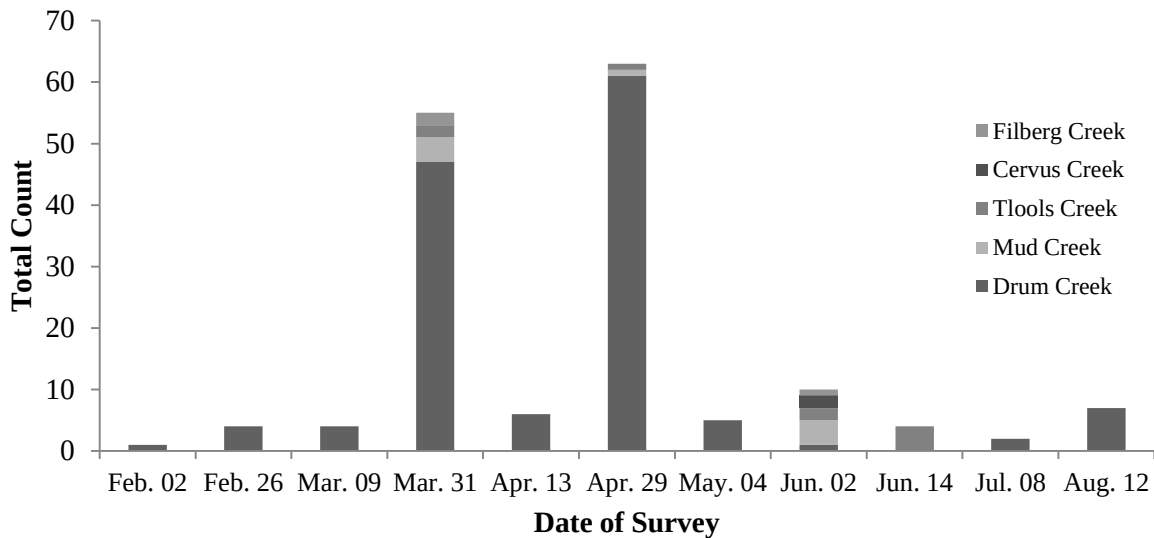


FIGURE 14. Number of adult cutthroat trout observed in Filberg, Cervus, Tloos, Mud and Drum Creek by date in 1998 and 1999 (Source: FLNRO files, Nanaimo).

Snorkel surveys to count spawning cutthroat in tributaries to Upper Campbell Lake were conducted weekly between December 18 – March 31, 2003 and the data is presented in Figure 6. The streams snorkelled included Crest Creek, Mud Creek and Drum Creek which eventually join the Elk River. A total of 32 adult cutthroat trout were observed over the survey period (Table 5). Most fish entered the study streams after Feb 21, 2003. Hay and Lough (2003) noted that the number of observed cutthroat trout represents only the minimum run size, since the stream residence time of these spawners appears to be brief. Hay and Lough (2003) observed on several occasions gravid cutthroat trout holding in the Elk River at the mouth of Drum Creek, suggesting that they had migrated upstream from Upper Campbell Lake to spawn. Hay and Lough (2003) predicted that the fish move into the stream at night, spawn and depart the area in a matter of days (Figure 15).

TABLE 5. Summary of fish counts, red counts, water temperature and discharge during weekly surveys between December 18, 2002 and March 31, 2003 (Source: Hay and Lough, 2003).

Date	Number of Cutthroat	Number of Cutthroat Redds	Spot Temp. Drum Creek (° C)	Metered Discharge Drum Creek (cms)
18-Dec	1		4.0	3.43
25-Jan	1		3.0	10.20
14-Feb	2		4.0	0.62
21-Feb	5	2	4.0	0.80
28-Feb		9	3.5	0.36
17-Mar	1	14	5.0	3.56
24-Mar	11	21	4.0	2.22
31-Mar	11	45	5.0	4.4

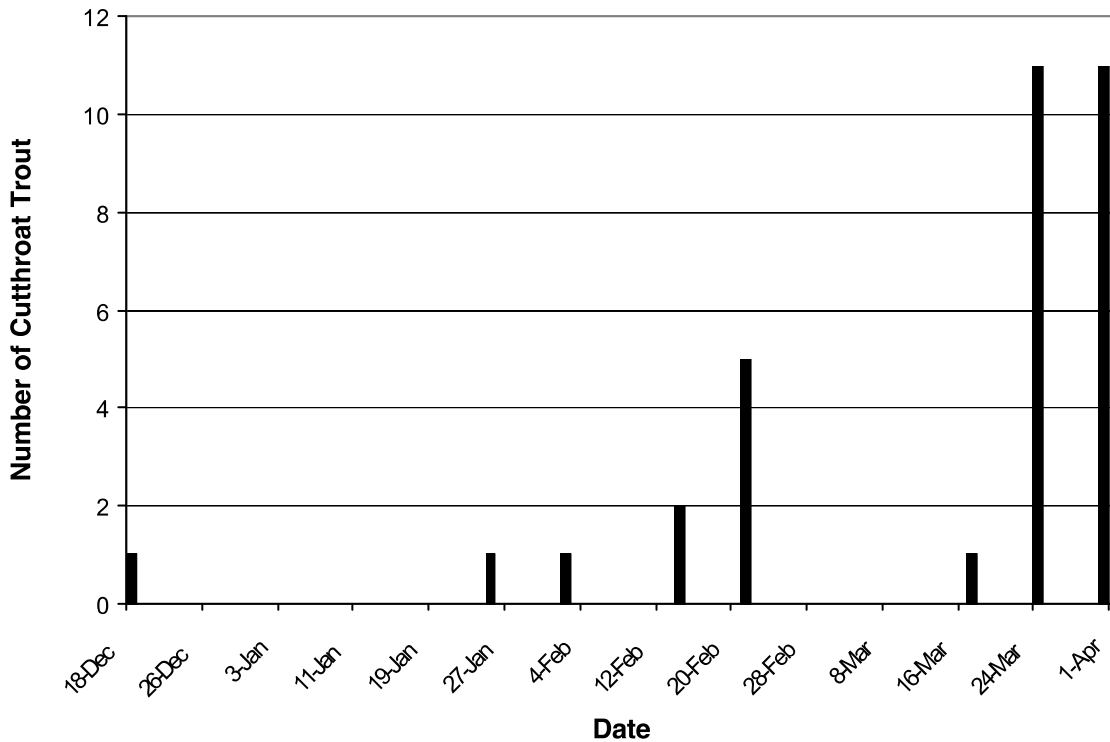


FIGURE 15. Adult cutthroat trout observed in weekly snorkel surveys in Crest Creek, Mud Creek and Drum Creek between December 18, 2002 and March 31, 2003 1999 (Reprinted from: Hay and Lough, 2003).

Hay and Lough (2003) used the weekly count of new redds to indicate cutthroat trout spawning activity, where a total of 91 cutthroat redds were observed during the survey period (Figure 16). The earliest redds were found in Drum Creek on February 21, 2003. Spawning activity increased during the week of February 28 to peak in the last two weeks of March when over 80% of the total redds were counted. Hay and Lough (2003) noted little spawning activity in Mud Creek prior to March 17, 2003 and found that peak spawning activity appeared shortly after that date.

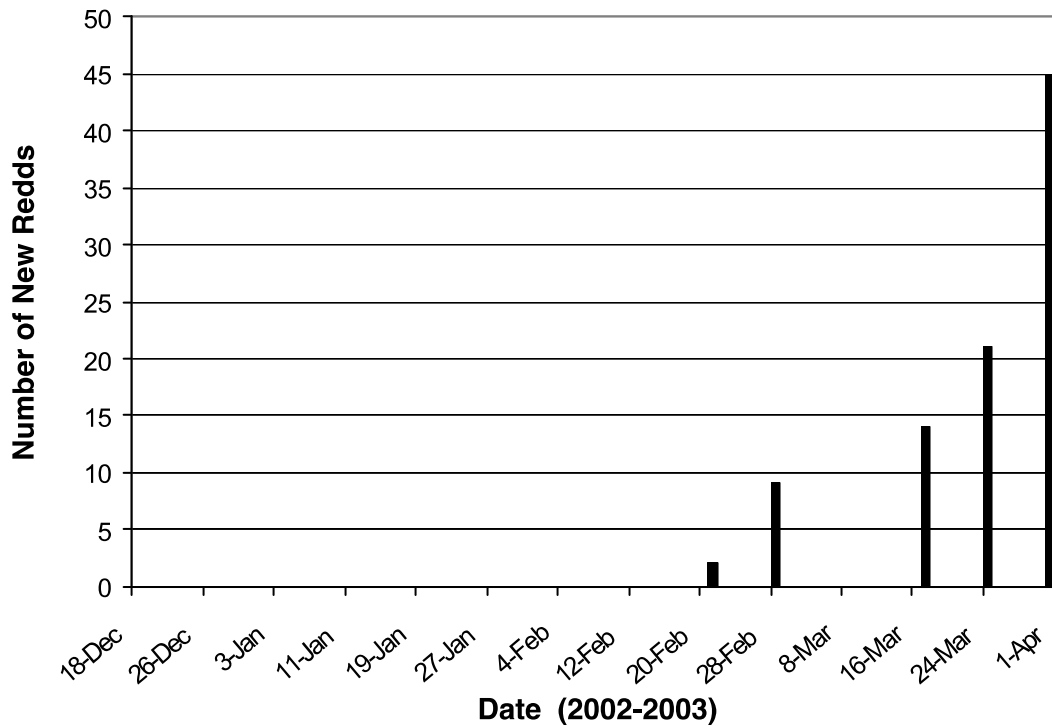


FIGURE 16. Number of new cutthroat trout redds observed in weekly snorkel surveys in Crest Creek, Mud Creek and Drum Creek between December 18, 2002 and March 31, 2003 1999 (Reprinted from: Hay and Lough, 2003).

Hay and Lough (2003) visually estimated the amount of functioning spawning habitat gravel in the study area during low and moderate flows on March 24, 2003. Trout and Char spawning gravel appeared to be quite limited. Hay and Lough (2003) found that Crest Creek (between Crest Lake and Mud Lake) and upper Mud Creek were essentially devoid of spawning habitat, except for a small patch of poor quality gravel at the outlet of Crest Lake.

Rainbow Trout

Population Data

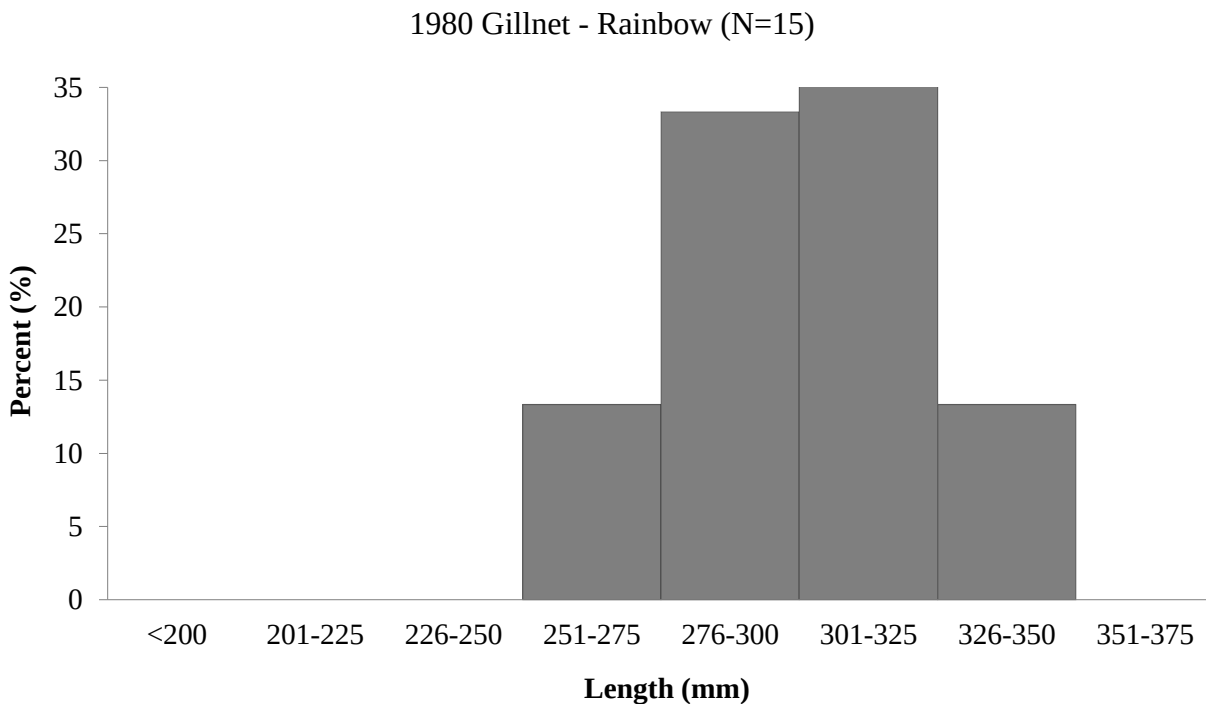
The minimum, maximum and mean length (mm) and weight (g) of rainbow trout captured in gillnets in Upper Campbell Lake in May-June 1980 and September 2010 is shown in Table 6. Minimum length was 251 mm in 1980 and 105 mm in 2010. Maximum fork length was 340 mm in 1980 and 280 mm in 2010. The mean fork length rainbow trout caught in 1980 was 300 mm and 150 mm in 2010. The mean weight of rainbow caught in 1980 was 280 g while in 2010 the mean weight was 50 g. Although the sample size was substantially large in 2010, minimum, maximum and mean sizes of rainbow trout captured were much smaller in this most recent sample. On average, rainbow trout were half the size in 2010 than they were 3 decades ago.

TABLE 6. Total numbers, and minimum, maximum and mean fork length of rainbow trout captured in gillnets in Upper Campbell Lake in May-June 1980 and September 2010 (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1980	15	251	340	299.7	279.8
2010	93	105	280	149.7	50.4

Length Frequency Distributions

The length frequency distribution of rainbow trout captured by gillnet in 1980 and 2010 is shown in Figure 17. A total of 15 rainbow trout were captured in gillnets in 1980 while 93 rainbow trout were captured in 2010. In 1980, fifteen rainbow trout caught in gillnets ranged in size from 251 – 340 mm. The modal length of the fish sampled in 1980 was between 301 mm – 325 mm. The modal length of the fish sampled in 2010 was <200 mm, representing approximately 90% of the fish captured that year. In 1980, ~10 % of the sample was > 325 mm. Note that the sample size from 1980 was small and may not have been representative of the lake's population of rainbow trout.



2010 Gillnet - Rainbow (N=93)

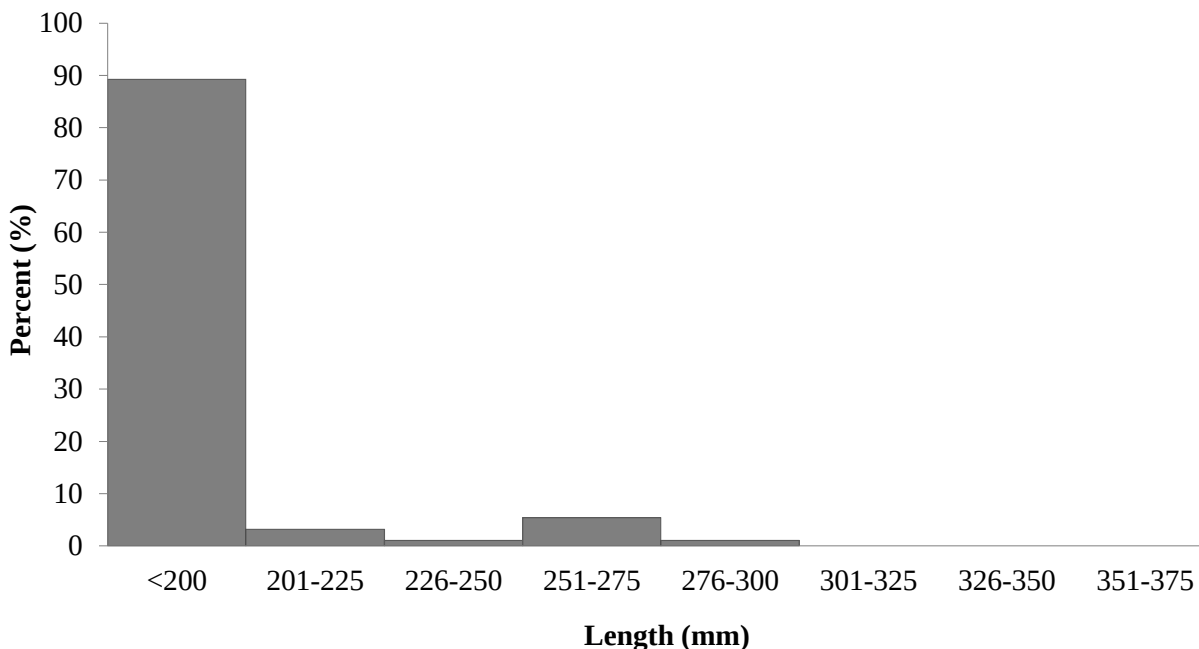


FIGURE 17. Length frequency of rainbow trout captured in gillnets in Upper Campbell Lake, 1980 (N=15); 2010 (N=93) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

We combined the angling and gillnet caught rainbow and calculated the length-weight relationship for Upper Campbell lake rainbow (Figure 18). The smallest rainbow captured was ~175 mm and 50 g. Most fish were >250 mm and weighed between 125 and 250 g. Only one captured fish was > 300 mm and it weighed only 250 g. Rainbow trout that reach ~300 mm are ~400 g (<1 lb).

