A Comprehensive Study of Fish Stocks and Fisheries of Cowichan Lake

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1.0 Introduction

1.1 The Cowichan Lake Operational Management Plan – Background

In 2007, the Province of B.C. cited the importance of large lakes[1] like Cowichan Lake in sustaining biodiversity and wild fish stocks, and providing angling-based economic opportunities. The Fisheries Program Plan outlined activities to address key issues affecting large lake fisheries, including assessing the status of large lakes fish stocks and fisheries, and developing monitoring and management plans for these habitats to optimize sustainable angling opportunities (Ministry of Environment 2007).

The management of provincial freshwater fisheries is challenging because of the large number of species and variety of their life history traits, the intricacy of B.C.'s geology, habitat and climate, and the complexity of overlapping jurisdictional responsibilities for the management of freshwater fish and their habitat (Ministry of Environment 2007). The primary purpose of the Freshwater Fisheries Program Plan was to assist Freshwater Fisheries Program staff in prioritizing their efforts and coordinating the activities of program partners, including external partners (Ministry of Environment 2007). The guiding principles of the Program Plan included that:

- Wild fish populations are an important component of healthy aquatic ecosystems and the foundation of significant social and economic benefits to the Province.
- Angling is a valued and healthy pursuit.
- The relationship among governments, First Nations, partners, and stakeholders involved in fisheries management must be clear, collaborative and productive.
- The best available science will be provided to decision makers and the public; decisions will be transparent about the trade-offs being made and the uncertainties that exist.
- Strong shared stewardship of our fisheries resource is dependent on increasing awareness and accountability for fish and fish habitat among all British Columbians.

The Freshwater Fisheries Program Plan (Ministry of Environment 2007) outlined the general objectives of fisheries management as:

1. Conserving wild fish and their habitats. Robust wild fish populations, as a key component of healthy watersheds and ecosystems, are the foundation of a sustainable freshwater fisheries program. Conserving wild fish requires management actions designed to protect, maintain and restore fish stocks. Conserving fish and fish habitats requires the combined efforts of land and water managers, resource developers and those involved in community stewardship.

[1] Large lakes are defined as lakes >1,000 ha. These lakes are usually 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 (Ministry of Environment 2007). Because each lake is unique, management normally requires lake-specific data collection, analysis and regulations (Parkinson, pers. com, 2009).

2. Optimizing recreational opportunities based on the fishery resource. A sustainable fishery resource that provides social, economic and recreational benefits to all British Columbians is the result of effective and well-coordinated fisheries management. It recognizes the interests and preferences of users and makes effective use of hatcheries and other enhancement programs.

In 2009, the Habitat Conservation Trust Foundation (HCTF) provided an opportunity to assess the stocks of wild fish and the fisheries of Cowichan Lake[2].

1.2 Lake Characteristics

Cowichan Lake is located ~70 km northwest of Victoria and 31 km west of Duncan and is one of the most heavily fished in the region offering year-round opportunities to catch Rainbow (*Oncorhynchus mykiss*) and Cutthroat Trout (*O. clarkii*), and Dolly Varden (*Salvelinus malma*). Cowichan Lake derbies which run almost weekly throughout the winter months are well-known and provide anglers with the opportunity to catch large Cutthroat Trout.

With a surface area 6,204 hectares, Cowichan Lake is the 2nd largest lake on Vancouver Island (Table 1); Figure 1). The lake is situated at an elevation of 164 meters, has a maximum depth of 152 meters and a mean depth of 50 m. Cowichan Lake is ringed by 1,500 m high hills and drains a watershed of ~300 km^2 (Epps and Phippen 2011). 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.

Table 1. Location, size, depth and water quality parameters at Cowichan Lake. (Source: Fish Information Summary System, Ministry of Environment).

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	8.0-9.4	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.
**Epps and Phippen 2011

[2] HCTF Project Number 1-456.

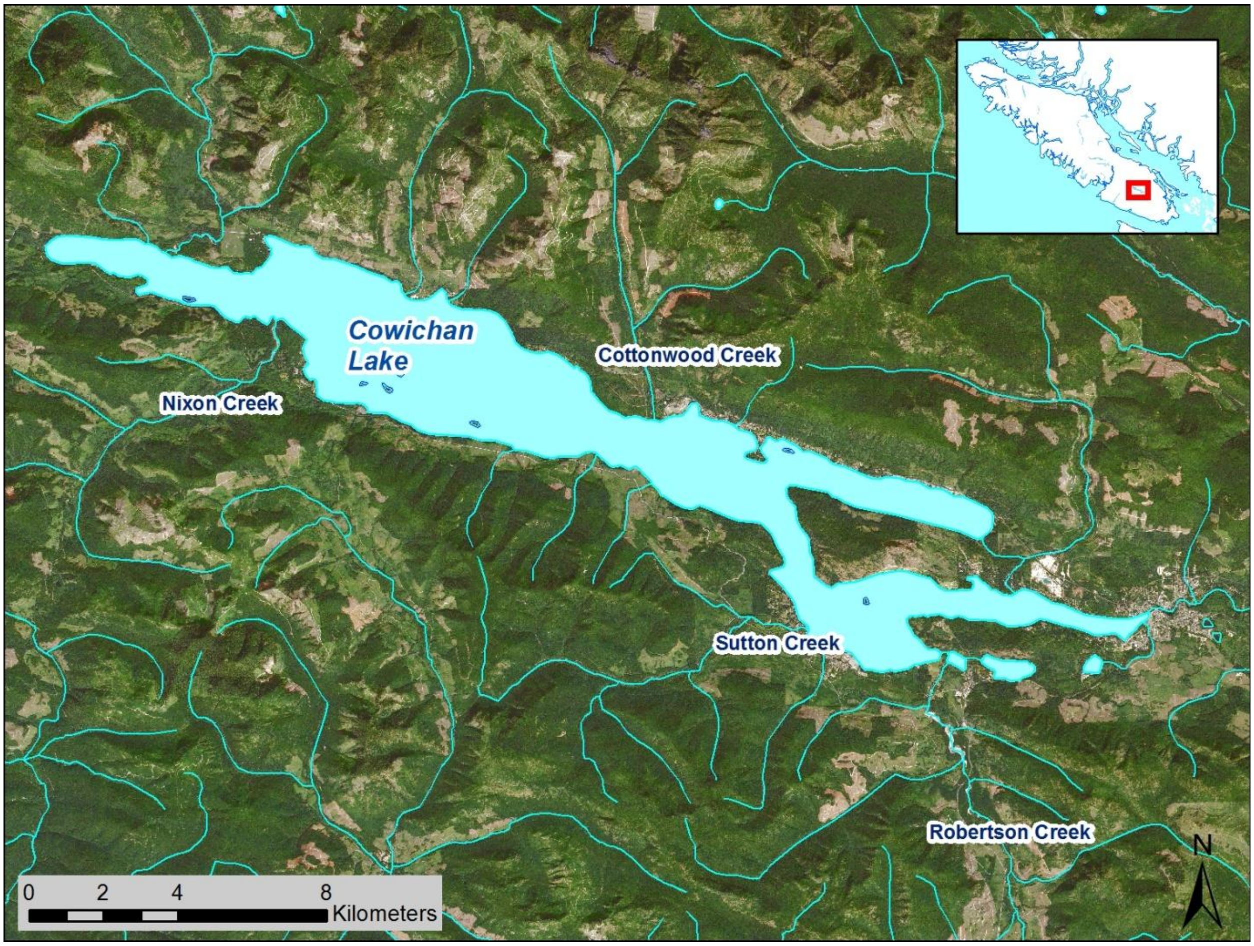


Figure 1. Location of Cowichan Lake watershed including major tributaries (Source: iMap BC Data BC).

Almost all of the land surrounding Cowichan Lake is privately owned by TimberWest Forest Corporation. Forest harvesting occurs throughout much of the upper Cowichan Lake watershed and the lake experiences high levels of recreational activity primarily during the summer months (Epps 2011). Water levels in Cowichan Lake are controlled by a weir at the east end of the lake operated by the Crofton Division of Catalyst Paper (Epps and Phippen 2011).

Cowichan Lake has several communities along its shores. The town of Lake Cowichan, which is the largest community, is located at the east end of the lake at the start of the Cowichan River. Mesachie Lake and Honeymoon Bay are located along the south side of the lake while Youbou is located on the north shore. In addition to these communities there are numerous private residences located along the lakeshore, many with their own private boat docks (Epps and Phippen 2011). Cowichan Lake supplies drinking water to the Town of Lake Cowichan, and the Cowichan Valley Regional District (Epps and Phippen 2011).

The Cowichan watershed supports an abundance and diversity of anadromous and resident salmonids. Anadromous species include Chinook (*O. tshawytscha*), Coho (*O. kisutch*) and Chum Salmon (*O. keta*), Steelhead *(O. mykiss)*, and Cutthroat Trout, while resident species include Brown Trout (*Salmo trutta*), which were introduced into the Cowichan River in the early to mid-1930's (Neave and Carl 1940), Dolly Varden, Rainbow and Cutthroat Trout, and Kokanee Salmon (*O. nerka*). Other species include the Cowichan Lake or Vancouver lamprey (*Lampetra macrostoma*), Pacific Lamprey (*L. tridentata*), Prickly Sculpin (*Cottus asper*) and Threespine Stickleback (*Gasterosteus aculeatus*).

1.3 Fisheries

Cowichan Lake is one of the most important fisheries in the Vancouver Island Region. According to the Vancouver Island Lakes Questionnaire (VILQ), angler effort averaged ~16,500 angler days/year over the past 25 years and is currently estimated at ~12,000 angler days/year; only Elk Lake near Victoria exceeds this total (Vancouver Island Lakes Questionnaire; unpublished data).