1951 Angler and 1980 and 2010 Gillnet Caught Rainbow (N=122)

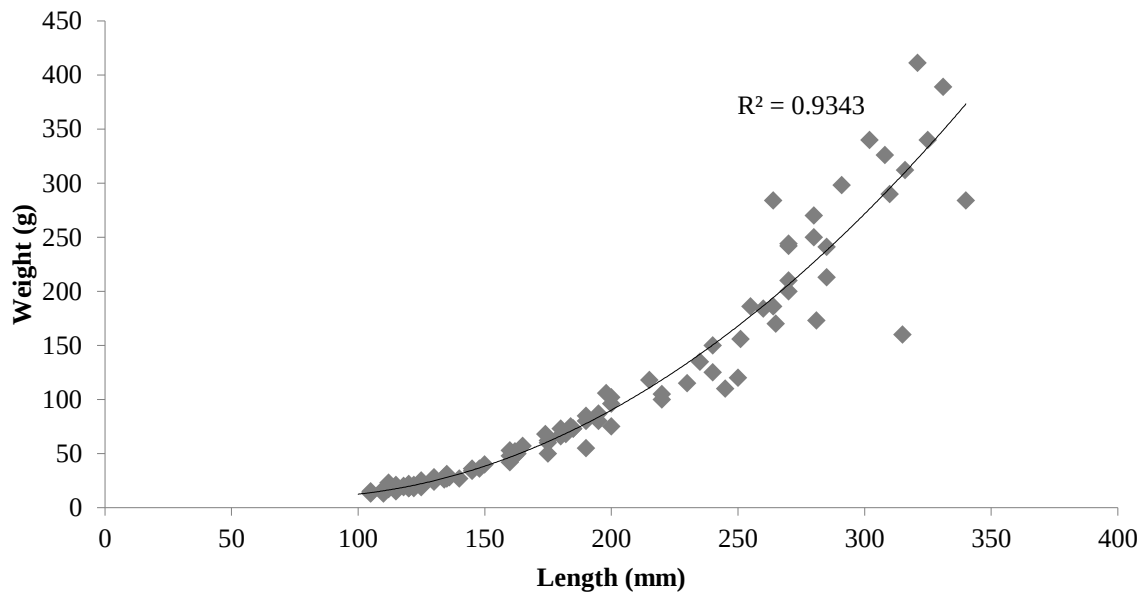


FIGURE 18. Length-weight relationship for rainbow trout captured by angling in 1951 and by gillnets in 1980 and 2010 in Upper Campbell Lake (N=122) (Source: FLNRO files, Nanaimo).

Age-at-Length of Rainbow Trout

We combined all the age at length data for rainbow trout from both Upper Campbell Lake and Elk River to determine age-at-length for rainbow trout in Upper Campbell Lake (Table 6). Most rainbow remain in the Elk River for 1 year then recruit to the lake (age 0+) and recruit to the fishery in their 3rd year (i.e. at 2+) and ~ 200 mm (Figures 19-21).

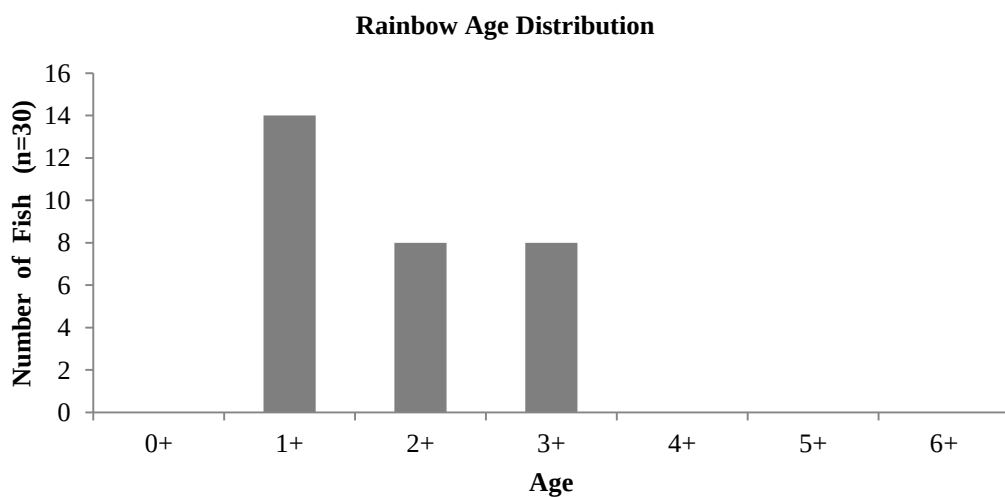


FIGURE 19. Age distribution of rainbow trout captured by gillnet in Upper Campbell Lake, September 2010 (N=30) (Reprinted from: Lough, 2010).

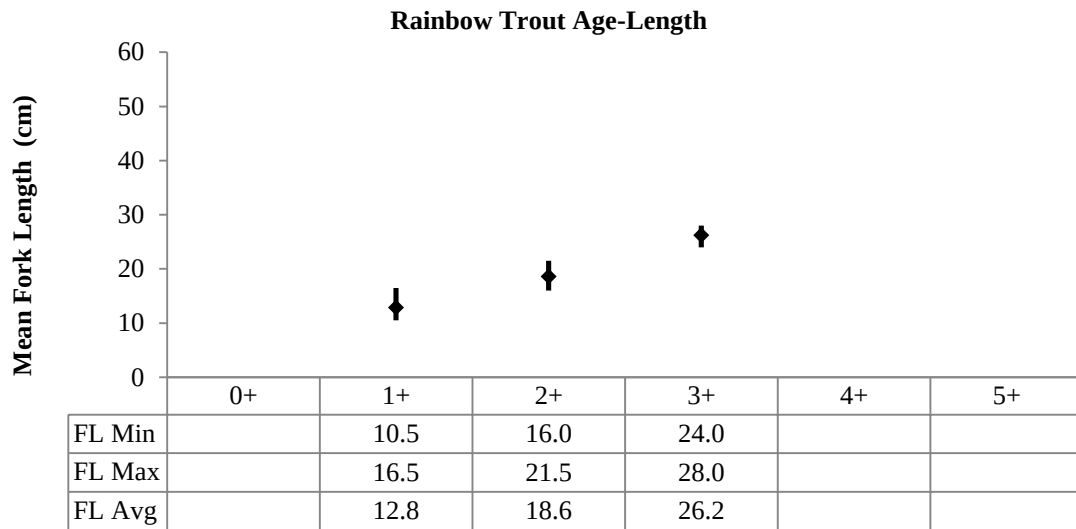


FIGURE 20. Age-length of rainbow trout captured by gillnet in Upper Campbell Lake, September 2010 (N=30) (Reprinted from: Lough, 2010).

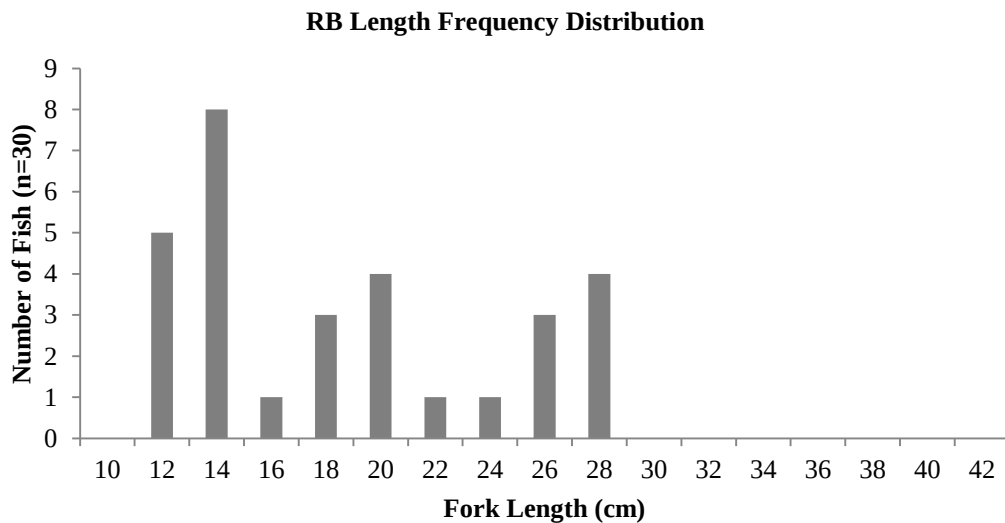


FIGURE 21. Length frequency of rainbow trout captured by gillnet in Upper Campbell Lake, September 2010 (N=30) (Reprinted from: Lough, 2010).

Side channels of the Elk River, Cervus Creek, Drum Creek, Filberg Creek, Tlools Creek and an unnamed tributary were electrofished in September and October of 1978 and Tredger (1979) calculated the migration patterns of rainbow into Upper Campbell Lake and found that 32% of 0+ and 32% 1+ rainbow migrate to Upper Campbell Lake, and 36% migrate at 2+ years (Table 7). He also determined that fish that migrate at 2+ years have a higher relative survival (60%) than those that migrate at 0+ or 1+ years (Table 8).

TABLE 7. Summary of migration patterns of juvenile rainbow trout to Upper Campbell Lake as determined by scale analysis (Reprinted from: Tredger, 1979).

Year of Sample	Number Readable	% Migrating to Upper Campbell Lake		
		Fry	1+	2+
1978	25	32	32	36

TABLE 8. Relative lake survival rates of age groups of migrant rainbow trout in tributaries to Upper Campbell Lake, September/October 1978. Tributaries included: Side channels of the Upper Elk River, Upper Mainstem Elk River, Cervus Creek, Drum Creek, Filberg Creek, Tloos Creek, and an unnamed tributary (Reprinted from: Tredger, 1979).

Factor	Age Group of Migration		
	0+	1+	2+
Standing Crop	60,000	4700	1200
Number of Migrants	60,000	4700	1200
Percent Lake Population	32	32	36
Relative Survival	1	14	60

Maturity and Size of Male and Female Rainbow Trout

We present maturity data for male and female rainbow trout captured in 1951, 1980 and 2010 in Table 9. In 1951, immature females ranged from 55 mm – 210 mm and averaged 228 mm while in 2010 immature females ranged from 182 - 280 mm and averaged 230 mm. Mature females averaged 245 mm in 1951, 294 mm in 1980 and 280 mm in 2010.

TABLE 9. Range of lengths and mean sizes of male and female rainbow trout captured by angling in 1951 and by gillnets in 1980, Upper Campbell Lake (Source: FLNRO files, Nanaimo).

Factor	1951		1980		2010	
	Female Rainbow N=5	Male Rainbow N=9	Female Rainbow N=6	Male Rainbow N=9	Female Rainbow N=6	Male Rainbow N=15
	Immature (n=4)	Mature (n=1)	Immature (n=0)	Mature (n=6)	Immature (n=5)	Mature (n=11)
Range	55-210	-----	-----	264-340	280-331	125-270
Mean	228.8	245	-----	294.8	230.4	228

Immature males ranged from 175 mm - 270 mm in 1951, 280 mm - 331 mm in 1980 and 125 mm - 270 mm in 2010. Mature males ranged from 200 mm - 310 mm in 1951, 280 mm - 331 in 1980 and 125 mm – 270 mm in 2010. Mature males averaged 253 mm in 1951, 309 mm in 1980 and 228 mm in 2010.

Adult Rainbow Trout Observed in Snorkel Surveys

In Figure 19 we present the total counts of rainbow trout from 1990 through to 2011 in the Elk River. Counts were not done in 1997, 1999, 2005 and 2011. In 2006-2008 the number of rainbow trout observed increased substantially from previous years. In 2009, counts were lower than the previous 3 years but still higher than any year prior to 2005. This pattern has been observed in both the Upper and Lower reaches of this river (Figure 22-24).

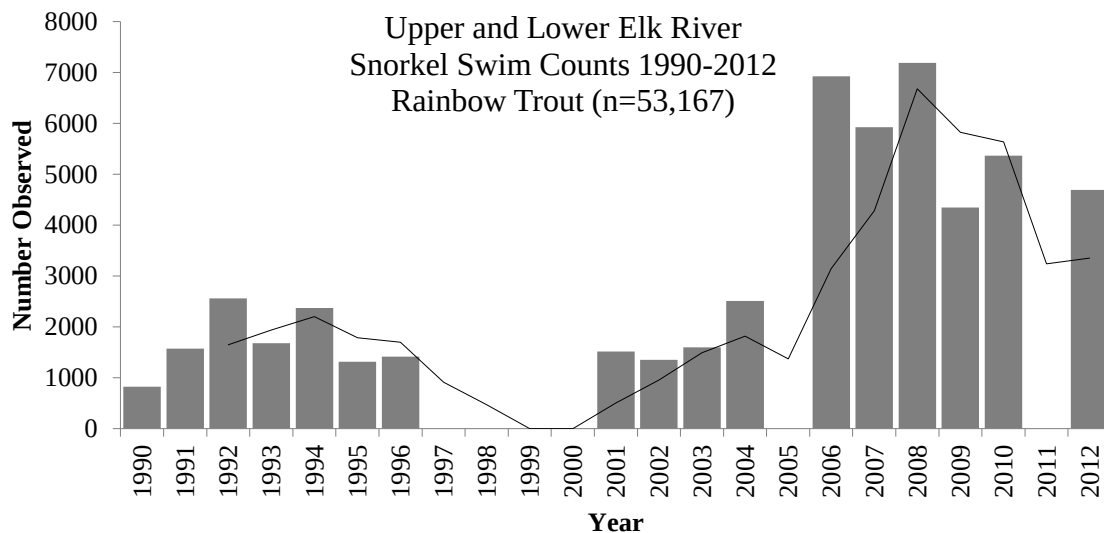


FIGURE 22. Total number and 3-year moving average of rainbow trout observed in June snorkel counts of the Elk River 1990 – 2012 (N=53,167; Mean = 2,311/year) (Source: FLNRO files, Nanaimo).