Catch and effort data are available from the VILQ for 6 of the last 25 years[3] (Figure 2). There was an apparent decline in effort between 1991 and 2005, after which effort appeared to remain effort relatively stable. Catch/effort was also relatively stable throughout this period.

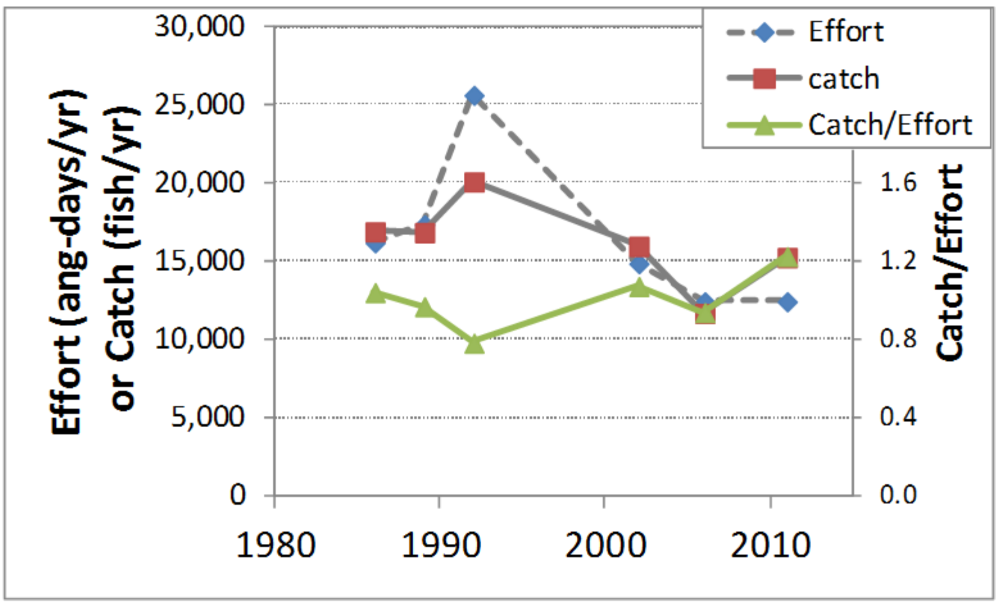


Figure 2. Historical data estimated for angler effort, catch and catch/effort at Cowichan Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Vancouver Island Lakes Questionnaire; unpublished data).

While there are limitations on the precision of statistical estimates of effort developed from data collected from the VILQ, there are a variety of factors that suggest a decline in angler effort at Cowichan including a general decline in license sales in BC (Clarke 2012) and across North America (Martin et al. 2012). It is possible there was an increase in participation in alternative fisheries such as catchable trout in lakes near Victoria, and/or smallmouth

[3] The VILQ is a tool designed by Ministry statisticians and implemented by biologists in the Vancouver Island region in the 1980's. The VILQ is a questionnaire of resident anglers regarding their angler effort, catch and, more recently, harvest at Vancouver Island lakes. This questionnaire provides data on lakes fished and estimates the number of fish caught and angler success (catch per angler day).

bass (*Micropterus dolomieui*) which have been introduced into many Island lakes and are gaining in popularity with anglers.

With respect to stock status, a number of factors could have influenced Cutthroat Trout abundance, angler catch rates and subsequent angler effort including both the natural variation in fish abundance, and development pressures around Cowichan Lake which could have impacted the Kokanee stocks, which are a major prey source for Cowichan Lake Cutthroat Trout. Although catch and catch rates are often poor indicators of stock status because factors such as increasing angler efficiency can mask true declines in spawner abundance (Walters and Martel 2004), it is also possible that the apparent decline in catch and catch rates was due to angler overharvest of the wild Cutthroat Trout for which the lake is renowned.

1.4 Management Issues

I examined the harvest of wild stocks and aspects of angler effort to better understand the Cowichan Lake fishery. A fit to a Schaeffer model of surplus production suggests that the high level of angler effort and total catch in the early 1990's approached a maximum on the yield curve (Figure 3). However, under lower levels of angler effort in 2006 and 2011, the fishery appears to be back on the ascending limb of the yield curve. With only six data points, this conclusion needs to be treated with some skepticism, especially if angler efficiency (catchability) has increased (i.e. 100 angler days achieves the same harvest rate of 200 angler days from 20 years ago), or other factors (e.g. environmental degradation) have led to a decline in maximum abundance. In addition, the Schaeffer model is probably more appropriate for a commercial fishery where the key objective is Maximum Sustainable Yield (MSY).

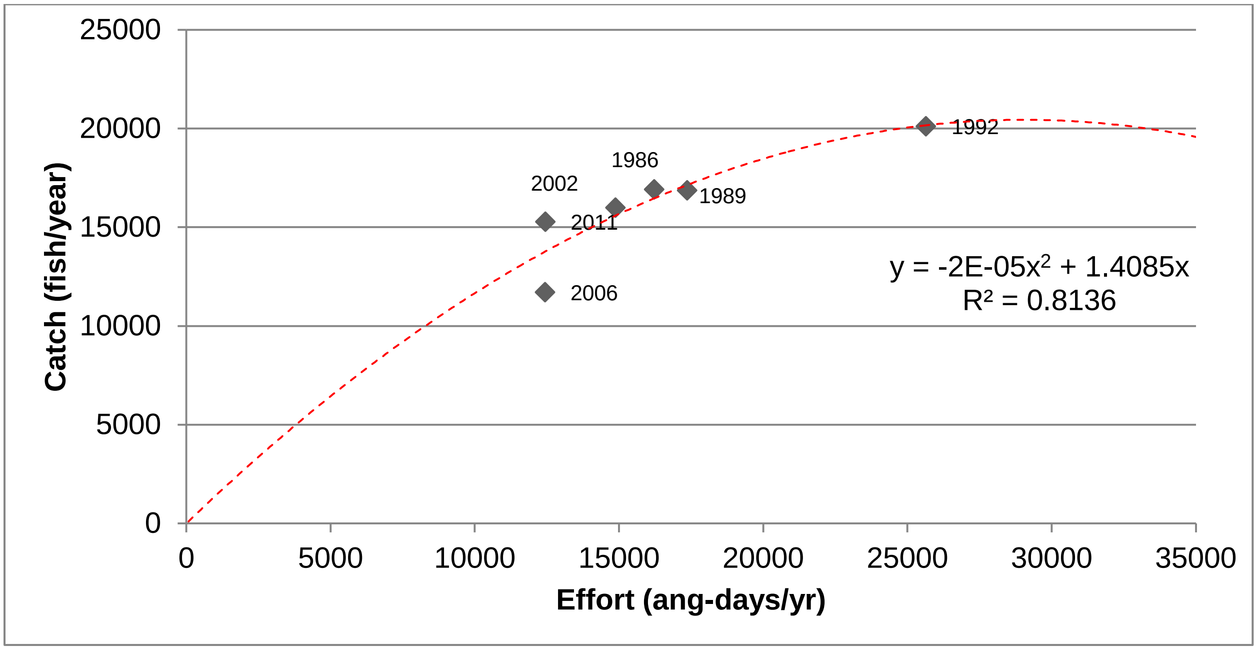


Figure 3. Angler effort (angler days) vs. total catch at Cowichan Lake 1986 – 2011 (Source: Aitzhanova, et al. 2003; Andrews, 2007, Vancouver Island Lakes Questionnaire; unpublished data). The fitted line represents a fit of a Schaeffer model (Ricker 1975, p374) to the catch and effort data. The fit of this model is marginally better than that of a simple linear relationship (ΔAIC=1.46).

Harvest pressure on wild stocks may increase in coming years because the population of the Cowichan Valley is projected to grow by 20% from 85,000 to just over 100,000 people in the next 20 years (BC Stats, 2013). If there is a concomitant increase in angler effort there could be challenges maintaining sustainable fisheries because, like all large lakes, sport fisheries at Cowichan Lake cannot be easily supplemented by stocking and these fisheries will be entirely dependent on native, wild fish stocks (Narver 1975). In addition, development pressures around Cowichan Lake associated with population increases could compromise Kokanee spawning grounds which incidental information suggests are limited to small sections of the lake.

Together with members of the Valley Fish and Game Club, I identified the study objectives listed below to provide additional data to evaluate mechanisms of possible decline in angler effort and catch, and to support future monitoring and management direction.

1.5 Specific Objectives

1. Review fisheries status and identify trends in Cowichan Lake.
2. Evaluate the sustainability of current levels of angler effort, catch and harvest levels for Cowichan Lake.
3. Review stock status data and identify trends in target populations.
4. Identify data gaps to support wild stock conservation, fisheries management and monitoring.
5. Identify possible strategies to promote stock conservation.
6. Outline stock and angler monitoring approaches.

2.0 Methods

2.1 Review of Historical Fisheries and Stock Data

I reviewed the results of the VILQ to identify trends and current status of the Cowichan Lake fishery. I also reviewed all files at the FLNRO office in Nanaimo, the on-line MoE Ecocat Report Catalogue, BC Fish Inventory Summary System (FISS) libraries and Cross-linked Information Repositories (CLIR), and the library at the Nanaimo Pacific Biological Station to gather all fish stock data from Cowichan Lake and tributaries. All data were entered into Excel spreadsheets for analysis.

2.2 Angler Counts and Interviews

Volunteers from the Valley Fish and Game Club conducted instantaneous angler counts and interviews from July, 2009 until June, 2011 to determine fisheries status and trends in Cowichan Lake (Figure 4). Volunteers conducted roving creels four times per month - twice on week days, and twice on weekends and/or holidays in 2010 and 2011 (Appendix 1). Our creel schedule was determined by randomly selecting weekdays and weekend days throughout the year, and assigning random start times within daylight hours on those days. I also divided Cowichan Lake into three sections (Figure 4) to determine if fishing pressure differed between areas on the lake.

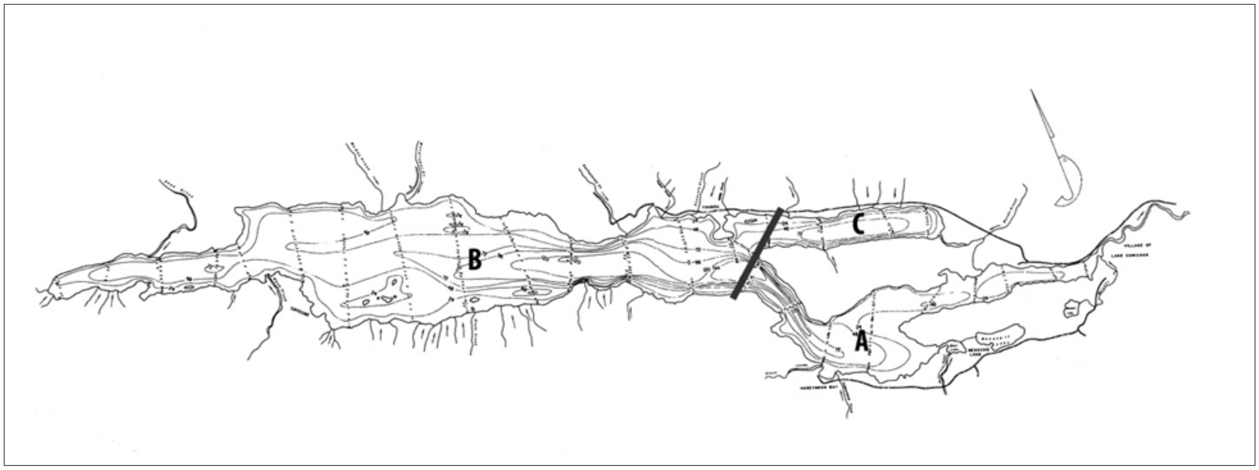


Figure 4. Bathymetric map of Cowichan Lake with lake sections A, B, C defined for stratifying results of roving creel (Source: Province of BC, Nanaimo).

Volunteers completed a circuit of Cowichan Lake and recorded the number of boats and anglers in each lake section. They then went back to each section and interviewed anglers. Volunteers were asked to interview at least 10% of the total number of anglers counted (Appendix 2). In cases where there was a low angler count, volunteers interviewed as many anglers as possible. Volunteers recorded catch data, water and air temperatures and weather conditions and took scale samples of angler-caught fish. I used the data collected during the instantaneous counts to calculate angler effort (Appendix 3). I assumed the creel sampling expansion included all anglers who fished and caught fish outside the defined sampling time. Instantaneous counts in time strata were expanded to total effort by multiplying the average count by the hours in the strata. Several time stratification schemes were compared using Akaike's Information Criterion (AIC) analysis (e.g. Maunder and Punt 2013). Total catch recorded during interviews is provided in Appendix 3.

Catch and Harvest

The interview data did not include the time spent fishing, however, this information is required to fully understand CE. Therefore, the catch to effort (CE) ratio was estimated from Regional averages for the Kamloops and Okanagan Regions[4]. This method predicts CE as number of fish per angler day (Figure 5) using the average length of harvested fish and lake characteristics (Parkinson et al. 2004, Wilson et al. in review). The key assumption when using this methodology is that the species preference is similar for Cutthroat and Rainbow Trout across the entire population of anglers fishing these lakes (i.e. not individual anglers). The equation used on Cowichan Lake is:

$$C_H=242{,}000L^{-3.7}= 0.48$$

where C_H is the estimated number of fish harvested in a four hour angler day, 242,000 is the average Kamloops and Okanagan Regional constant and *L* is the average length of harvested fish, which was 34.7 cm from the Cowichan Lake survey. These numbers are similar to those estimated from Elk, Prospect and Langford lakes near Victoria whose average constant is 254,000, which reflects an average C_H of 0.63 fish/angler day (0.16 fish/angler hour) with an average length of 32.6 cm (i.e. slightly better quality reflecting higher catch rates but lower fish sizes than those projected for Cowichan Lake). Anglers release about 40% of the fish that they catch, which implies that the catch rate is higher at 1.2 fish per four-hour angler-day.

[4] No similar information is available for large lakes on Vancouver Island. Data collected for 2004 Ministry of Environment Regions.

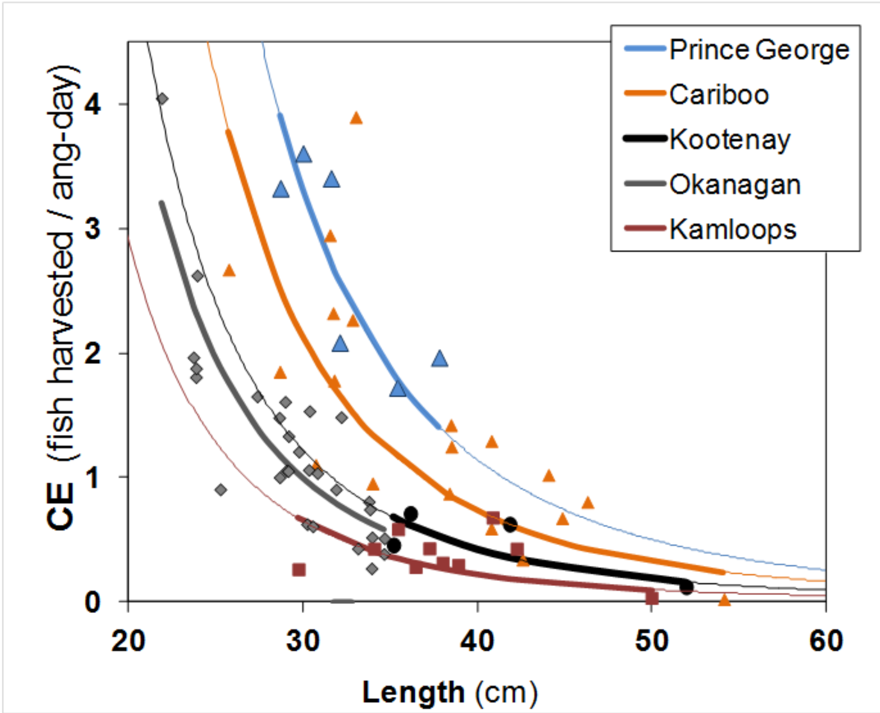


Figure 5. Catch to effort ratio (CE) as a function of length in the catch for a variety of lakes in the BC interior. The curves are similar to Equation 1 and share a common exponent (-3.7) with different intercepts.

In addition to collecting life history data from anglers during the roving creel survey, we attended weekend and holiday Cutthroat Trout derbies to collect additional data and information (Appendix 4). Ministry staff, contractors and volunteers attended 23 derbies between October, 2009 and March, 2012. We collected length, weight, maturity and sex data and scale samples at derby weigh-ins. We also interviewed anglers about their total catch and whether they released fish >50 cm[5] .

2.3 Angler Preference Surveys

We conducted angler preference surveys during creel surveys in 2009 to assess anglers' levels of satisfaction with angling at Cowichan Lake, and determine whether anglers would support changes to regulations to improve the fishery. Anglers were asked to rate fishing in Cowichan Lake, why they fish Cowichan Lake, the species they prefer to catch, and whether they would support size limits, harvest limits, season or area closures or Catch-and-Release regulations to improve the fishery.

2.4 Gillnet and Trap Net Sampling

[5] The current regulation prohibits anglers keeping Cutthroat Trout >50 cm length.

We conducted gillnet assessments to collect life history and stock status data and compare current stock status to historic gillnetting results. We followed Resource Inventory Standards Committee (RISC) standards and set floating and sinking nets overnight in 2009 and 2011. We set the nets in locations also sampled by Griffith (1989). Ministry staff and volunteers retrieved nets, recorded species (Appendix 5), fork lengths, weights, sex and maturity, identified stomach contents and took scale samples of fish caught.

I used net trap data collected by FLNRO Fish & Wildlife staff and volunteers from the Cowichan Lake Enhancement Society in 1996 and 1998 to account for movements of Cutthroat Trout and Rainbow Trout <200 mm. Free floating trap nets were set on shoals of Cowichan Lake and allowed to fish overnight for several evenings in May and June and November of 1996 and 1998. Nets were fixed in position with a four point anchoring system. Trapping components consisted of a main lead, wing lead(s), heart section, funnel(s) and trap box (see Tsumura et al. 1999 for a discussion of trap net design and implementation by the Fisheries Branch 1994 - 1999). Traps fished overnight and fish sampled were identified to species, weighed and measured. The data were recorded on data sheets and stored in the Cowichan Lake files at the Ministry office in Nanaimo.

2.5 Spawning Surveys

MJ Lough Environmental consultants conducted snorkel surveys of tributaries to Cowichan Lake in 2011 and 2013 to document the number and estimated size of spawning Cutthroat Trout and redds in the Robertson River, Nixon, Sutton and Shaw Creeks. A representative index site ranging from 2.5 to 3.7 km in length was established in each stream.