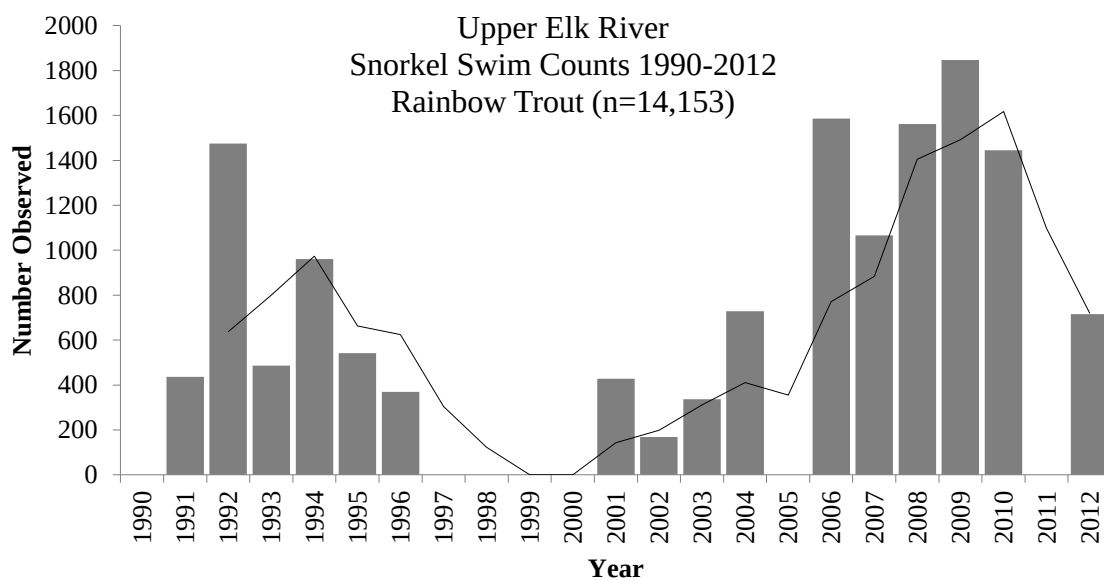


FIGURE 23. Total number and 3- year moving average of rainbow trout observed in June snorkel counts of the Upper Elk River from 1990 – 2012 (N=14,153; mean = 615/year); the Upper Elk River is defined as the confluence of Drum Creek to the highway bridge or pullout (Source: FLNRO files, Nanaimo).

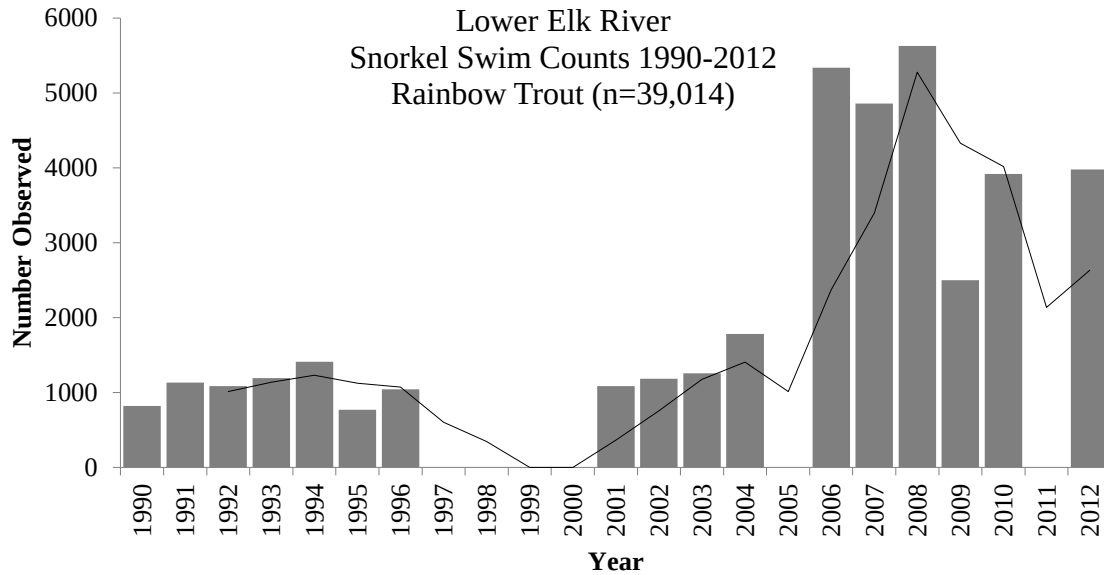


FIGURE 24. Total number and 3-year moving average of rainbow trout observed in snorkel counts of the Lower Elk River 1990– 2012 (N=39,014; mean = 1,696/year); the Lower Elk River is defined as the water gauging station to Upper Campbell Lake (Source: FLNRO files, Nanaimo).

We reviewed number of rainbow trout observed by date since 1991 in the Elk River to determine the peak spawning time and present this information in Figure 25. Rainbow trout begin arriving in the river in early June and the peak is within the first 2 weeks of that month. By far the greatest numbers of spawning rainbow have been observed from June 9 to June 12.

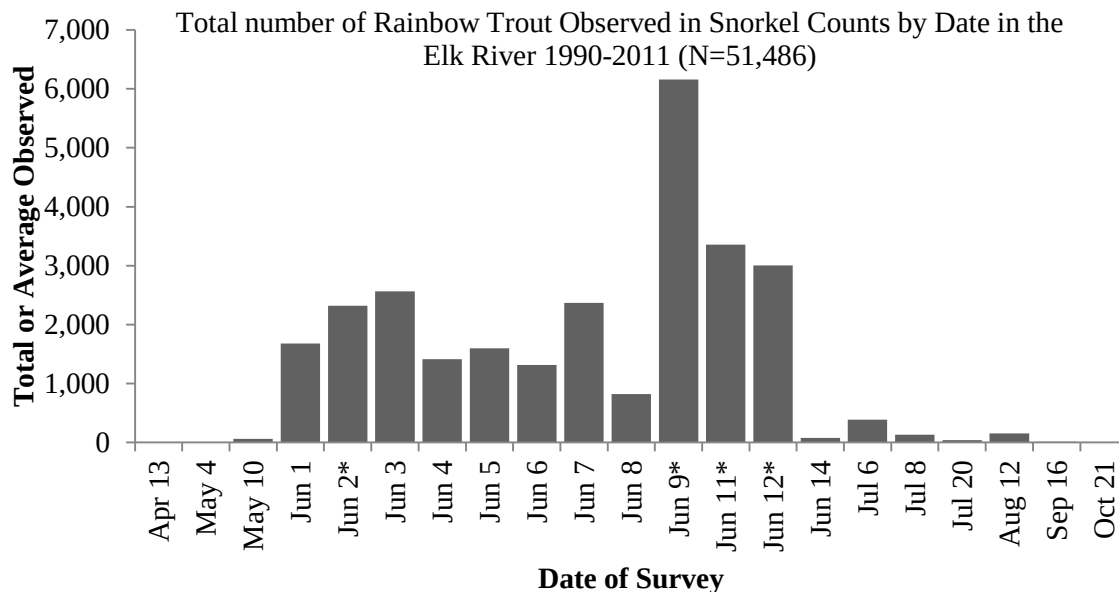


FIGURE 25. Total number of rainbow trout observed in snorkel counts by date in the Elk River 1990 – 2011 (N=51,486). Counts on June 2; June 9, June 11 and June 12 are average numbers of rainbow observed as counts were done on those same dates on more than one year (Source: FLNRO files, Nanaimo).

Dolly Varden

Population Data

The minimum, maximum and mean length (mm) and weight (g) of Dolly Varden captured in gillnets in Upper Campbell Lake in September 2010 is shown in Table 10. The minimum fork length of Dolly Varden captured was 105 mm while the maximum fork length was 410 mm. Dolly Varden caught in 2010 had a mean length of 218 mm and a mean weight of 169 g.

TABLE 10. Total numbers, and minimum, maximum and mean fork length of Dolly Varden captured in gillnets in Upper Campbell Lake September 2010 (Source: FLNRO files, Nanaimo)

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
2010	31	105	410	218.0	168.9

Length Frequency Distributions

The modal length of Dolly Varden captured by gillnet in 2010 was <200 mm and consisted of >50% of the sample (Figure 26). Although larger Dolly Varden (i.e. >350 mm) were sampled in 2010, they only constituted ~5% of the sample.

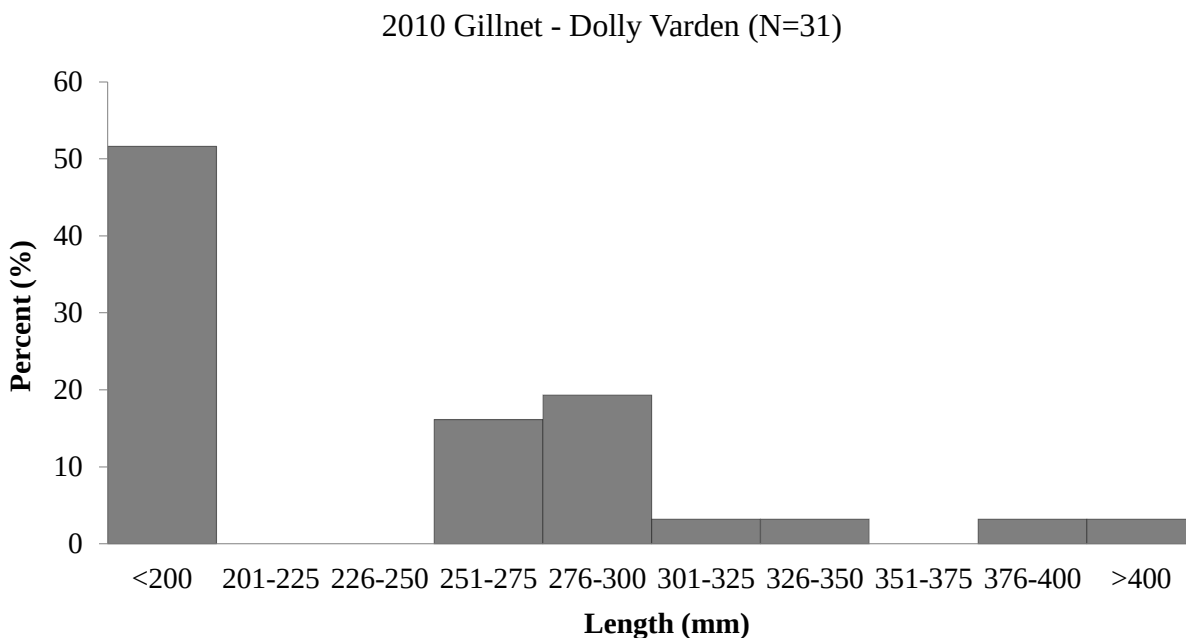


FIGURE 26. Length frequency of Dolly Varden captured in gillnets in Upper Campbell Lake, 2010 (N=31) (Source: FLNRO files, Nanaimo).

Length-Weight Relationship

We've presented the length-weight relationship for Upper Campbell lake Dolly Varden in Figure 27. The smallest Dolly Varden captured were ~100 mm and <20 g, while the largest were >400 mm and ~800 g. Most fish (7) were <300 mm and 200 g.

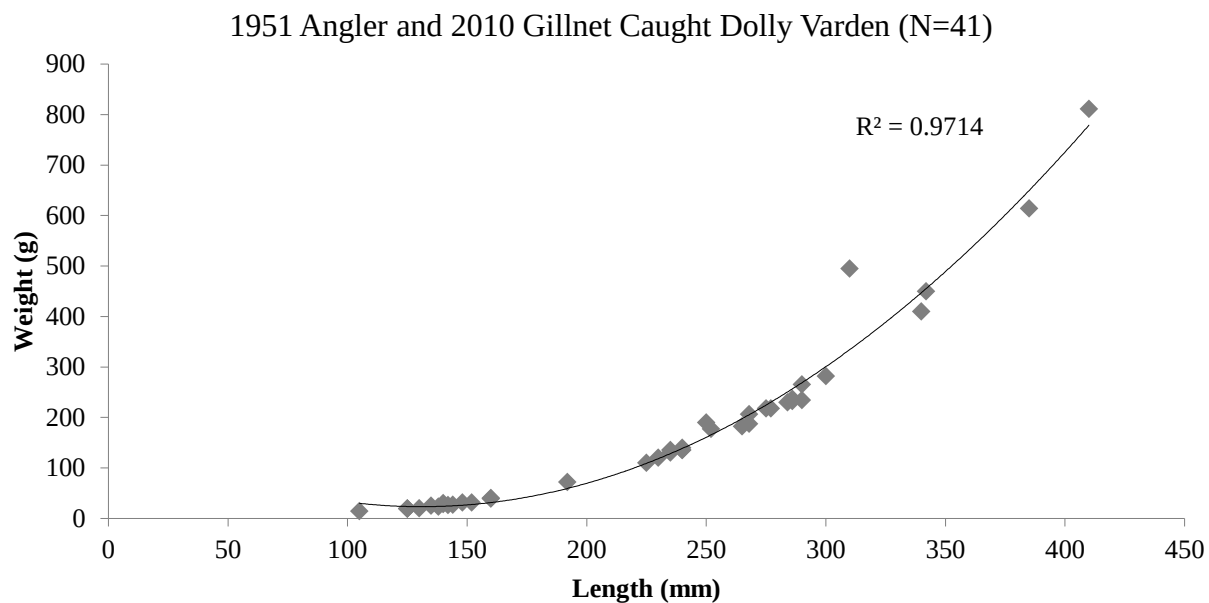


FIGURE 27. Length-weight relationship for Dolly Varden captured by angling in 1951 and gillnets in 2010 in Upper Campbell lake (N=41) (Source: FLNRO files, Nanaimo).

Age-at-Length

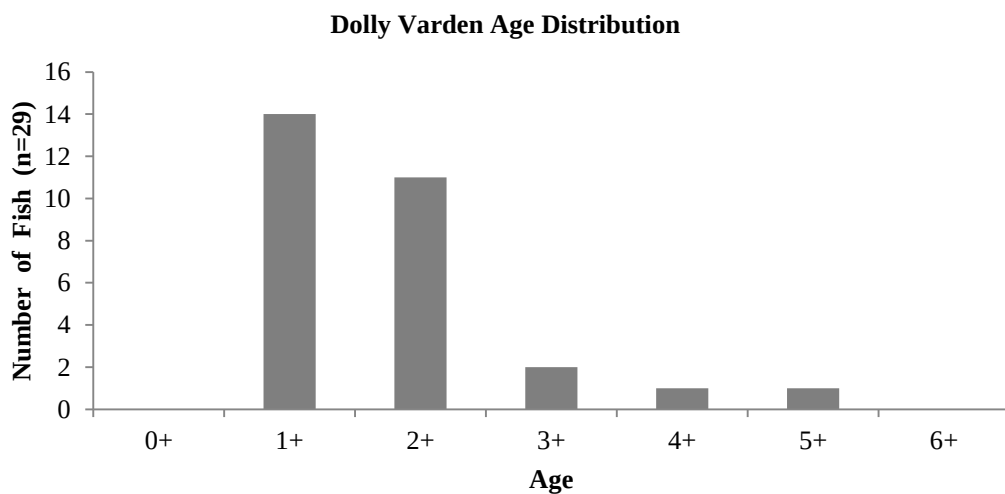


FIGURE 28. Age distribution of Dolly Varden captured by gillnet in Upper Campbell Lake, September 2010 (N=29) (Reprinted from: Lough, 2010).

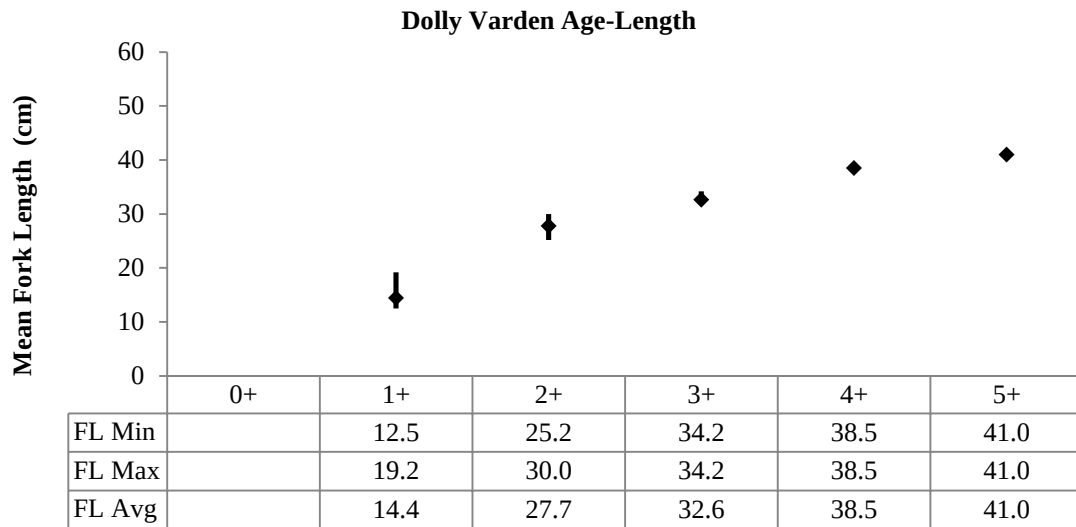


FIGURE 29. Age-length of Dolly Varden captured by gillnet in Upper Campbell Lake, September 2010 (N=29) (Reprinted from: Lough, 2010).