A detailed account of the methods can be found in Lough et al. (2011a). In short, swimmers conducted weekly snorkel surveys to determine the location and periodicity of Cutthroat Trout spawning, and to enumerate the spawning adults when they moved into the study streams to spawn (Table 2) Cutthroat Trout redds were also identified and new redds enumerated, geo-referenced and flagged to prevent double counting. Occasional validation of redds was done by inspecting eggs to ensure eggs were from Cutthroat and not fall-run Dolly Varden.

Table 2. Survey period, number of surveys, index site location and length of index site for snorkel surveys conducted at Robertson River and Sutton, Nixon and Shaw Creeks February 22, 2011 – May 27, 2011 In addition to conducting surveys on the mainstem, the lower portions of 4-1st and 2nd order, unnamed tributaries to the Robertson River and Sutton and Nixon creeks were also surveyed during the period of peak spawning activity. No fish or redds were found in these areas (reprinted from Lough et al. 2011a).

Parameter	Robertson River	Sutton Creek	Nixon Creek	Shaw Creek
Survey Period	Feb 22-May 26	Mar 6-May 26	Mar 5-May 27	Mar 5-May 27
Number of Surveys	9	9	9	9
Index Site Location	Km 7.9-Km 4.2	Km 4.7-Km 1.9	Km 4.3-Km 0.9	Km 2.5-Km 0
Length of Index Site	3.7 km	2.8 km	3.4 km	2.5 km

2.6 Electrofishing Surveys

Ministry staff conducted an electrofishing survey in September, 2012 to determine abundance and size of salmonid juveniles in Nixon and Sutton Creeks. I chose these streams based on the results of Griffith (1989) and Lough (2012) which identified the importance of these streams to Cutthroat Trout relative to the other streams in the watershed.

We sampled two sites per stream by securing stop-nets at the upstream and downstream site boundaries and conducting a multiple-pass removal using a backpack electrofisher. Unfortunately, the discharge at some sites created less than ideal conditions as evidenced by low catch rates and high 2nd pass catches. Nonetheless, fish were weighed and measured and returned to the site following the assessment. I used Microfish 3.0 (Van Deventer 2013) to estimate population sizes for Coho, trout and Dolly Varden at each site.

2.7 Fish Aging

Lew Carswell analyzed Cutthroat and Rainbow Trout and Dolly Varden scales collected by gillnetting in 2009, and Mike Lough analyzed scales collected by anglers between October 2010 and May 2011 by gillnetting in 2011, and during an annual fishing derby held on January 2012.

Scales were stored in scale envelopes until they could be read. Scales were removed from each scale envelope, spread out, sandwiched between 2 microscope slides and viewed on a 60X digital dissecting microscope (Lough et al., 2011a). Standard ageing methodologies described by Narver (1975) where summer growth was denoted with a "+" symbol were used. Both Carswell and Lough validated their estimated scale age using length frequency analysis.

Anterior scale radius measurements can be used for back-calculating lengths of fish at the time of earlier annulus formation (Everhart et al. 1975) and, therefore, can be used to determine growth rates of fish. Digital images of scales from each Cutthroat Trout captured by gillnetting were created, and one representative image was used for digital measurement of the anterior scale radius (Lough 2012). The digital measurement was derived using a linear measurement tool calibrated to a known reference scale and a single scale radius for each fish was measured from the center or focus of the scale to the outer margin, on the long axis of the scale (Lough 2012). Linear regressions were derived for fork length and anterior scale radius using methods described in Everhart and Youngs (1981).

2.8 Kokanee Surveys

Dale Sebastian and David Johner of the Ministry of Environment, Stock Assessment Branch conducted hydro acoustic and trawl surveys in July 2010 to assess the pelagic fish population in Cowichan Lake with particular emphasis on Kokanee. The night-time surveys followed the standard survey design by Sebastian et al. (1995a) and used the same habitat areas as Rutherford et al. (1988). A total of 18 acoustic transects and four trawls were completed during the new moon on July 6-8, 2010. Ministry and contract staff used a 7.3

welded aluminum research boat with a dual drum hydraulic winch and boom system to conduct hydro acoustic and trawl sampling (Johner and Sebastian, 2011).

Specific details regarding methodology are outlined in Johner and Sebastian (2011). In short, acoustic transects were conducted using a splitbeam echosounder operating at 120 kHz with a 7^0 nominal beam angle. Trawling was conducted using a three by seven meter net directed at the main fish layer ranging from 10–24 m depth. There were four trawl locations and each one-hour trawl consisted of 2-30 minute layers (10-17 m and 17-24 m) except for Trawl 1 which consisted of 3-20 minute layers ranging from 12-31 m (Johner and Sebastian 2011). All Kokanee, Sculpin and Stickleback were retained to sample for length, weight, sex, age and maturity while all lamprey were weighed and measured and returned to the lake. Oxygen and temperature profiling was conducted at three locations on the lake and vertical casts were completed from surface to a depth of at least 50 m.

Acoustic data processing was done using SONAR5-pro version 6.0.0. Files were analyzed and fish populations were estimated. Mean fish densities by depth were combined in a Monte Carlo Simulation to determine the maximum likelihood population estimate (MLE) with 2.5 and 97.5 percentiles representing the lower and upper statistical bounds of the distribution (Sebastian et al. 1995a). Fish were partitioned into three general size groups: fish<70 mm; fish 70-220 mm; and fish >220 mm (Johner and Sebastian 2011).

2.9 Determining Fisheries Objectives and Management Strategies

A sub-committee of the Valley Fish and Game Club participated in the review of study data and the development of study objectives. Before starting this process, the subcommittee and I developed a Terms of Reference (Appendix 6), and agreed on core principles to guide the study and bring forward when considering future actions:

1. Conservation of wild stocks will be an overarching principle.
2. Providing sustainable fishing opportunities for wild stocks is a priority.
3. Monitoring and adaptive management will be supported.
4. Enhancing habitat for wild stocks is a priority.

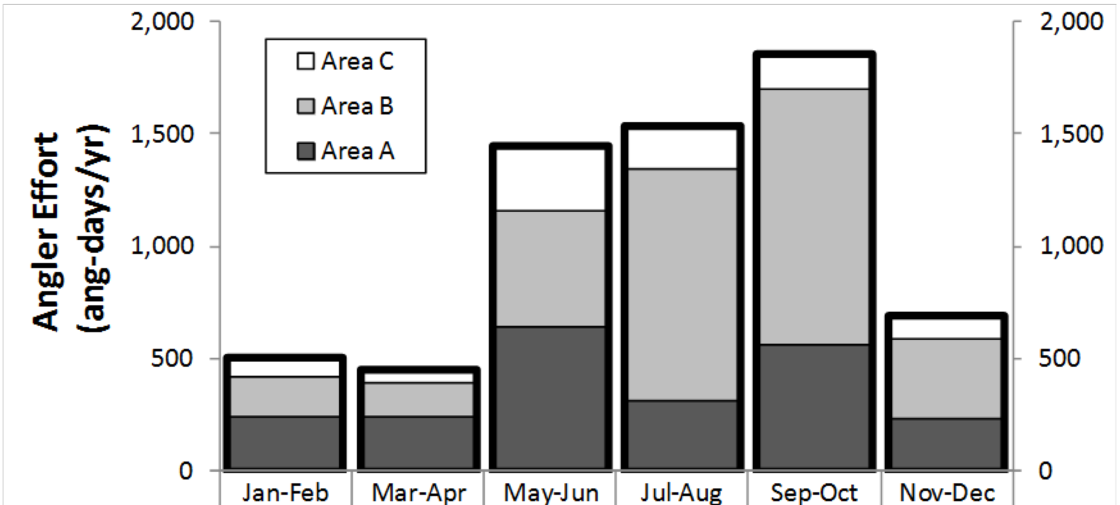
I met with the subcommittee four times and with the Valley Fish and Game Club three times during the course of the project during which I provided updates on the research progress, data summaries and potential management actions.

3.0 Results

3.1 Angler Effort

Comparisons of different stratification models using the Akaike information criterion (AIC) criteria indicated the most parsimonious stratification scheme involved weekend (WE) *versus* weekday (WD) and a two month seasonal stratification. Seasonal models with two or three seasons did not fit the data as well as the two month periods. A model with coefficients for individual months provided a good fit but was over parameterized. The addition of time-of-day and year strata was not supported by the data because there were few consistent differences among years and times.

Estimated angler effort during the sampling period was 6,500 + 1,500 angler days/year with most of the effort in the May to October period (Figure 6). Weekends accounted for 60% of this effort. Effort density was distributed widely across the lake with sections A, B, and C supporting 35%, 52% and 14%, respectively. Anglers fished year round, but 75% of the effort took place in the May-October period.



	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Area C	86	59	291	188	161	108
Area B	175	146	512	1,028	1,131	349
Area A	244	243	646	316	566	237
Total	505	448	1,448	1,531	1,858	694

Figure 6. Angler effort distribution across lake sections and months.

Our estimate of angler effort is substantially less that the VILQ, which estimated 12,447 angler days in 2011 (Table 2; Vancouver Island Lakes Questionnaire; unpublished data). However, recall and response bias typically results in an upward bias of angling effort in mail-out questionnaires (Brown 1991). For example, Degisi (1999) found that angler effort measured by field data collection was only 62% of that estimated by the mailed Steelhead harvest analysis.

Combining the effort estimate with the CE estimate from Equation 1 gave an estimated harvest of 2,900 trout per year. The combination of error in effort estimate (+25%) and error associated with Figure 5 means that the confidence limits on this estimate are fairly large, in the order of + 50%.