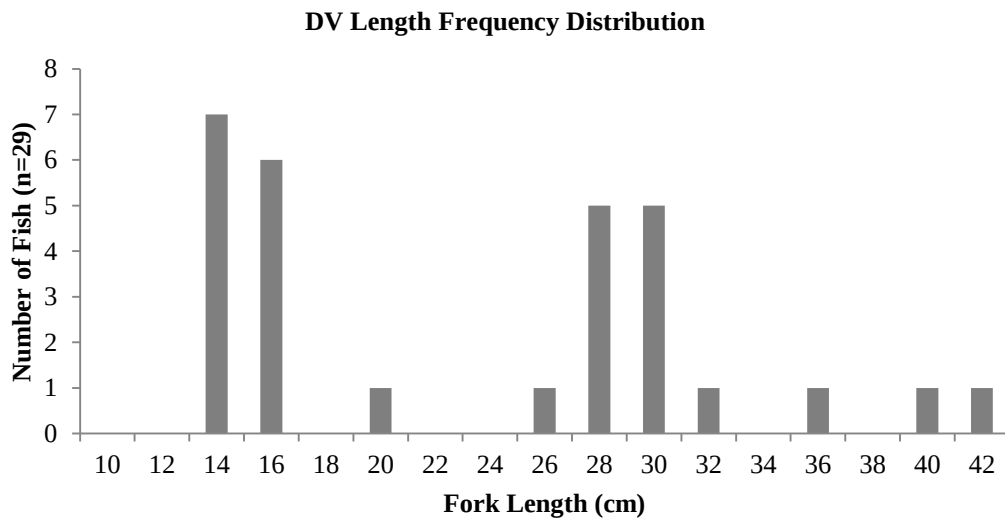


FIGURE 30. Length frequency of Dolly Varden captured by gillnet in Upper Campbell Lake, September 2010 (N=29) (Reprinted from: Lough, 2010).

Tredger (1979) analyzed age-length curves from Dolly Varden sampled in the Elk River and tributaries during spawning. He showed that a great difference in size between similar age groups of each species captured in the lake as compared to the stream environment. For example, age 2+ rainbow captured in Upper Campbell Lake averaged 76 mm greater in fork length than those captured in the Elk River. This was demonstrated in all three species present, and represents better growth conditions present in the lake environment.

Tredger (1979) also found that the older the lake migrant, the better the survival. For rainbow trout, for example, Tredger found that the survival of age 1+ migrants was an estimated 14 times the fry survival, while age 2+ survival was 60 times that of fry.

Tredger (1979) analyzed scales of Dolly Varden sampled from Upper Campbell Lake and concluded that 50% of the adults had entered the lake as fry, 25% as 1 year olds and 25% as 2 year olds (Table 11). However, his in-stream sampling during the late summer found only 0+ and 1+ juveniles, suggesting that the 2+ parr apparently moved downstream into the lake sometime prior to the summer months. Note that previous studies in the Campbell watersheds have documented a rearing population of Dolly Varden juveniles in the Elk River during the summer months (e.g. Griffith 1995, Tredger 1979 and Caw, 1977). However, very few juvenile Dolly Varden were observed during snorkel surveys by Lough and Hay (2003).

Table 11. Summary of migration patterns of Dolly Varden to Upper Campbell Lake as determined by scale analysis (Source: Tredger, 1979).

Species	Year of Sample	Number Readable	% Migrating to Lake		
			Fry	1+	2+
Dolly Varden	1978	8	50	25	25

Maturity and Size of Male and Female Dolly Varden

We present maturity data for male and female Dolly Varden captured in 1951 and 2010 in Table 12. No mature Dolly Varden were captured in 1951. That year, immature females ranged from 230 mm - 250 mm and averaged 239 mm while immature males ranged from 225 mm - 340 mm and averaged 266 mm. Most of the female Dolly Varden analyzed from the 2010 sample were mature and these ranged from 252 mm – 410 mm and averaged 306 mm. Both immature females captured that year were 286 mm while immature males ranged from 125 mm - 300 mm and averaged 227 mm. Two mature males were captured and these averaged 472 mm.

TABLE 12. Range of lengths and mean sizes of male and female Dolly Varden captured in gillnets in Lower Campbell Lake in 1951 (Source: FLNRO files, Nanaimo).

Factor	1951		2010			
	Female (N=5)	Male (N=5)	Female (N=9)		Male (N=7)	
	Immature (n=5)	Immature (n=5)	Immature (n=2)	Mature (n=7)	Immature (n=5)	Mature (n=2)
Range	230-250	225-340	286	252-410	125-300	450-495
Mean	239	266	286	306	227	472.5

Adult Dolly Varden Observed in Snorkel Surveys

Hay and Lough (2003) investigated Dolly Varden populations in Upper Campbell Lake between September 2001 and June 2002. Field data was collected primarily through snorkel surveys on Cervus Creek, Drum Creek, Elk River, Filberg Creek, and Tlools Creek. These surveys found that a few gravid adults moved into their spawning streams by mid- September. Numbers of fish generally increased during late-September and early-October as the adults moved from the reservoir into the streams to spawn. These researchers found that spawning activity varied between the streams that were surveyed, but generally occurred between mid-October and

early December and counts generally peaked around mid-October (Hay and Lough, 2003). Most of the spawning occurred in streams that were relatively cold and stable, often in low gradient reaches the headwaters or in canyon reaches. Few juvenile Dolly Varden were observed during the snorkel surveys and little useful data regarding the life history of juvenile Dolly Varden was collected. Elk River and Cervus Creek were used as index streams of the Upper Campbell Lake watershed (Figures 31-32).



FIGURE 31. Abundance of Dolly Varden spawners (adults per survey km) in Elk River, as determined from snorkel surveys, September 13 to November 26, 2001 (Reprinted from: Hay and Lough, 2003).

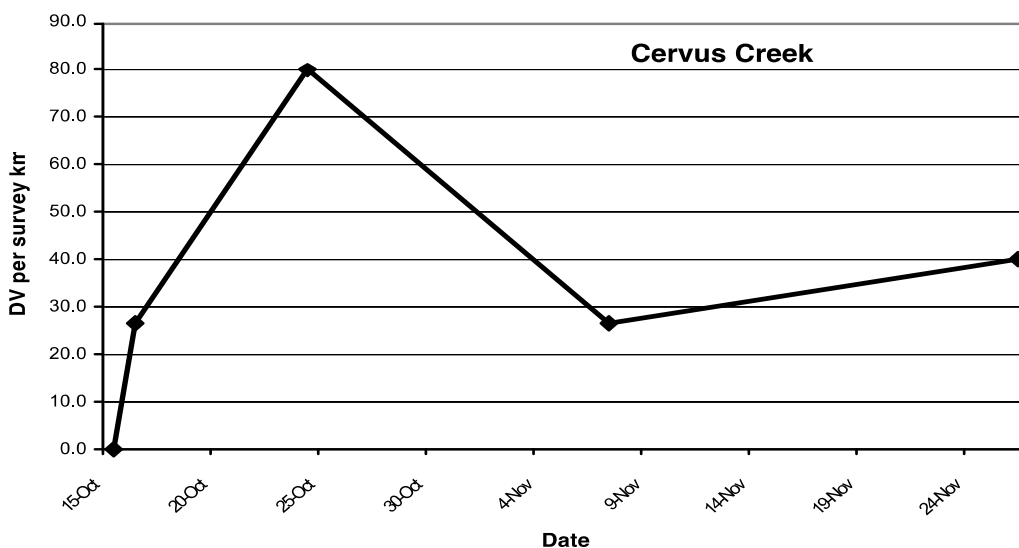


FIGURE 32. Abundance of Dolly Varden spawners (adults per survey km) in Cervus Creek, as determined from snorkel surveys, September 13 to November 26, 2001 (Reprinted from: Hay and Lough, 2003).

Results of snorkel surveys conducted by the Ministry from 1990 - 2011 are presented in Figure 33. Note that these annual June swim surveys are targeting rainbow trout peaks, thus only a total of 69 Dolly Varden have been observed over this time period in the month of June with the highest count in 2006. In August 1998, a total of 50 Dolly Varden were observed in the Upper and Lower Elk River and in October 1998, a total of 118 Dolly Varden were observed.

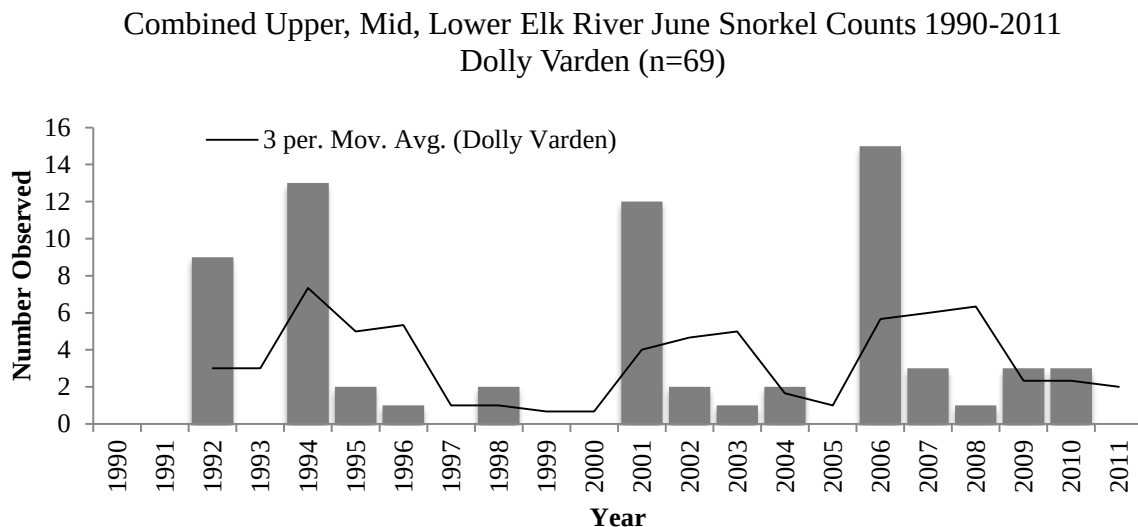


FIGURE 33. Total number and 3-year moving average of Dolly Varden observed in June snorkel counts of the Elk River 1990 – 2011 (N=69; mean = 3/year) (Source: FLNRO files, Nanaimo).

Our observation of the highest counts of Dolly Varden agrees with the findings of Hay and Lough (2003) and suggests peak spawning in the Upper Elk is during October (Figure 34). Ministry surveys have also documented Dolly Varden in the Lower Elk River in June, however (Figure 35) and this suggests this species is behaving similar to cutthroat and following spawning rainbow trout into this reach of the Elk River (see Figure 11).

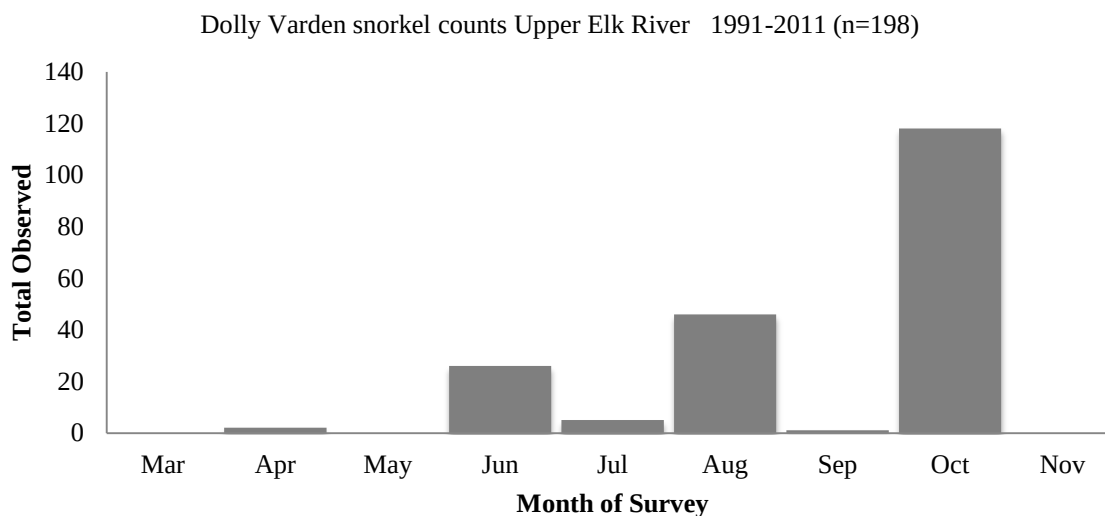


FIGURE 34. Total number of Dolly Varden observed in snorkel counts of the Upper Elk River by month from 1991 – 2011 (N=198); the Upper Elk River is defined as the confluence of Drum Creek to the highway bridge or pullout (Source: FLNRO files, Nanaimo).

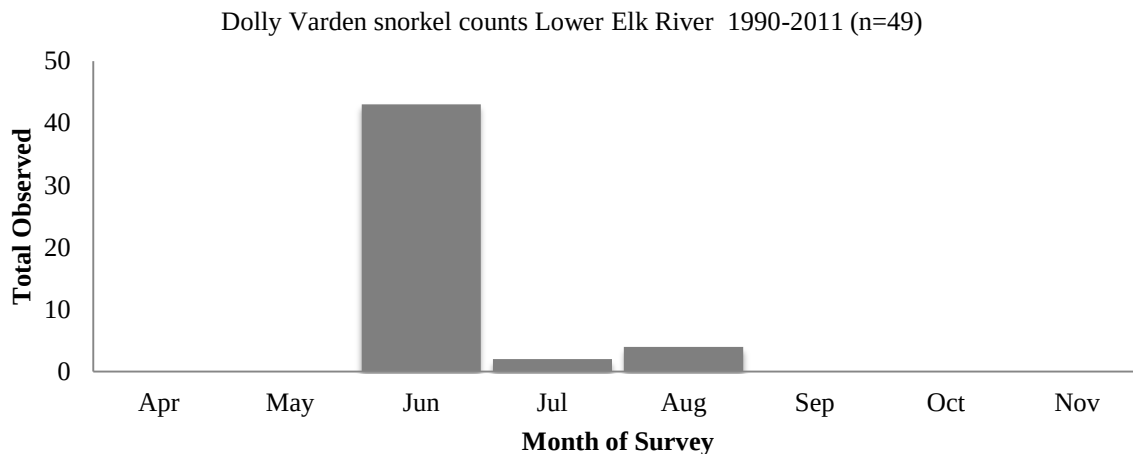


FIGURE 35. Total number of Dolly Varden trout observed in snorkel counts of the Lower Elk River by month from 1990 – 2011 (N=49); the Lower Elk River is most often defined as the water gauging station to Upper Campbell Lake (Source: FLNRO files, Nanaimo).

Snorkel surveys were conducted in tributaries to Upper Campbell Lake between December 18 – March 31, 2003 as part of a fish and fish habitat assessment (Hay and Lough, 2003). The streams snorkelled included Crest Creek, Mud Creek and Drum Creek, which eventually join the Elk River. Hay and Lough (2003) identified 9 Dolly Varden redds at the outlet of Crest Lake in December 2002 which were likely constructed during the late fall of 2002 just prior to the start of their snorkel survey study (Table 13). Hay and Lough (2003) did not find any other Dolly Varden redds during their January 2003 swims in the areas downstream of Crest Lake, however a storm event had occurred creating high water levels and redds may have been smoothed over prior to the snorkel swims. Hay and Lough (2003) also observed two Dolly Varden kelts between Mud Lake and Upper Drum Lake on February 14, 2003.

TABLE 13. Summary of fish counts, redd counts, water temperature and discharge during weekly surveys of Crest Creek, Drum Creek and Mud Creek between December 18, 2002 and March 31, 2003 (Reprinted from: Hay and Lough, 2003).

Date	Number of Dolly Varden	Number of Dolly Varden Redds	Spot Temp. Drum Creek (° C)	Metered Discharge Drum Creek (cms)
28-Dec		9	3.5	0.65
14-Feb	2		4.0	0.62

Fisheries Objectives and Management Strategies

TABLE 14. Number of responses and percent of total responses by anglers regarding the quality of fishing, reasons for fishing, preferred species, and suggestions for regulations to improve angling at Upper Campbell Lake determined from box angler creel surveys conducted July, 2010 – September, 2011 (Reprinted from: Michalski, 2011b).

Survey Question and Responses	Number of Responses	Percent
1. How do you rate fishing in this lake?		
Excellent	0	0.0
Good	14	77.8
Poor	4	22.2
2. Why do you fish this lake?		
Catch fish to eat	12	70.6
Catch large fish	2	11.8
Catch many fish	3	17.6
3. Which species do you prefer to catch?		
Cutthroat trout	11	64.7
Rainbow trout	3	17.6
Dolly Varden	1	5.9
Does not matter	2	11.8
4. If new regulations were implemented to improve the fishery and conserve fish stocks, which regulation would be acceptable to you?		
Size limits	5	38.5
Reduction on the number of fish killed	5	38.5
Season or area closure	2	15.4
Catch-and-Release regulation	1	7.7
Total Responses	65	

Appendix 22. Victoria Lake

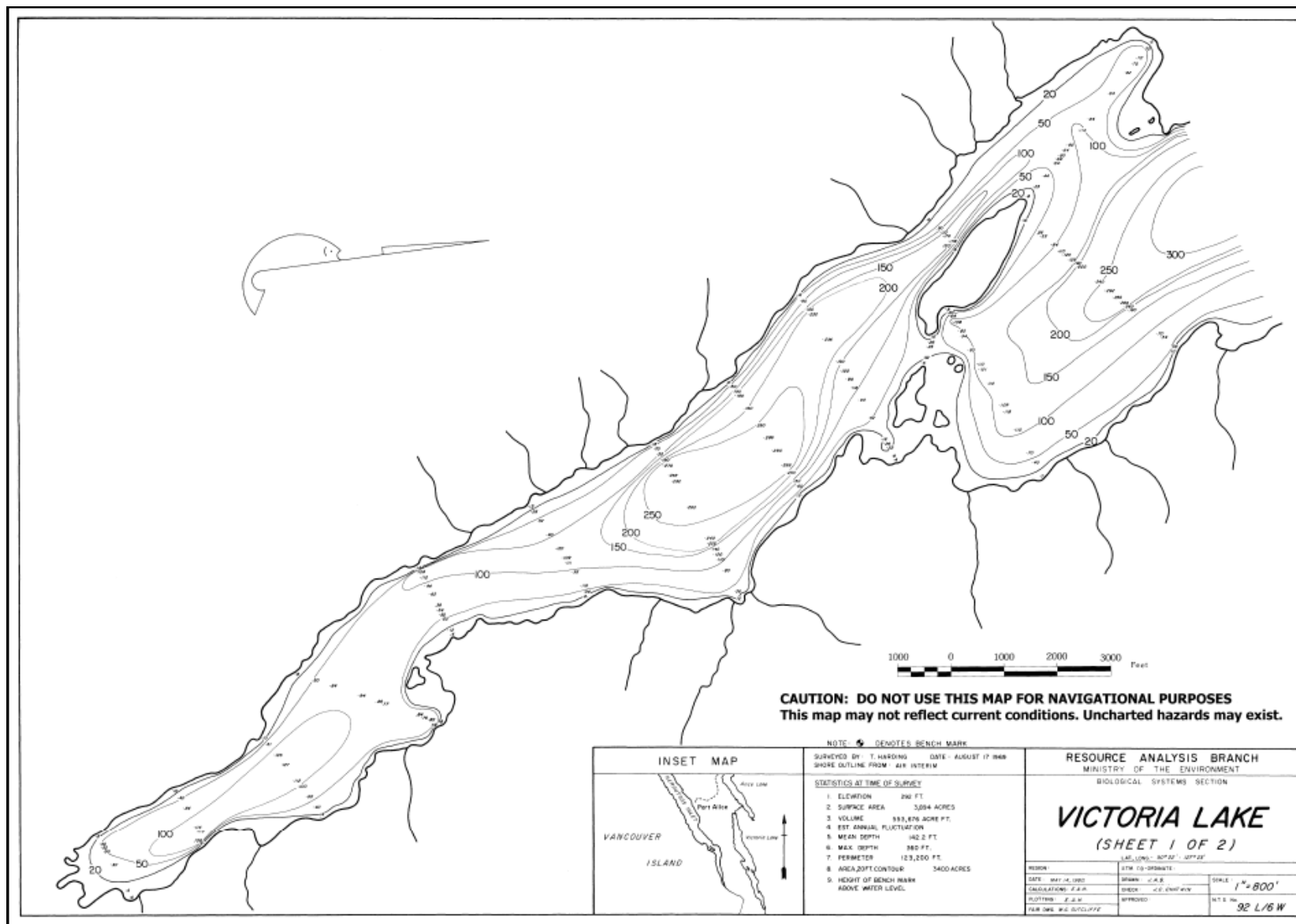


FIGURE 1. Bathymetric map of Victoria Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

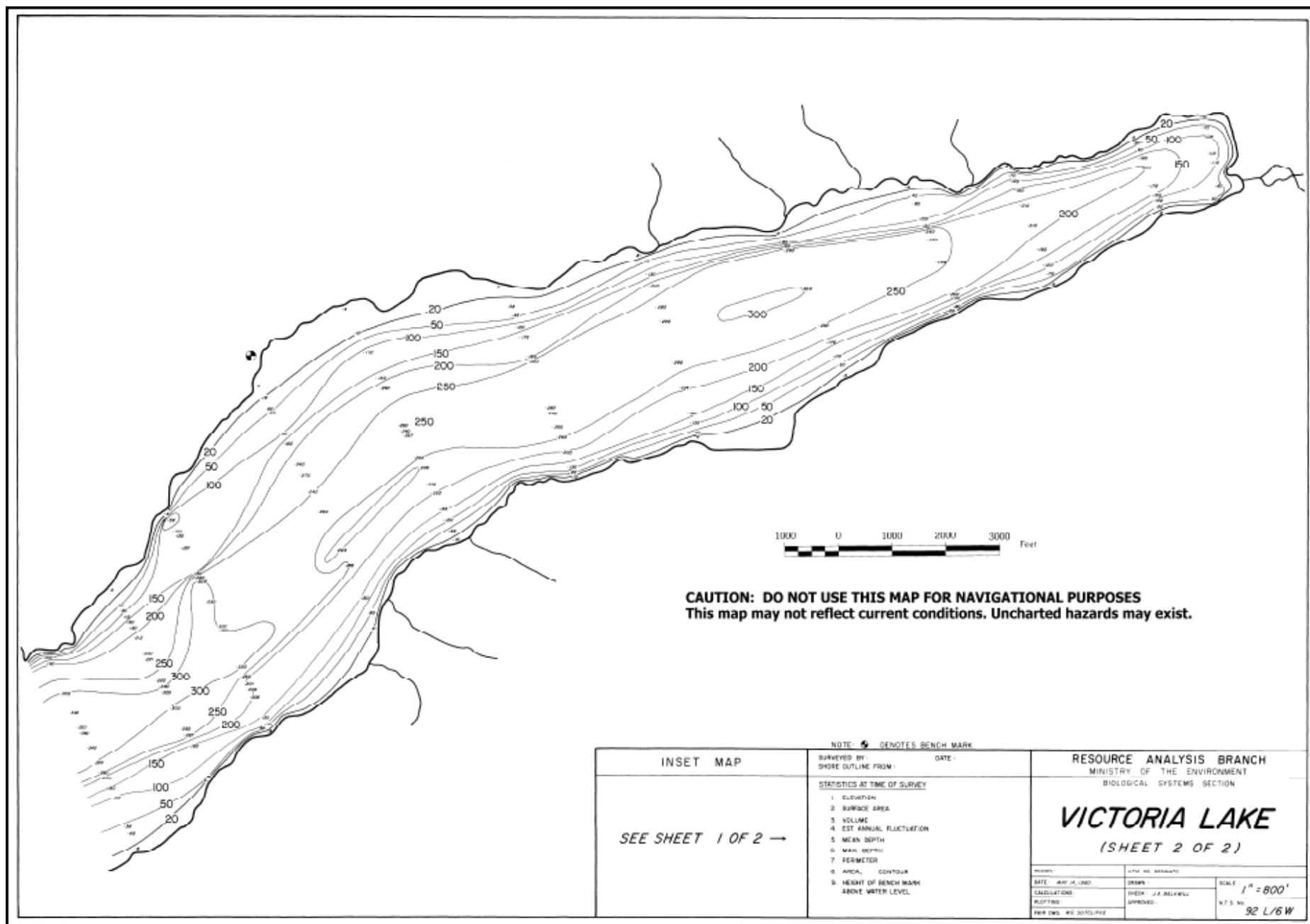


FIGURE 1 (CONTINUED). Bathymetric map of Victoria Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Stock Status Indicators

Cutthroat Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of cutthroat trout captured in gillnets in Victoria Lake from 1992 - 1996 is shown in Table 1. Thirty-six cutthroat trout ranging from 75 mm – 272 mm were captured in 1992. The following year, 27 cutthroat trout were captured and these ranged from 180 mm – 390 mm. Only 8 cutthroat trout were captured in 1994 and 7 cutthroat trout were captured in 1995, with a mean length of 190 mm and 214 mm, respectively. In 1996, the sample included 12 cutthroat trout and these included the largest cutthroat captured during the survey period. That year, cutthroat ranged between 180 mm – 375 mm while the mean length of fish captured was 241 mm.

TABLE 1. Total number and minimum, maximum and mean fork length of cutthroat trout captured by gillnet in Victoria Lake 1992 – 1996 (N=90) (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1992	36	75	272	206.7	54.5
1993	27	180	390	223.2	127.8
1994	8	22	240	189.7	79.5
1995	7	170	250	214.3	94.7
1996	12	180	375	241.3	147.5

Length Frequency Distribution

We've presented the length-frequency distributions of cutthroat trout sampled from 1992 – 1996 in Figures 2–6. With the exception of 1992 when the mode was 151 mm - 200 mm, the mode of fish sampled throughout the sampling period has remained between 201 mm – 250 mm. Note, however, that in 1996, that cutthroat in the 251 mm – 400 mm length categories (Figure 12). The only other year when fish >351 mm were captured was in 1993 when a 390 mm fish was sampled.

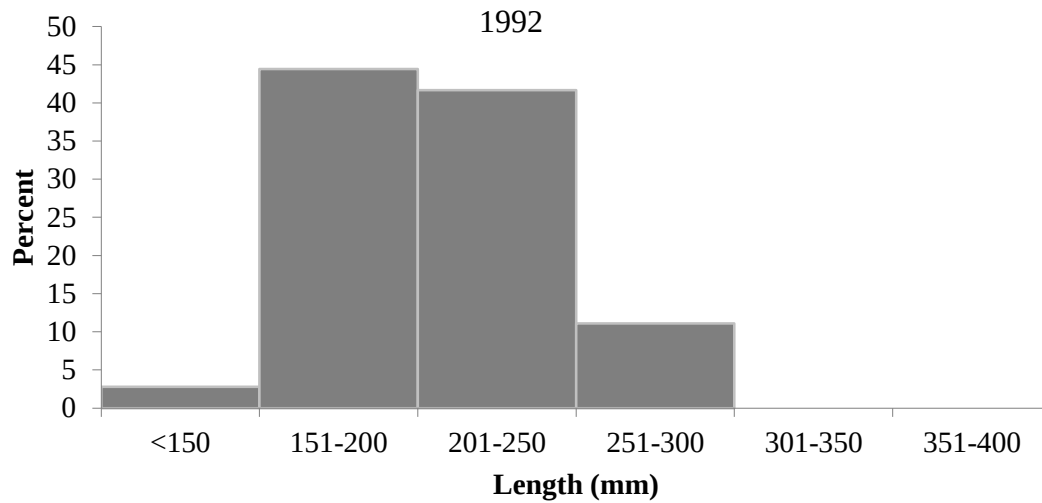


FIGURE 2. Length frequency of cutthroat trout captured in gillnets in Victoria Lake, 1992 (N=36) (Source: FLNRO files, Nanaimo).

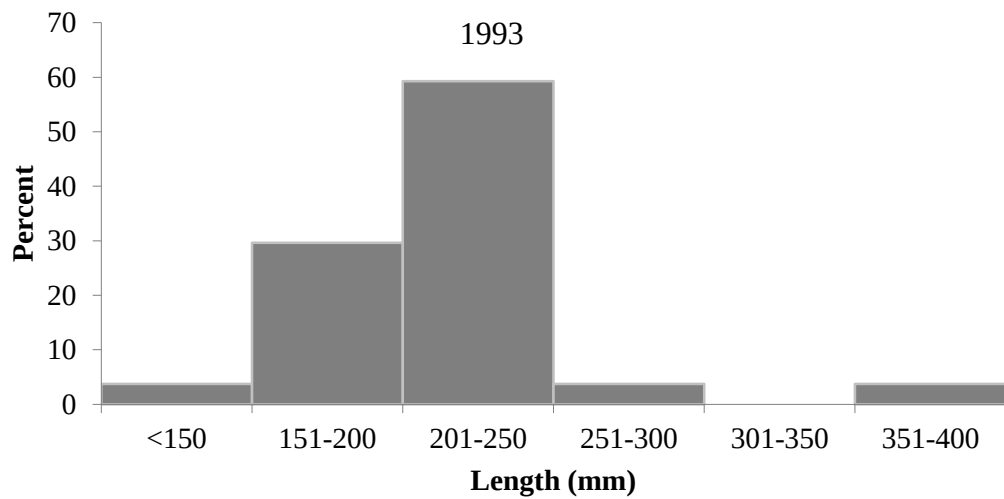


FIGURE 3. Length frequency of cutthroat trout captured in gillnets in Victoria Lake, 1993 (N=27) (Source: FLNRO files, Nanaimo).

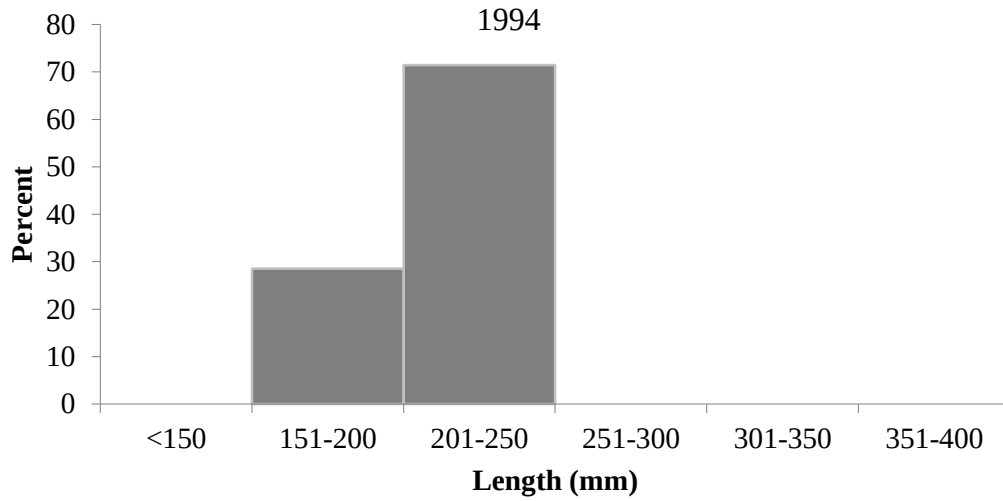


FIGURE 4. Length frequency of cutthroat trout captured in gillnets in Victoria Lake, 1994 (N=7) (Source: FLNRO files, Nanaimo).