3.2 Catch and Harvest

Anglers report catching more Cutthroat than Rainbow throughout the year (Table 3, X^2=72.0, p<0.001). Although a higher proportion of spring and fall catches are Cutthroat

Trout, these seasonal differences are not statistically significant (X^2=2.03, p=0.57). Harvest as a proportion of catch is much higher for Cutthroat (45%), than Rainbow Trout (13%) (X^2=6.2, p=0.013).

Table 3. Seasonal variation in the proportion of Cutthroat and Rainbow Trout reported during creel survey interviews.

Season	Cutthroat Trout			Rainbow Trout			% Cutthroat in Catch	Total Catch
	Kept	Caught	% Kept	Kept	Caught	% Kept		
Winter (Jan-Mar)	5	15	33%	0	8	0%	65%	23
Spring (Apr-June)	22	46	48%	0	3	0%	94%	49
Summer (July-Sept)	12	30	40%	0	10	0%	75%	40
Fall (Oct-Dec)	24	50	48%	4	9	44%	85%	59
Total	63	141	45%	4	30	13%	82%	171

3.3 Size of Angler-Caught and Harvested Fish

The average size of angler-caught Cutthroat Trout was well below the maximum legal size limit of 50 cm (Table 4). However, measurements from released Cutthroat indicate a maximum size of at least 66 cm. The average size of Rainbow Trout was <30 cm and both the average and maximum size of Rainbow were smaller than for Cutthroat Trout.

Table 4. Total number, minimum, maximum and average length (mm) of Cutthroat and Rainbow Trout harvested and released by anglers at Cowichan Lake July, 2009 – June, 2011. (Source: angler interviews conducted following instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011).

	Number	Length (mm)			
Species	Kept	Minimum	Maximum	Average	Standard Deviation
Cutthroat Trout	51	200	560	350.4	69.4
Rainbow Trout	2	200	360	280.0	113.1
Dolly Varden	0		N/A		
	Released				
Cutthroat Trout	75	150	660	302.2	139.1
Rainbow Trout	23	120	450	247.8	73.7
Dolly Varden	1		430		

Anglers caught Cutthroat Trout as small as 150 mm, but rarely harvested Cutthroat Trout <200 mm (Table 4; Figure 7; Figure 8). The average size of Cutthroat harvested was ~350 mm. Approximately 50% of the Cutthroat harvested were <14" (355 mm) and 30% were <12" (300 mm). Anglers also caught, but did not harvest Cutthroat Trout >450 mm. Fish larger than the legal limit were still being harvested at the time of my study.

Neither frequency distribution shows any evidence of multimodal age structure, probably because the fish in Figures 7 and 8 were sampled throughout the growing season.

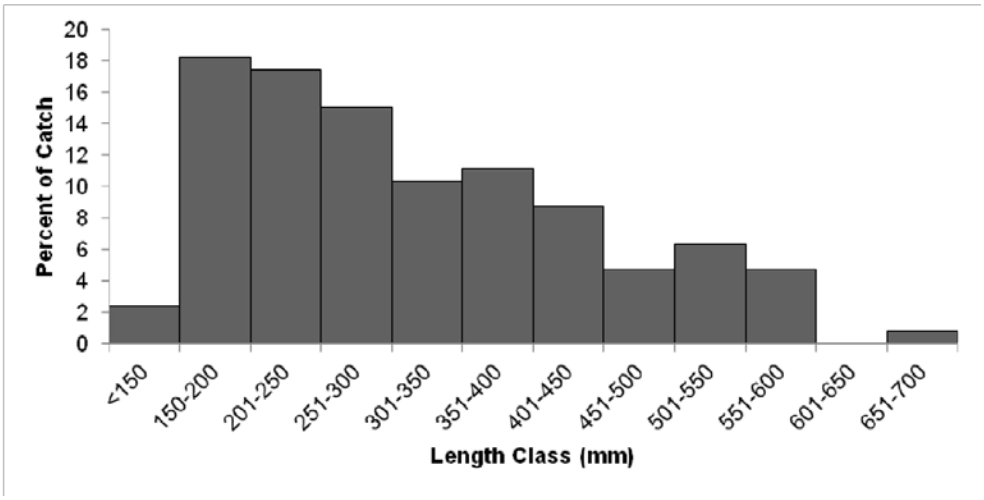


Figure 7. Length-frequency of Cutthroat Trout caught by anglers at Cowichan Lake July, 2009 – June, 2011 (N=126). (Source: angler interviews conducted following instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011).

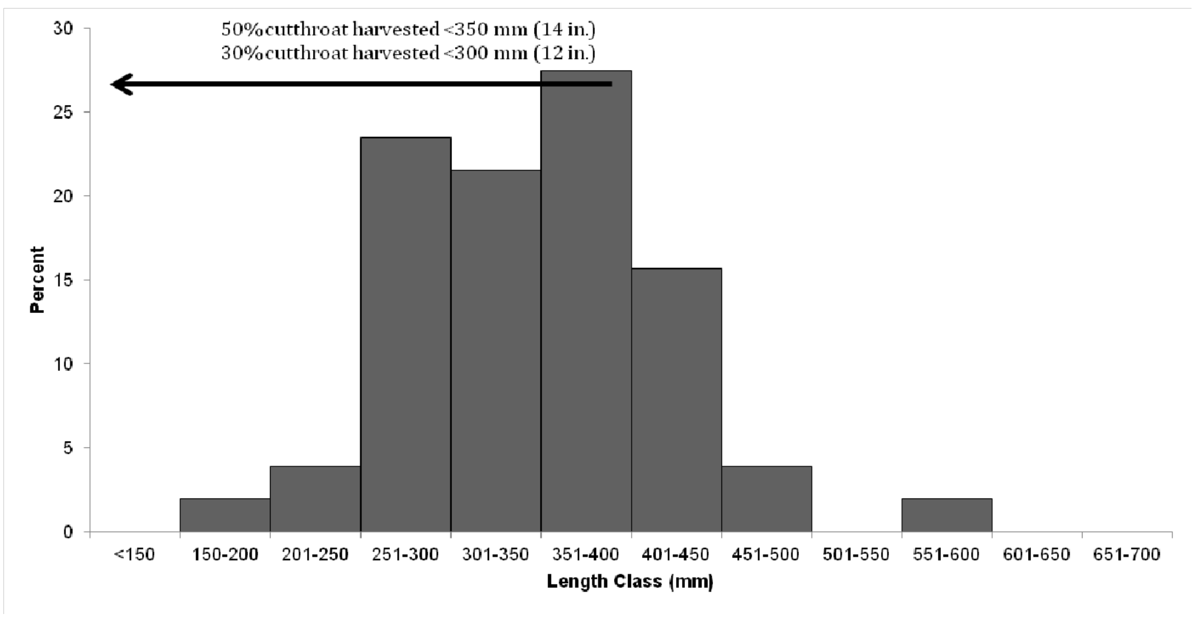


Figure 8. Length-frequency of Cutthroat Trout harvested by anglers at Cowichan Lake July, 2009 – June, 2011 (N=51). (Source: angler interviews conducted following instantaneous counts conducted by Valley Fish and Game Club volunteers July, 2009 – June, 2011).

3.4 Angler Preferences

A total of 123 anglers participated in our angler preference survey conducted during the 2009 creel survey (Table 5). Only 12% of anglers said the angling at Cowichan Lake was excellent, while most anglers (~46%) said the angling was good, and 37% said it was poor.

Table 5. Percent of responses by anglers during an angler preference survey at Cowichan Lake conducted during the July, 2009 – December 2009 creel surveys by Valley Fish and Game Club volunteers, contractors and ministry staff.

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
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
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 5). About equal numbers (~45%) like to fish for Cutthroat as like to fish for Rainbow Trout, while <1% said they fish for Dolly Varden.

When asked if they would be in favour of changes in regulations designed to improve the fishery and conserve stocks, 18% said they were happy with the current regulations (Table 6). 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 to catch fish to eat (Table 5).

Table 6. 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 creel surveys by Valley Fish and Game Club volunteers, contractors and ministry staff.

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

I reviewed the comments regarding regulations preferences made by anglers who said they preferred to fish for Cutthroat Trout *vs*. those who prefer to fish for Rainbow Trout to see if there was a difference between the two types of anglers (Table 7). I found that 44% of Cutthroat Trout anglers liked the existing regulations and 33% of these anglers suggested stocking Cowichan Lake with Rainbow Trout. Just over 11% of Cutthroat anglers would like to see a regulation that allows them to keep a Cutthroat >50 cm, and the same number would support limited harvest of small fish.

Table 7. Percent of responses from anglers who prefer to angle for Cutthroat Trout vs. those who prefer to fish for Rainbow Trout as to what regulations they would prefer on the lake. Note: these responses were gathered as a part of the comments made during the interview; these were not answers to the specific question regarding regulations changes.

Angler Type	Like Existing Regulations	Stock with Rainbow	1>50cm & 1<50 cm	Limit Harvest of Small Fish
Cutthroat (N=9)	44.4	33.3	11.1	11.1
Rainbow (N=11)	27.3	18.2	54.5	

Over 50% of the anglers who prefer to fish for Rainbow also said they would like to keep one large fish, although ~27% said they were happy with the current regulations (Table 7). Roughly 18% of these anglers also suggested stocking Cowichan Lake with Rainbow.

3.5 Cowichan Lake Derbies

Angler Effort

The number of anglers weighing fish in at derbies between 2009 and 2012 ranged from two to 33 anglers with an average of 15 anglers per derby (Table 8). Approximately 35% of the derby effort occurred in October and November and the remaining ~65% occurred from January to May (Figure 9). Note that we did not monitor any derbies in December and incidental information from anglers suggests that few if any derbies are held during this month.