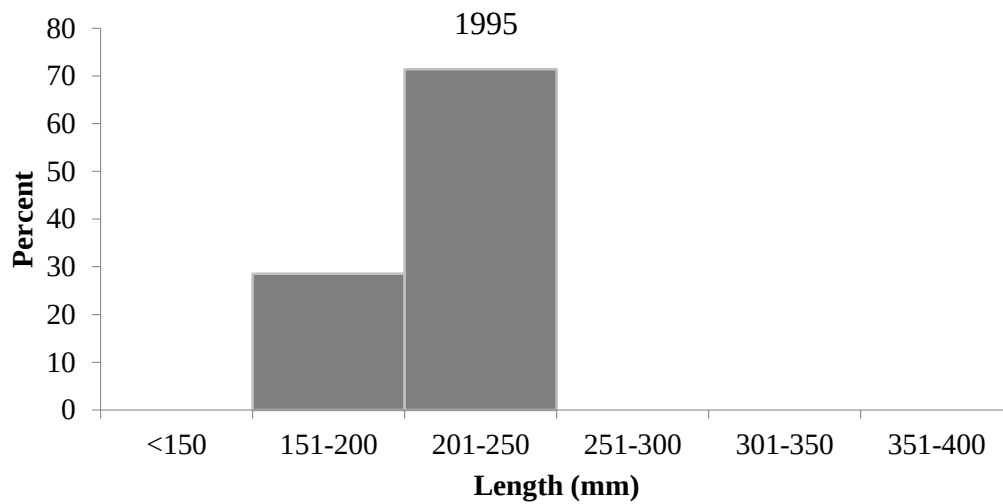


FIGURE 5. Length frequency of cutthroat trout captured in gillnets in Victoria Lake, 1995 (N=7) (Source: FLNRO files, Nanaimo).

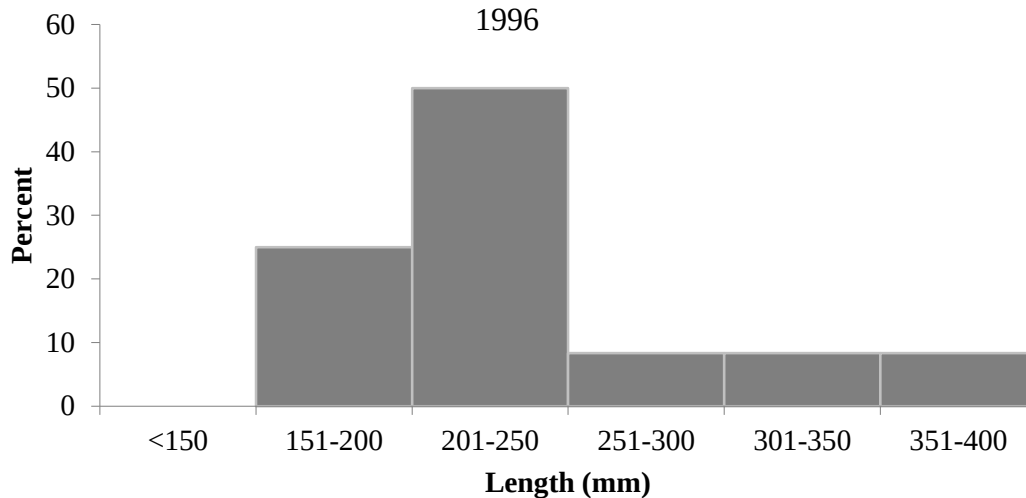


FIGURE 6. Length frequency of cutthroat trout captured in gillnets in Victoria Lake, 1996 (N=12) (Source: FLNRO files, Nanaimo).

Length Weight Relationship

We've shown the length-weight relationship of cutthroat trout sampled in gillnets in 1992 - 1996 in Figure 7. Most fish sampled during that period were <300 mm and 180 g. The smallest fish captured were ~80 mm and <50 g, while the largest were ~400 mm and 600 g.

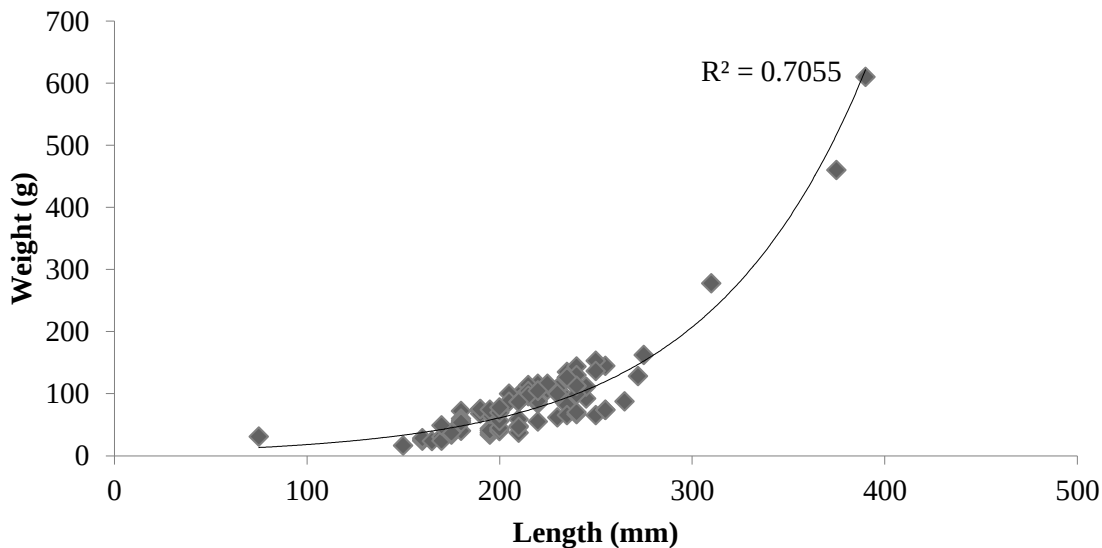


FIGURE 7. Length-weight relationship for mature cutthroat trout captured in gillnets in Victoria Lake 1992 – 1996 (N=88) (Source: FLNRO files, Nanaimo).

Age at Length of Male and Female Cutthroat Trout

We've summarized the mean lengths of each age class of cutthroat trout sampled in Victoria Lake from 1992 – 1996 in Table 2. Immature females ranged from 34 – 390 mm and averaged

205 mm and 86 g, while immature males ranged from 75 – 272 mm and averaged 220 mm and 92 g over the 5 year sampling period. Mature females ranged from 195 – 265 mm and averaged 228 mm and 64 g, while mature males ranged from 201 – 245 mm and averaged ~220 mm and 85 g over the survey period. Note that no mature fish were sampled after 1993.

TABLE 2. Number, range of fork length and mean fork lengths of immature and mature male and female cutthroat captured in gillnets in Victoria Lake 1992 – 1996 (N=82) (Source: FLNRO files, Nanaimo).

	1992				1993				1994				1995				1996			
	Females (N=13)		Males (N=21)		Females (N=15)		Males (N=13)		Females (N=4)		Males (N=2)		Females (N=3)		Males (N=1)		Females (N=7)		Males (N=3)	
	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature
N	10	3	14	7	14	1	7	26	4	0	2	0	3	0	1	0	7	0	3	0
Range	150-200	210-265	75-272	210-245	34-390	195	170-240	201-225	175-240	-----	220-230	-----	170-230	-----	210	-----	180-250	-----	200-460	-----
Mean	175	240	213	222.7	214.6	195	213.6	215	208.8	-----	225	-----	193.3	-----	210	-----	214.4	-----	270	-----

Rainbow Trout

Population Data

The minimum, maximum and mean length (mm) and weight (g) of rainbow trout captured in gillnets in Victoria Lake from 1994-1995 is shown in Table 3. Rainbow trout ranged from 175 mm to 260 mm over the 2 sample years. The largest rainbow trout (260 mm) was sampled in 1994. Mean lengths were 219 mm in 1994, and 203 mm in 1995. Sampling was done during April in both years. No rainbow trout were captured in gillnets set in 1992, 1993 or 1996.

TABLE 3. Total number and minimum, maximum and mean fork length of rainbow trout captured by gillnet in Victoria Lake 1994 and 1995 (N=40) (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	
1994	37	175	260	219.5	85
1995	3	190	220	203.3	72

Length Frequency Distributions

We've presented the length-frequency distribution of rainbow trout captured in 1994 and 1995 in Victoria Lake in Figure 8 and Figure 9. In 1994, almost 70% of the fish captured were 201 – 250 mm while in 1995 almost the same percentage capture were within the 151-200 mm length class.

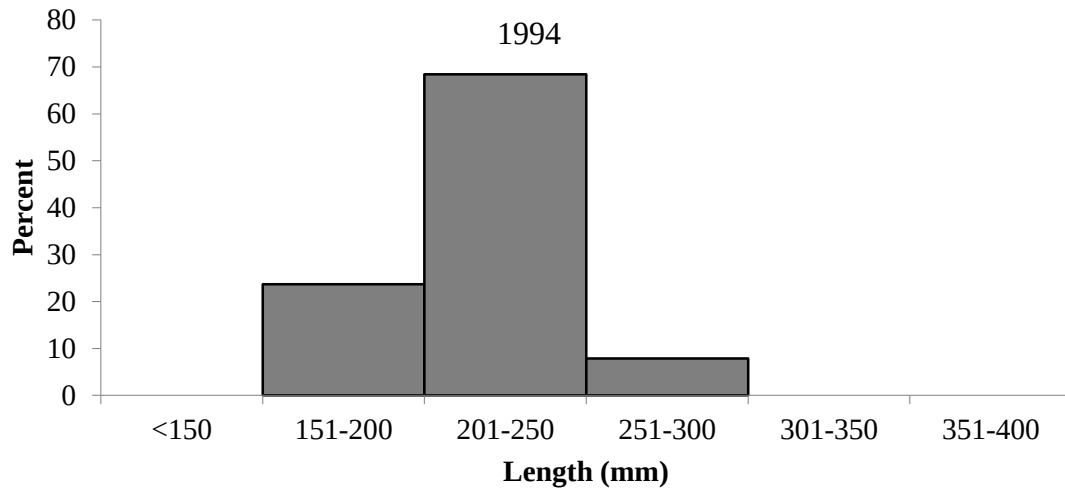


FIGURE 8. Length frequency of rainbow trout captured in gillnets in Victoria Lake, 1994 (N=37) (Source: FLNRO files, Nanaimo).

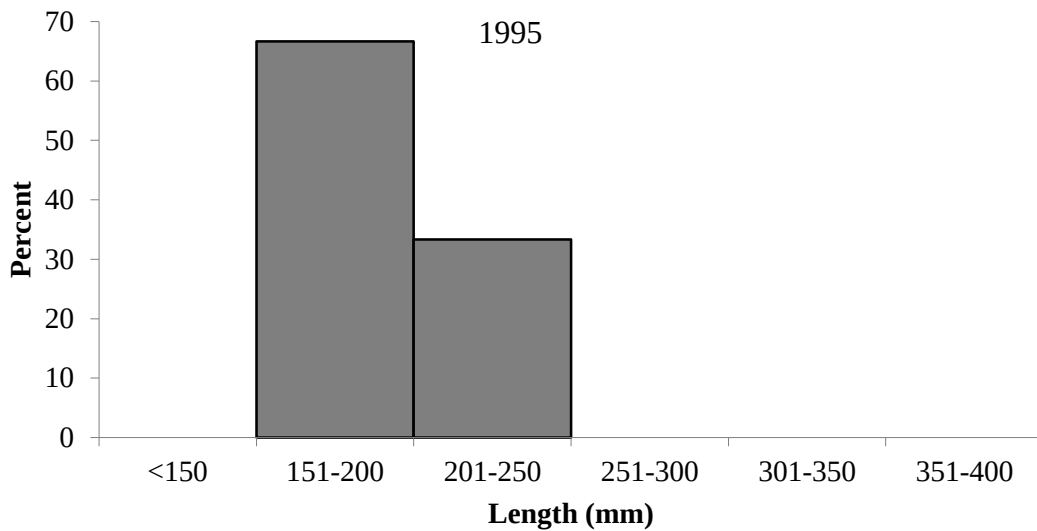


FIGURE 9. Length frequency of rainbow trout captured in gillnets in Victoria Lake, 1995 (N=3) (Source: FLNRO files, Nanaimo).

Length Weight Relationship

Most of the 41 rainbow trout captured in 1994 and 1995 were <250 mm and 100 g (Figure 10). The smallest fish were 175 mm and 49 g, while the largest were 260 mm and 149 g.

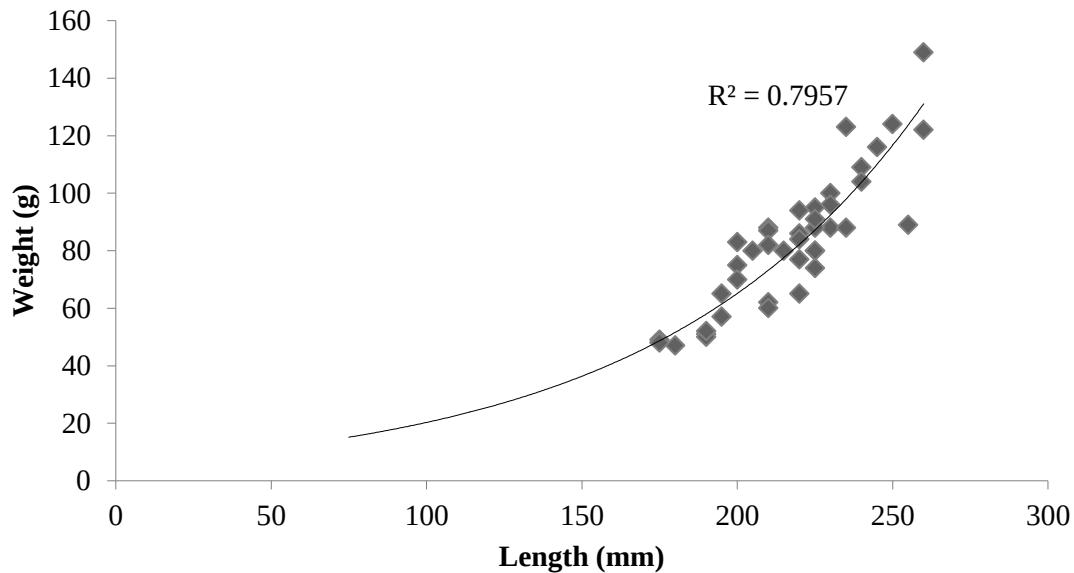


FIGURE 10. Length-weight relationship for mature rainbow trout captured in gillnets in Victoria Lake 1994 - 1995 (N=41) (Source: FLNRO files, Nanaimo).

Maturity of Male and Female Rainbow Trout

Nineteen female and 16 male rainbow trout were captured in gillnets in 1994 (Table 4). Of the females sampled, 18 were immature and ranged in size from 175 – 250 mm. The one mature female was 255 mm. Equal numbers of mature vs. immature males were sampled in 1994; immature males ranged from 195 – 260 mm, while mature males ranged from 200 – 235 mm. The mean size of mature males was only 215 mm while immature males captured averaged 228 mm. Two immature females and 1 immature male were captured in 1995 with females averaging 195 mm. The only male captured was 220 mm (Table 4).

TABLE 4. Number, range of fork length and mean fork lengths of immature and mature male vs. female rainbow trout captured in gillnets in Victoria Lake 1994 and 1995 (N=38) (Source: FLNRO files, Nanaimo).

Factor	1994		1995		1995		1995	
	Females (N=19)		Males (N=16)		Females (N=2)		Males (N=1)	
	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature
N	18	1	8	8	2	0	1	0
Range	175-250	255	195-260	200-235	190-200	-----	220	-----
Mean	214	255	228	215	195	-----	220	-----

Dolly Varden

Population Data

The minimum, maximum and mean length (mm) and weight (g) of Dolly Varden captured in gillnets in Victoria Lake from 1992 - 1996 is shown in Table 5. Gillnet sample counts ranged from 3 in 1993 to 19 in 1996. Minimum fork lengths varied from 165 mm – 200 mm. Maximum

lengths were between 180 – 250 mm. Dolly Varden averaged ~190 mm over the 5-year survey period.

TABLE 5. Total number and minimum, maximum and mean fork length of Dolly Varden captured by gillnet in Victoria Lake 1992 – 1996 (N=49) (Source: FLNRO files, Nanaimo).

Year	N	Length (mm)			Weight (g)
		Minimum	Maximum	Mean	Mean
1992	5	200	240	216	48
1993	3	165	180	172	59
1994	13	165	230	203	66
1995	9	170	250	201	93
1996	19	110	210	167	53

Length Frequency Distributions

We've presented the length-frequency analyses of Dolly Varden sampled between 1992 and 1996 in Victoria Lake in Figure 11-14. Between 1992 and 1994 the mode of sampled fish shifted from 201 – 250 mm to 151 – 200 mm where it stayed until 1996.

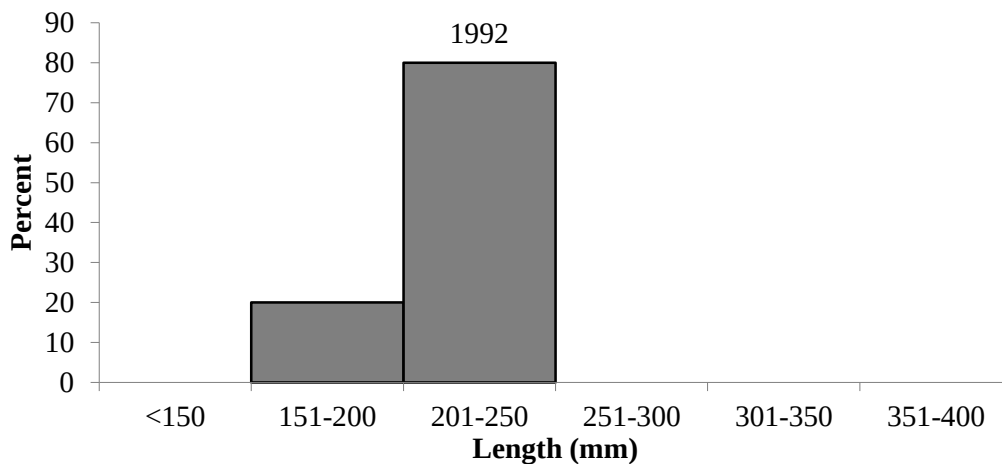


FIGURE 11. Length frequency of Dolly Varden captured in gillnets in Victoria Lake, 1992 (N=5) (Source: FLNRO files, Nanaimo).

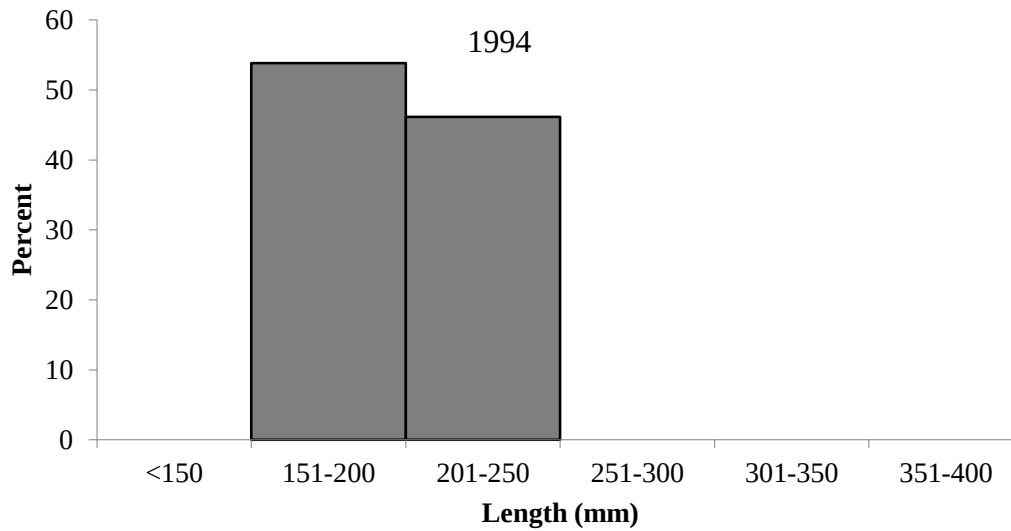


FIGURE 12. Length frequency of Dolly Varden captured in gillnets in Victoria Lake, 1994 (N=13) (Source: FLNRO files, Nanaimo).

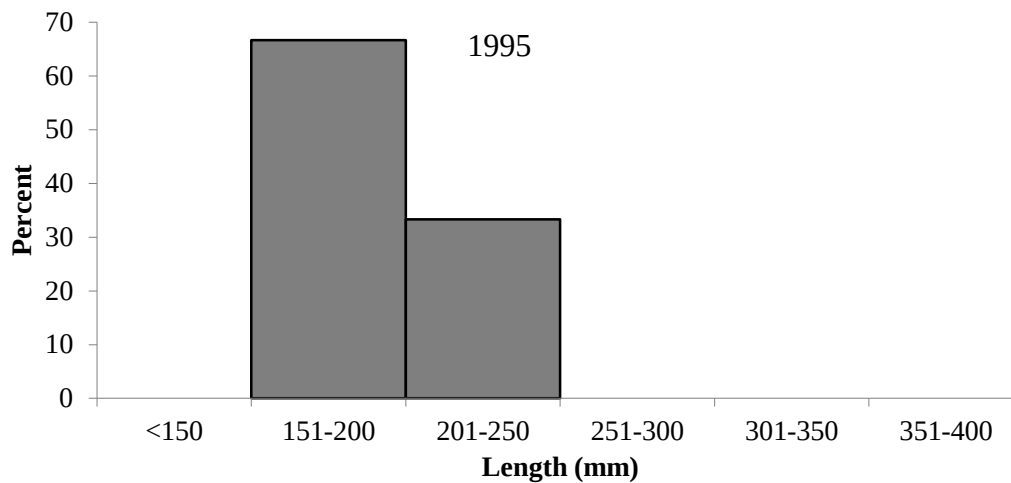


FIGURE 13. Length frequency of Dolly Varden captured in gillnets in Victoria Lake, 1995 (N=9) (Source: FLNRO files, Nanaimo).

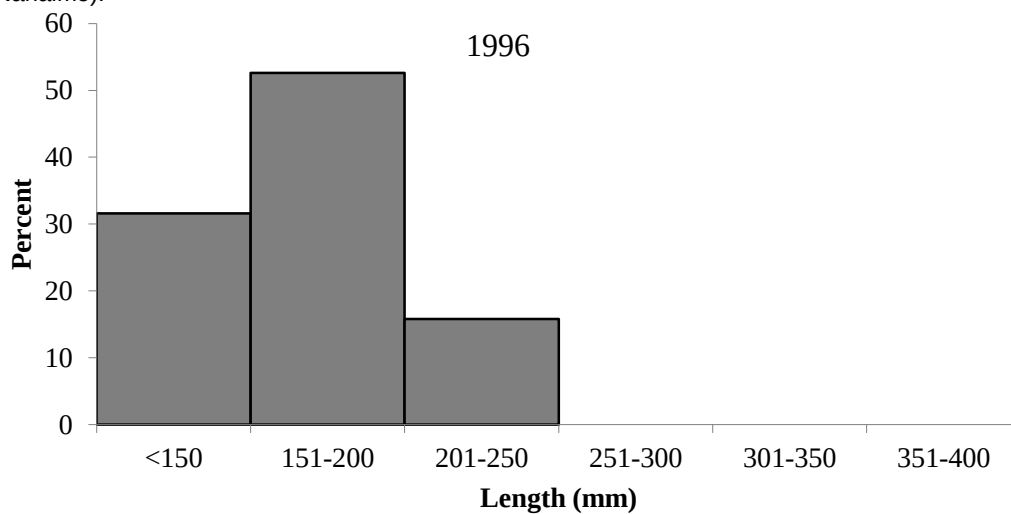


FIGURE 14. Length frequency of Dolly Varden captured in gillnets in Victoria Lake, 1996 (N=19) (Source: FLNRO files, Nanaimo).

Length Weight Relationship

We show the length-weight relationship of Dolly Varden captured in gillnets in Victoria Lake between 1992 and 1996 in Figure 15. Most fish sampled during that period were between 160 – 230 mm and <100 g. The smallest fish captured were ~110 mm and 20 g, while the largest was ~250 mm and 180 g.

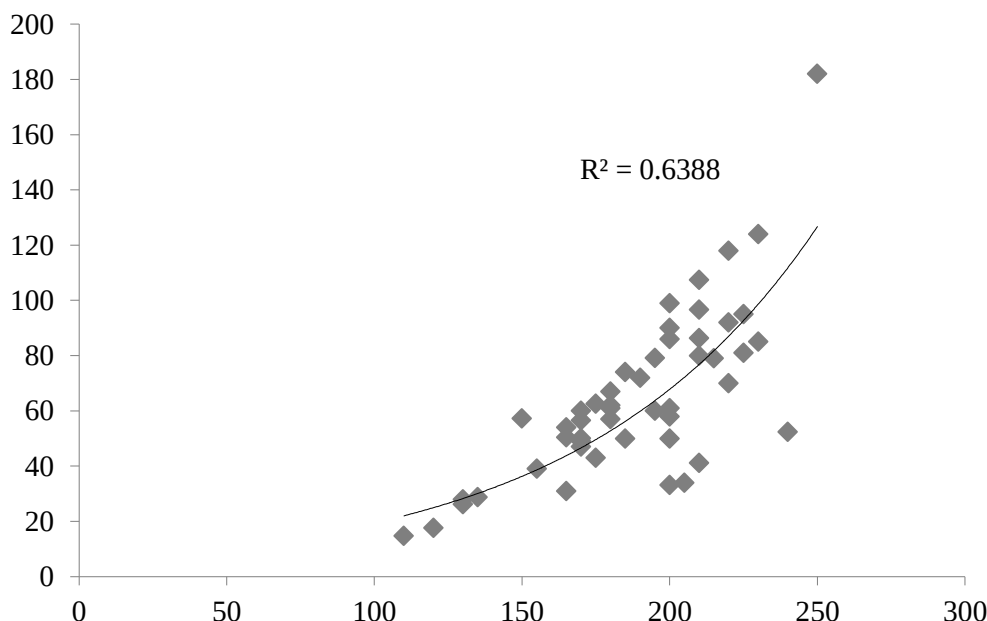


FIGURE 15. Length weight relationship of gillnet caught Dolly Varden captured in Victoria Lake 1992-1996 (N=49). (Source: FLNRO files, Nanaimo).

Maturity of Male and Female Dolly Varden

Of the 40 Dolly Varden captured in Victoria Lake from 1992 to 1996, only 2 mature fish, both females, were captured (Table 6). One mature female was 205 mm in length and was sampled in 1992, and the other was 210 mm and sampled in 1996. Most Dolly Varden captured were immature females ranging in length from 110 – 250 mm and averaging 191 mm over the 5-year study. Immature males ranged from 58 – 195 mm and averaged 190 mm over the 5 years.

TABLE 6. Number, range of fork length and mean fork lengths of immature and mature male and female Dolly Varden captured in gillnets in Victoria Lake, 1992 – 1996 (N=40) (Source: FLNRO files, Nanaimo).

	1992 (N=3)			1993 (N=3)		1994 (N=12)		1995 (N=9)		1996 (N=13)	
	Females (n=3)		Males (n=0)	Females (n=2)	Males (n=1)	Females (n=10)	Males (n=2)	Females (n=6)	Males (n=3)	Females (n=12)	Males (n=1)
	Immature	Mature	Immature/Mature	Immature	Immature	Immature	Immature	Immature	Immature	Immature	Mature
n	2	1	0	2	1	10	2	6	3	11	1
Range	225-240	205	-----	165-185	185	165-230	58-60	110-250	62-90	110-210	210
Mean	233	205	-----	175	185	206	59	208	76	165	195

Growth and Migration of Juvenile Dolly Varden

The mean fork length of Dolly Varden captured in June in the Marble River and Fry Creek in the Lower Campbell Lake watershed is presented in Table 7. Rimmer (2002) notes that the tributary streams in the Victoria Lake watershed are very cold which affects trout and char life history. He also points out that fish enter the streams to spawn in June and fry emergence occurs in late August. The fry likely move directly into Victoria Lake with the fall rains, which is similar to the life history pattern found in Campbell and Buttle Lakes.

TABLE 7. Number, range of fork lengths and mean fork lengths of Dolly Varden parr captured in minnow traps in the Marble River on June 12, 2002 compared with Dolly Varden captured by electrofishing in Fry Creek (Lower Campbell Lake) on June 10, 2003 (Source: DeDominicis, 2002; Michalski, 2003).

Factor	Marble River	Fry Creek
N	11	50
Range of Fork Lengths (mm)	83 – 202	40 -100
Mean Fork Length (mm)	131	80

Appendix 23. Woss Lake

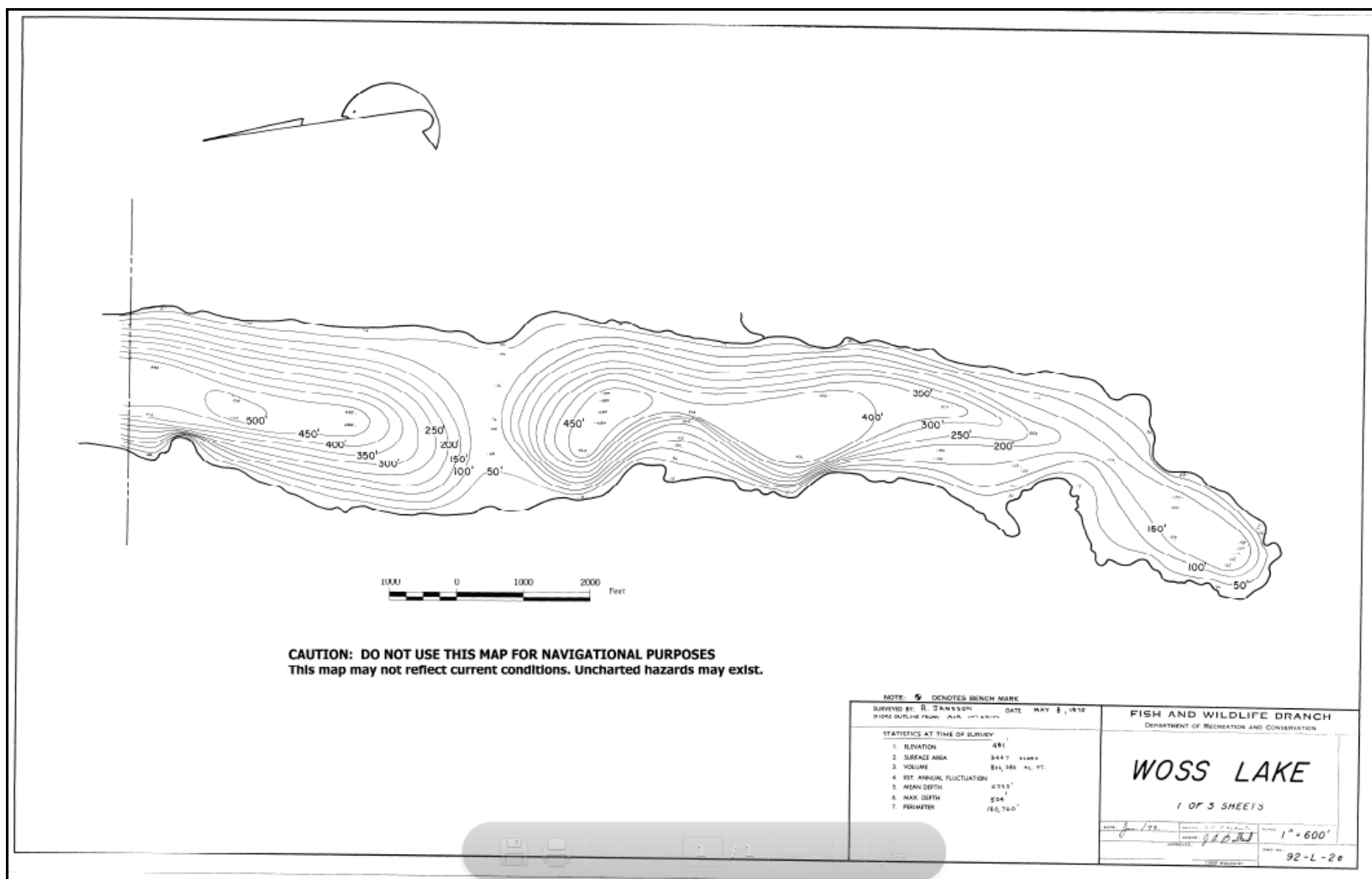


FIGURE 1. Bathymetric map of Woss Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