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.

Year	Derbies Monitored	Total Number of Calendar Days	Total Number of Anglers Interviewed	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

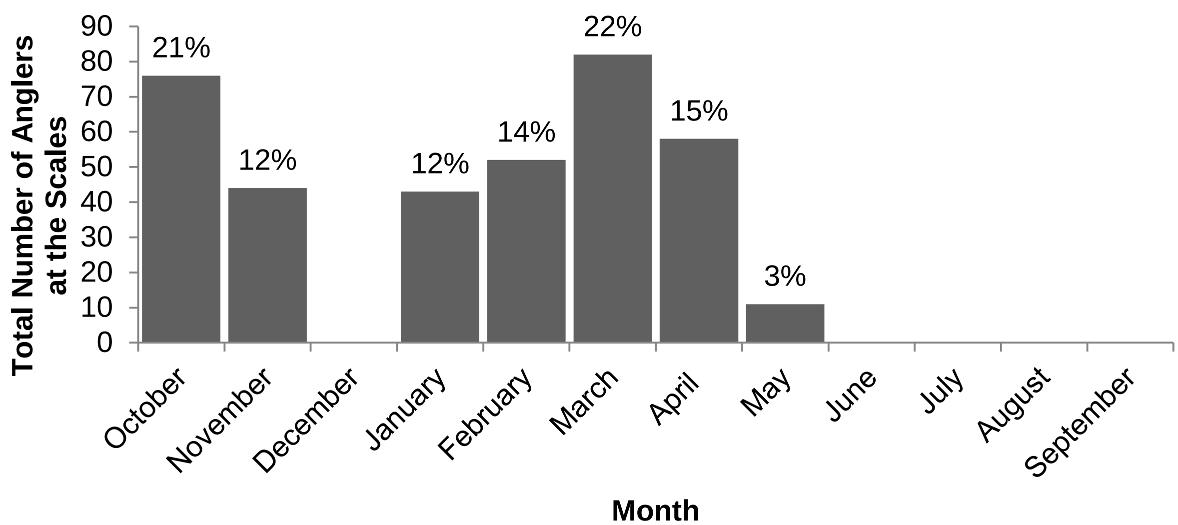


Figure 9. Total number and percent of total by month of anglers weighing fish at Cowichan Lake derbies from October 2009 until March 2012. Derbies were monitored by volunteers from the Valley Fish and Game Club, contractors and ministry staff.

Creel Survey and Weigh-In at the 2012 Frost Bite Derby

We conducted a creel survey and attended the weigh-in of the March 3, 2012 Legion Frost Bite Derby. Forty anglers were counted during the instantaneous count with >50% of the anglers counted in Section A of Cowichan Lake, and the remaining anglers equally distributed in Sections B and C (Table 9).

Table 9. Total number of boats and boat and shore anglers counted during an instant count during the Legion Frost Bite Derby on March 3, 2013 at Cowichan Lake. Instantaneous count and creel survey was conducted by Conservation Officer Staff of the Ministry of Environment and Enforcement and Compliance staff of FLNRO.

Parameter	Lake Section			Total
	A	B	C	
Number of Boats	9	4	4	17
Number of Anglers	21	9	10	40

Of the 40 anglers counted during the instantaneous count, 23 (~60%) were registered for the derby so some angler effort that day can be attributed to non-derby anglers. We conducted instantaneous angler counts in March, 2010 and March 2011 and found that instantaneous angler counts on non-derby weekend days in March varied from 0-30 anglers.

All 23 anglers registered for the Frost Bite derby were encountered during the creel survey and provided information about their catch. At the time of the creel survey (11:00 am), anglers had caught 13 fish. Assuming that these anglers were intercepted half way through their angling day, their catch rate was 1.1.fish/angler day. At the end of the day, 19 anglers (~85% of the anglers registered for the derby) weighed-in 24 fish resulting in a harvest rate of 1.3 fish/angler day. The average time spent fishing was 7.2 hours, which results in a harvest rate of 0.18 fish/angler hour. The hourly CPUE is similar, but the daily rate is about half of that calculated earlier from Figure 5 because angler days were longer than average (see Equation 1). Most CPUE data is calculated from interviews of hours and catch, with an hour/angler-day conversion.

Derby Catch

Anglers weighed-in 573 fish at the 23 derbies we monitored (Table 10). Approximately 95% of fish (544) were Cutthroat, ~5% (26 fish) were Rainbow, and <1% (3 fish) were Dolly Varden.

Table 10. 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.

Year	Cutthroat Trout	Rainbow Trout	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

A total of 544 Cutthroat were weighed-in by 366 anglers participating in the 23 derbies. The number of Cutthroat Trout weighed-in varied from six to 66 and the average number of Cutthroat Trout weighed-in per derby was 24.

I grouped the number of fish weighed-in by month to determine the percentage of Cutthroat Trout harvested each month during our monitoring. Almost 40% of the Cutthroat were harvested in October and November with just over 25% of the total number of Cutthroat harvested in October (148 fish), and ~15% harvested in November (83 fish) (Figure 10). February and March accounted for 36% of the total harvest of Cutthroat Trout with ~18% harvested in each of those months.

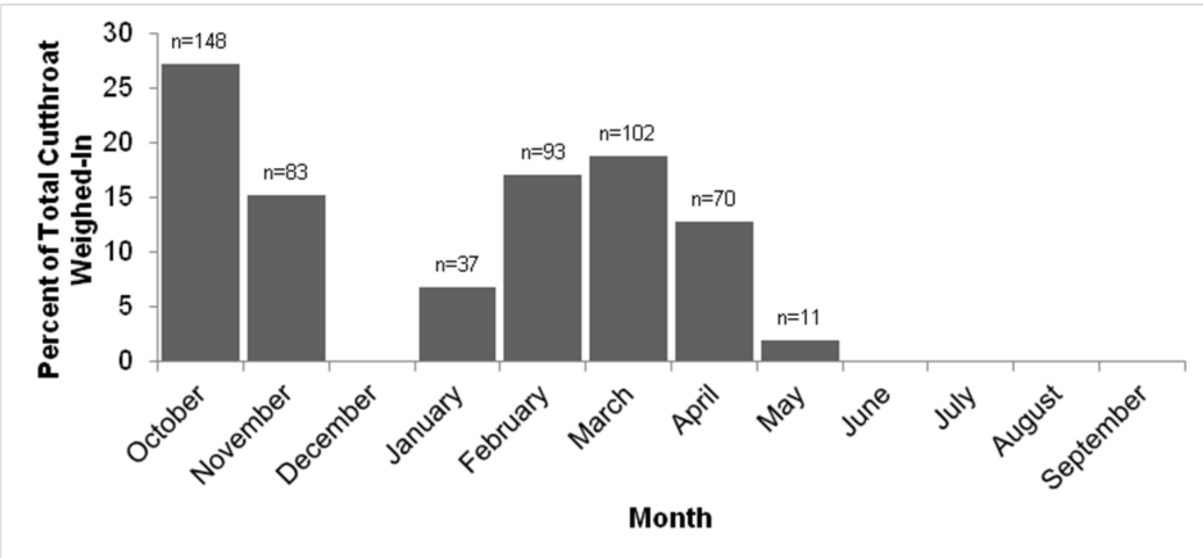


Figure 10. Percent by month of Cutthroat Trout weighed-in at 23 derbies conducted from October 2009 until March 2012 at Cowichan Lake (N=544). Derbies were monitored by volunteers from the Valley Fish and Game Club, contractors and Ministry staff.

Size of Derby-Caught Cutthroat Trout

Four hundred and seventy-six Cutthroat Trout ranging from 160 mm to 650 mm were weighed-in at derbies (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 CCT in Vancouver Island large lakes (Appendix 7).

		Length (mm)			
	n	Minimum	Maximum	Mean	Mode
Weighed-In	476	160	650	397.2	400
Released	38	140	635	476.7	500

Some anglers also provided information about fish they released while angling in derbies. Thirty-eight Cutthroat ranging from 140 mm – 635 mm were released; the mean length of these fish was ~477 mm, and the modal length was 500 mm (Table 11).

Almost 50% of the Cutthroat Trout retained by derby anglers were 350 – 450 mm, ~17% were 450 – 500 mm and almost 10% were >500 mm (Figure 11). Approximately 50% of the fish weighed-in were between 350 – 450 mm, ~50% of Cutthroat released were 500 mm and larger (Figure 11B) and, despite the regulation (Figure 11C),~6% of Cutthroat Trout weighed-in were >500 mm.

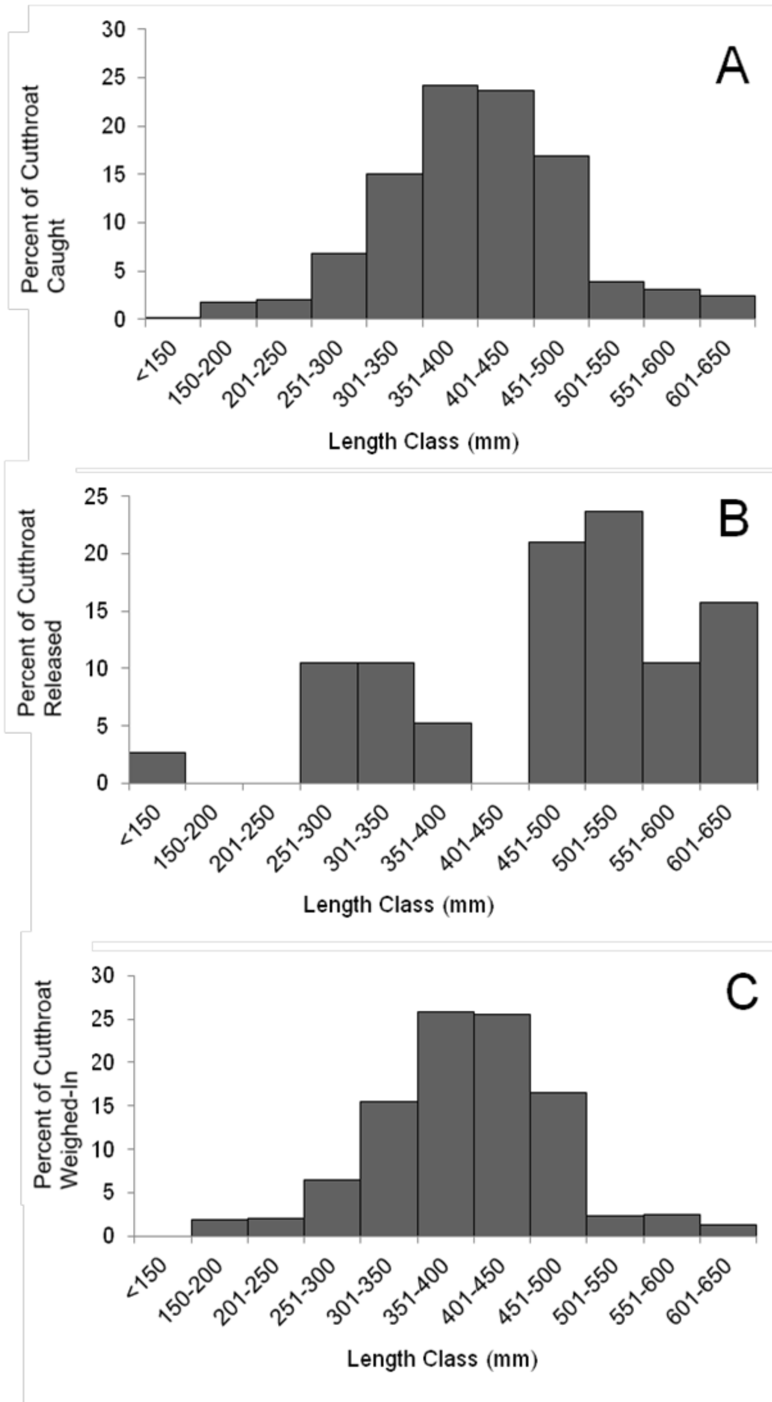


Figure 11. Percent of (A) all Cutthroat Trout caught in Cowichan Lake derbies (n=511) (B) Cutthroat Trout released by derby anglers (n=38) and (C) Cutthroat Trout weighed-in at derbies (n=473) by size class. Derbies were monitored by volunteers from the Valley Fish and Game Club, contractors and ministry staff.

3.6 Stock Assessment

Relative Abundance

I have plotted the percent of each species captured by electrofishing, net trapping and gill-netting and presented the relative abundance of each species in stream and littoral habitats in Cowichan Lake in Figure 12. I found that in the late 1980's, trout were more abundant in stream habitats, but in 2012, Coho dominated our samples.

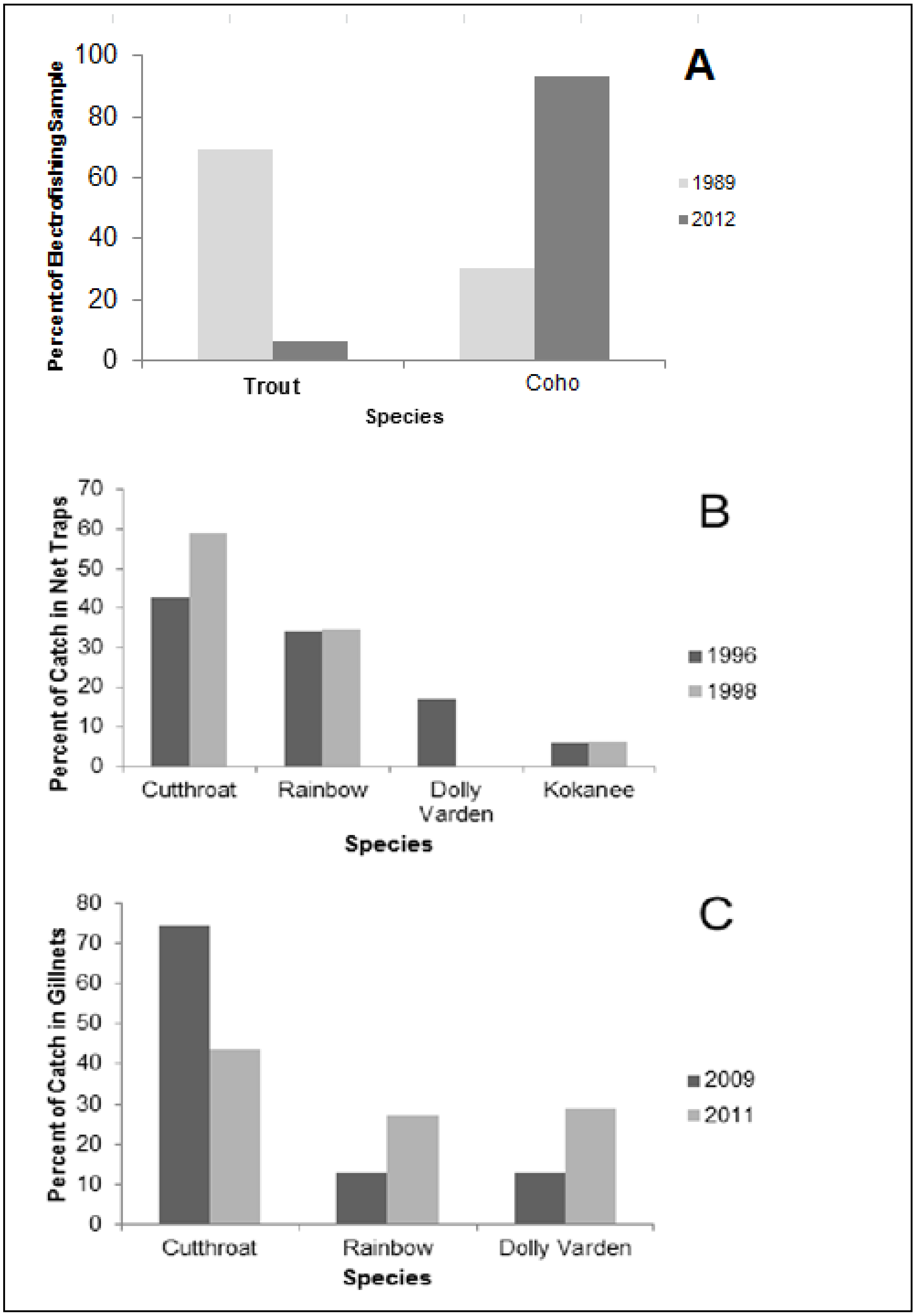


Figure 12. Relative abundance (percent of catch) of (A) trout and Coho salmon captured by electrofishing in 1989 and 2012, (B) Cutthroat and Rainbow Trout, Dolly Varden and Kokanee captured in net traps in 1996 (n=82) and 1998 (n=314) and (C) Cutthroat and Rainbow Trout and Dolly Varden captured in gillnets in 2009 (n=47) and 2011 (n=55). (Source: Griffith, 1989; Fish Inventory Summary System and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

Cutthroat Trout were more abundant than Rainbow Trout, Dolly Varden and Kokanee in the net traps set in Cowichan Lake shoal areas in 1996 and 1998. Our sinking and floating gill-nets set off the shoals captured 80% Cutthroat and 10% each of Rainbow and Dolly Varden in 2009, and 40% Cutthroat and 20% Rainbow and 20% Dolly Varden in 2011.

Length and Weight

The mean length of Cutthroat Trout captured by anglers increased by 33 mm between 1989/90 and 2009-2012 (Table 12, $p<0.01$). The size of Rainbow captured by anglers de-creased by 17 mm during the same period but this difference was not statistically significant (Table 12, $p=0.29$).

Table 12. Historical data on sizes of Cutthroat, Rainbow and Dolly Varden captured by angling and in gillnets by decade. Periods in which <10 fish were captured are not included. All Rainbow>500 mm have been removed as these are defined as Steelhead. (Source: Fish Inventory Summary System and files of Ministry of Forests, Lands and Natural Resource Operations, Nanaimo).

				Lengths (mm)		
Method	Species	Period	n	Minimum	Maximum	Mean
Angling	Cutthroat	1989/90	85	140	660	353.3
		2009-12	637	140	660	386.6
	Rainbow	1989/90	47	172	495	307.9
		2009-12	46	120	460	290.7
Gillnetting	Cutthroat	2009&11	59	113	525	296.7
	Rainbow	2009&11	21	180	374	246.2
	Dolly Varden	2009&11	22	100	420	286.6

Gillnetting in earlier decades resulted in <ten fish of each species being captured so I have only presented the results of gillnetting conducted in 2009-2011 (Table 12). Cutthroat Trout captured ranged from 113 – 525 mm and averaged ~296 mm in length. Rainbow Trout ranged from 180 – 374 mm and averaged ~246 mm while Dolly Varden ranged from 100 – 420 mm and averaged ~286 mm in length.

Length Frequency Analysis

I compared the length frequencies of Cutthroat Trout captured by net trapping in the 1990's with our gillnetting data and found that ~80% of the Cutthroat Trout captured on shoals and near shore were <200 mm (Figure 13). Approximately 15% of Cutthroat sampled by gillnets were also <200 mm but 85% of Cutthroat sampled with this method were >200 mm and up to 550 mm (Figure 13). Cutthroat Trout currently captured in gillnets ranged from 113-525 mm and averaged ~296 mm in length.