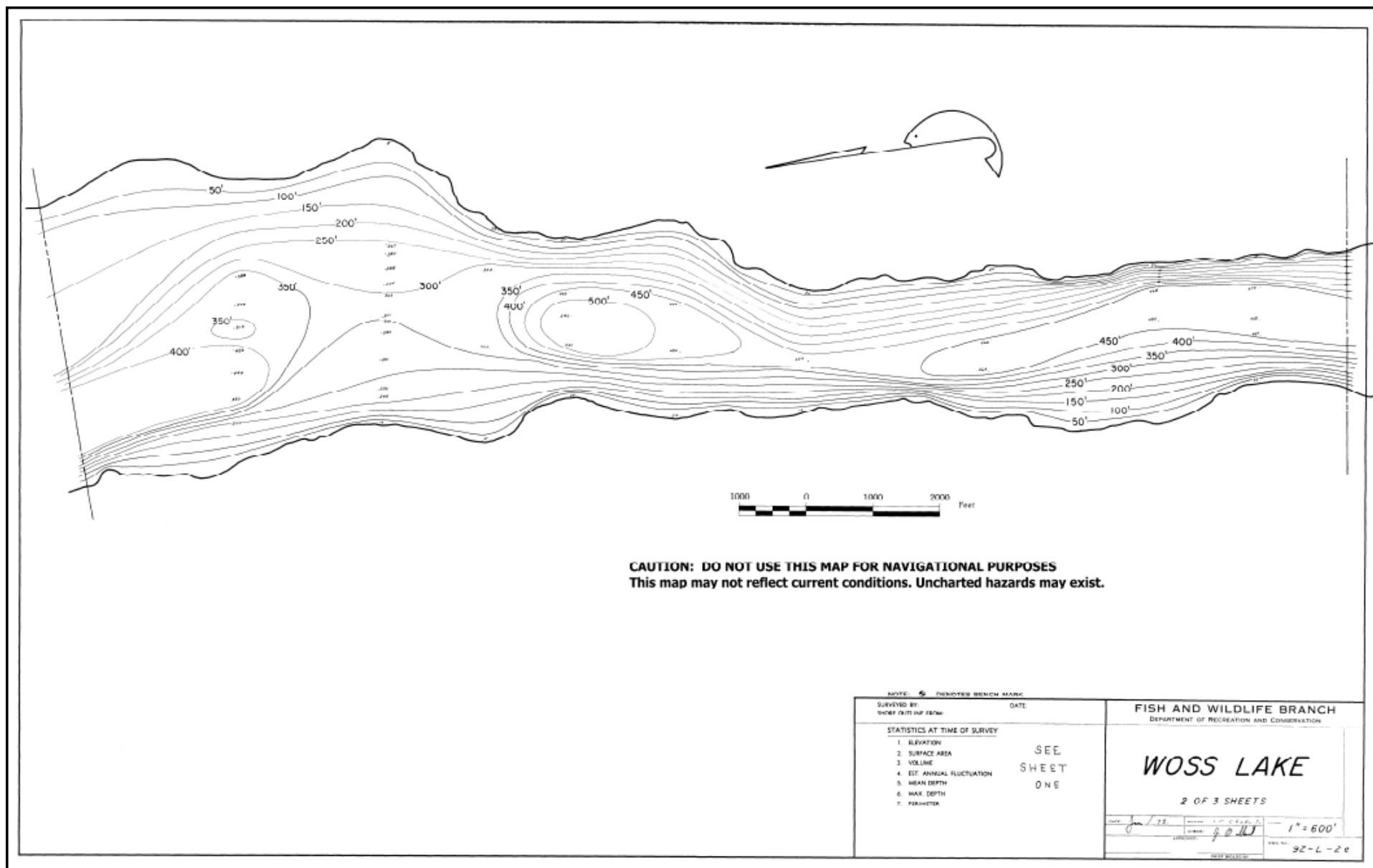


FIGURE 1 (CONTINUED). Bathymetric map of Woss Lake ((Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

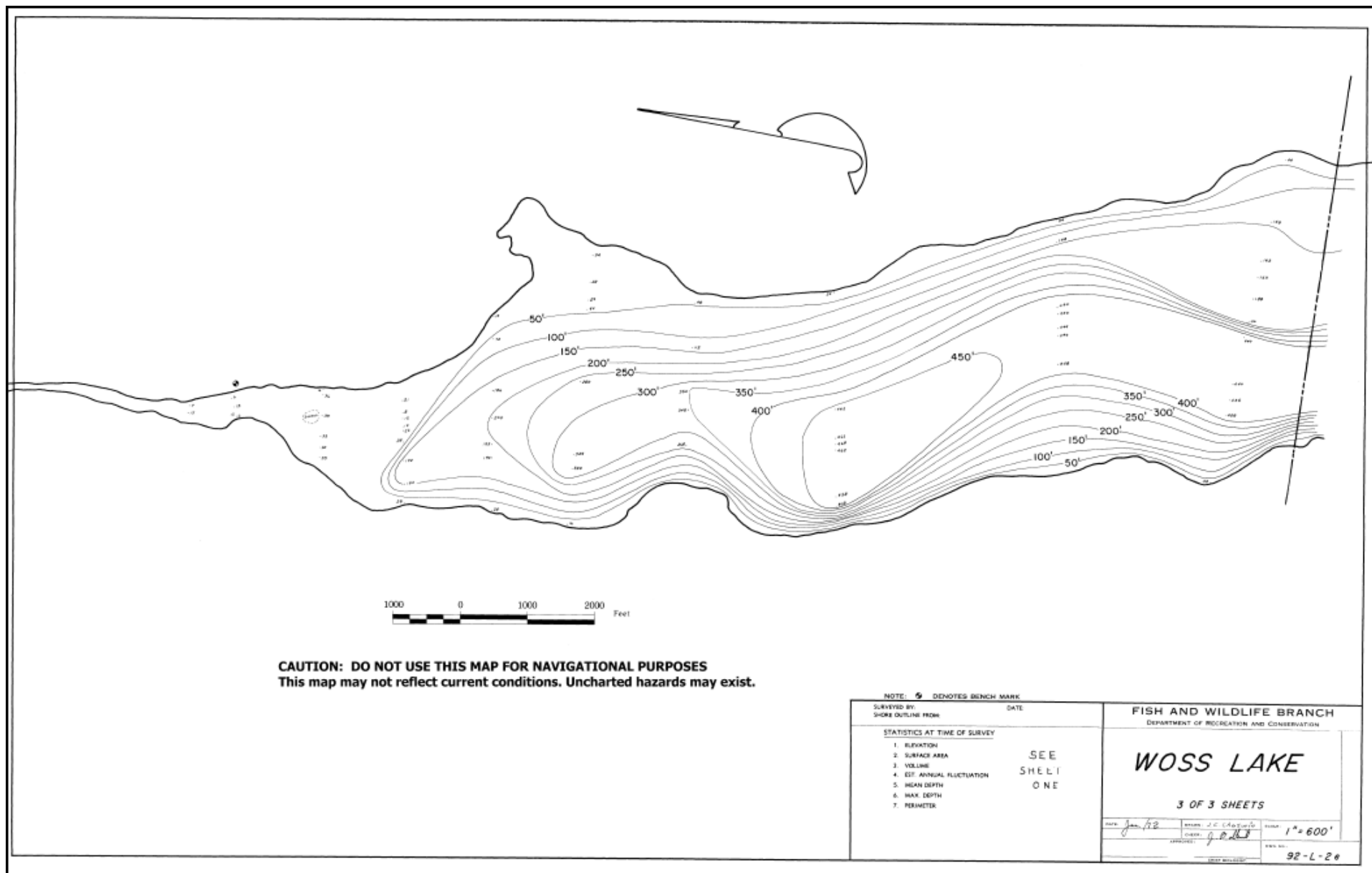


FIGURE 1 (CONTINUED). Bathymetric map of Woss Lake (Source: MOE, Fish Inventory Data Queries; bathymetric (depth) maps).

Tributary Information

TABLE 1. Names, order, length and/drainage area and other information for tributaries to Woss Lake (Source: Truelson and Lyon, 1974).

Tributary	Location	Length (km) and/or Drainage Area (km ²)	Other Information
Tributary #1	East side	0.27 miles	Beaver dams cause passable barriers and cause stream to pool; extensively logged; low water; stickleback identified.
Tributary #2a	East side	0.6 miles	Most riffle and cascades deciduous riparian on steep banks; very steep gradient.
Tributary #2b	East side	0.65 miles	Narrow, cascading stream; large amounts of burned logging debris; coniferous riparian; impassable obstruction at ~150 ft.; discharge <5cfs.
Tributary #3	East side and flows into north end of Woss Lake	0.8 miles	Small fast stream with steep gradient; only a few pools and possible spawning areas only noted in lower area.
Tributary #4	East side	1.4 miles	Creek is fast with beaver dams and unstable gravel banks; floodplain at lower reaches may have good spawning; watershed has been logged.
Tributary #5	East side	2.7 miles	Small size, 1 blocked channel and some other dry unused channels; unstable banks; logging has removed much of the cover; sedimentation in log jams creating barriers in some cases; low water in some areas.
Tributary #6	East side	2.2 miles	Fair size creek; logged but some deciduous cover left; some unstable banks; may be spawning in first ~500 ft; falls at 600 ft upstream may be a barrier; steep gradient above falls.
Tributary #7	East side	3 miles	Small creek with logged banks; creek bed is a deep ravine in upper reaches; gradient increase to >40% in upper reach; log jam at road may be barrier but could be cleared.
Tributary #8	East side	1 mile	Small creek with gravel build-up at mouth; some back channels but logging at mouth has removed cover; falls created by log jams at ~500 ft is probably impassable; discharge ~1 cfs.
Tributary #9	East side	0.7 miles	No water when surveyed – probably only has water during certain periods; cover is logged off for first 0.5 mile.
Tributary #10	East side	1 mile	Small creek running over weak limestone sinkhole band and flows underground near the road; banks unstable and sloughing; gravel bar near mouth; discharge <0.5 cfs.
Tributary #11	East side	1 mile	Steep creek with no cover for first 0.5 mile due to logging; unstable banks in some areas; no creek channel above 0.5 mile; productivity estimated to be low.
Tributary #12	East side	12.5 miles	Fast flowing with cover starting 0.5 miles upstream; gravel deposits may block tributary on this stream; fairly stable banks; discharge ~60 cfs; could have resident trout population upstream; good habitat and spawning beds; size and surrounding area make it worth protecting.
Tributary #13	East side	0.6 miles	Swift creek at beginning but levels off ~300 ft from lake; alder cover with no barriers initially but cascade with 2-3 ft falls at 300 ft; could be spawning and rearing areas in lower reach; may have small fish population.
Tributary #14	East side	1.5 miles	Forested cover but unstable banks in many sections; high water and flash flooding has caused sedimentation and

Tributary	Location	Length (km) and/or Drainage Area (km ²)	Other Information
Tributaries #15 – #23 and #26	East side	< 2miles each	debris accumulation. These are very small creeks dropping down the mountain side into Woss Lake; all are forested; much of streams flows over rock faces; continuous cascades and waterfalls; gradient >50% in all cases; no fish noted.
Tributary #24	East side	8 miles	Fairly large creek but steep falls near mouth; gradient increases to >70% upstream of falls; only first 100 ft could be used by fish.
Tributary #25	East side	~3 miles	Good flow but ~500 ft upstream a cascading falls over bedrock section is impassable; low gradient initially but increasing to >35% quickly; no fish noted.
Tributary #27	East side	3.5 miles	Small stream flowing into Woss Lake with gradient up to 8%; 2 channels one of which goes underground; cascade at ½ km could prevent passage.
Tributary #28	East side	~2 miles	Fish, including coho noted in lower sections; forested cover; gradient increases to 10-20% after 1/8 mile.
Tributary #29	East side	5 miles	Fairly large stream entering lake through many channels; cover is forest and marsh present in lower watershed; lower area has spawning and rearing areas and fish including coho noted; impassable falls at ~1/8 mile upstream.
Tributary #31	East side	0.6 miles	Small, slow flowing stream; forested with low bush cover; stable banks
Tributary #32	East side	9 miles	Good sized creek with excellent fish habitat; stable banks and lower 1/8 mile has numerous channels in a flood plain; coho present in lower reaches and numerous spawning gravel sections present; good flow.
Tributary #33	East side	1.6 miles	Small stream with gradient ~5% to 1/8 mile upstream where it increases to ~15%; overall productivity may be low because of turbulence and lack of organic matter.
Tributary #34; #35	East side	1 – 2 miles	Both creeks small with steep gradients (10% for first 600 ft, increasing to 40% for #34; 40% from mouth for #35); no fish noted.
Tributary #36	West side	2 ½ miles	Fast flowing stream; gradient 10 – 15%; forested cover with stable banks; log jams impede passage below 1/5 mile upstream to waterfall where gradient increases to >25%; discharge 5-6 cfs.
Tributaries: #37 - #40	West side	All <3/4 miles	Small streams that flow directly down mountainside into Woss Lake; tributary #40 passable for short distance until waterfalls block the stream; all other tributaries have impassable falls at their mouths.
Tributaries: #41 - #44	West side	All <1 ½ miles	These streams are a series of cascades and waterfalls with no pool area; gradient in each case >50% from mouth to headwaters with frequent waterfalls; no fish noted.
Tributary #46 – Clint Creek	East side	10.5 miles	Large creek with long stretch of low gradient gravel bars and pool areas; cover logged off for first ½ mile; discharge ~30 cfs good spawning; fry noted in a backwater ~1/2 mile upstream.
Tributary #47	East side	2.5 miles	Small creek with gradient <5% but underground channel at mouth caused by limestone sinkholes; discharge ~2 cfs; no fish noted.
Tributary #48	East side	½ mile	Small creek; steep gradient unstable banks cause sedimented log jams some of which may be barriers;

Tributary	Location	Length (km) and/or Drainage Area (km ²)	Other Information
Tributary #49	East side	½ mile	discharge <1 cfs; no suitable spawning or habitat areas. Small creek almost all riffle; gradient low at mouth but increases to >40% after 100ft; cascades after 200 ft; could be limited spawning in gravel sections near mouth.
Tributary #50 – Fiddle Creek	East side	12.5 miles	Sizeable creek with pools behind boulder jams; boulder jam at ~1 mile creates 10 ft falls that may not be passable; probably supports spawning population at falls; upper reaches with low gradient could be made accessible if log jam at falls cleared.
Tributary #51	East side	2.1 miles	Fairly large with flood plain in lower 100 ft; gradient <5% in lower reach, 20% in first ½ mile; area near mouth is a limestone sinkhole with underground channels; 9 ft falls at 50 ft impassable.
Tributary #52 – Woss River		6.5 miles	Tributary to Nimpkish River; fairly large river with no blocks; mostly stable banks with cover; discharge ~240 cfs; ~ 3 miles accessible to anadromous fish; Chinook and coho fry noted, cutthroat and rainbow also likely; good river for fishing.

Stock Status Indicators

TABLE 2. Results of snorkel surveys conducted on the Woss (September 15, 1993) and Nimpkish Rivers September 6, 1993 by FLNRO staff (Source: FLNRO files, Nanaimo).

		Woss River			Nimpkish River		
Steelhead		Sockeye	Chinook	Coho	Sockeye	Chinook	Coho
Wild	Hatchery	7,000	50	30	5,600	200	30
3	6		~15 kg				