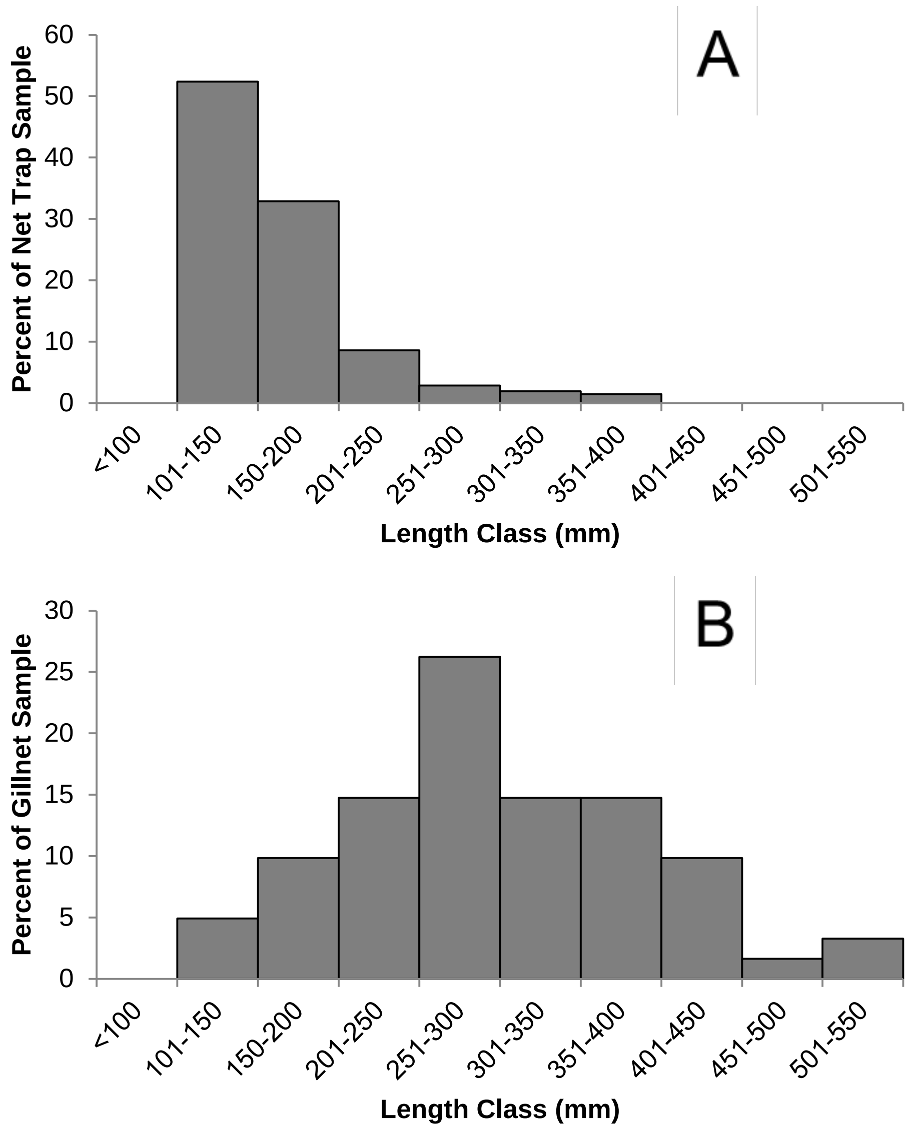


Figure 13. Percent of each length class of Cutthroat Trout sampled in (A) net traps in 1996 and 1998 (N=210) and (B) in gillnets in 2009 and 2011 (N=61). (Source: Fish Inventory Summary System and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

Cutthroat Trout captured by anglers ranged up to >650 mm in length in both the 1989/1990 and 2009-2012 time periods (Figure 14). In the 1989/1990's, 34% of the Cutthroat caught by anglers were <300 mm and 34% were >400 mm. In 2009-2012, only 16% of the Cutthroat Trout captured by anglers were <300 mm, but 50% were >400 mm.

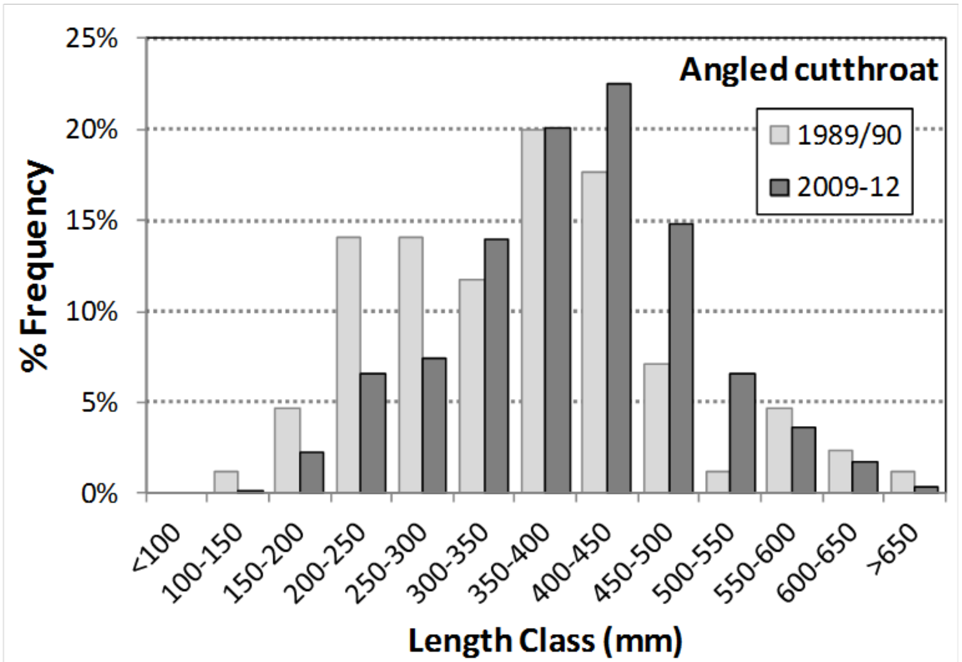


Figure 14. Percent of each length class of Cutthroat Trout caught by anglers in 1989/90's (N=84) and 2009-2012 (N=637). Data from 2009-2012 includes creel survey and derby caught fish (Source: Fish Inventory Summary System and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

In both 1989/90 and 2009-2012 time periods the largest Rainbow Trout captured by anglers were close to the 500 mm length used to define individuals of this species as Steelhead Trout (Figure 15). There was little evidence of a change in size distribution between the two periods. In 1989/90, 47% of the Rainbow Trout caught by anglers were <300 mm and 15% were >400 mm. In 2009-2012, 46% of the Rainbow captured by anglers were <300 mm, and 13% were >400 mm.

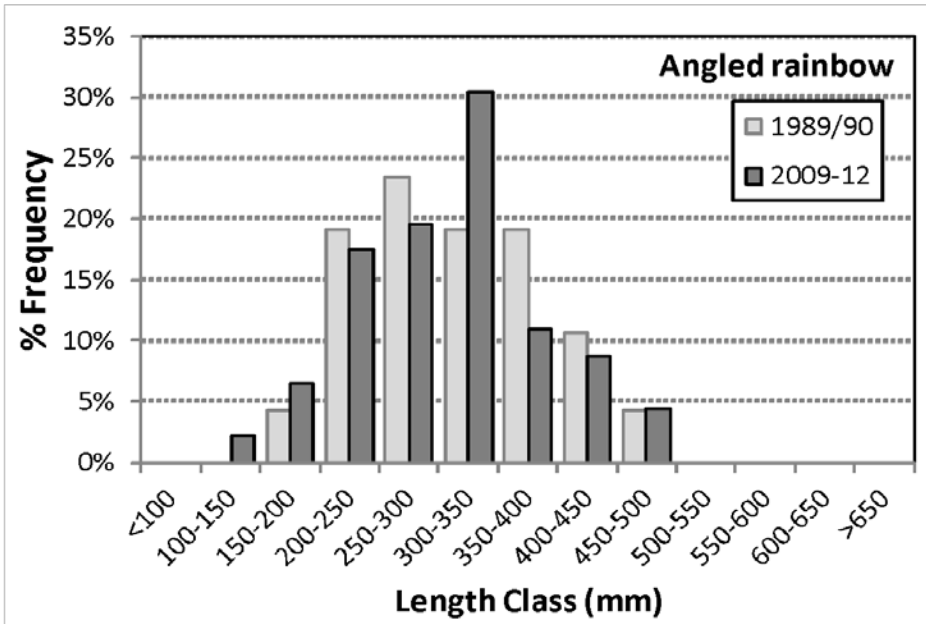


Figure 15. Percent of each length class RB caught by anglers in 1989/1990 (N=47), and in 2009-2012 (N=46). Data from 2009-2012 includes creel survey and derby-caught fish (Source: Fish Inventory Summary System and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

The largest proportion (40%) of Dolly Varden caught by anglers in the 1990's and currently are 400 – 450 mm with 15% 450 – 500 mm, and 7% 500 – 550 mm.

Gillnetting

Length-frequency patterns from gillnet samples are broadly similar to those from angler catches in that the maximum size of Cutthroat Trout is greater than that of Rainbow Trout (Figure 16). However, the largest individuals of both species were missing from the gillnet samples and fish <300 mm made up 53% and 76% of Cutthroat and Rainbow catches respectively.

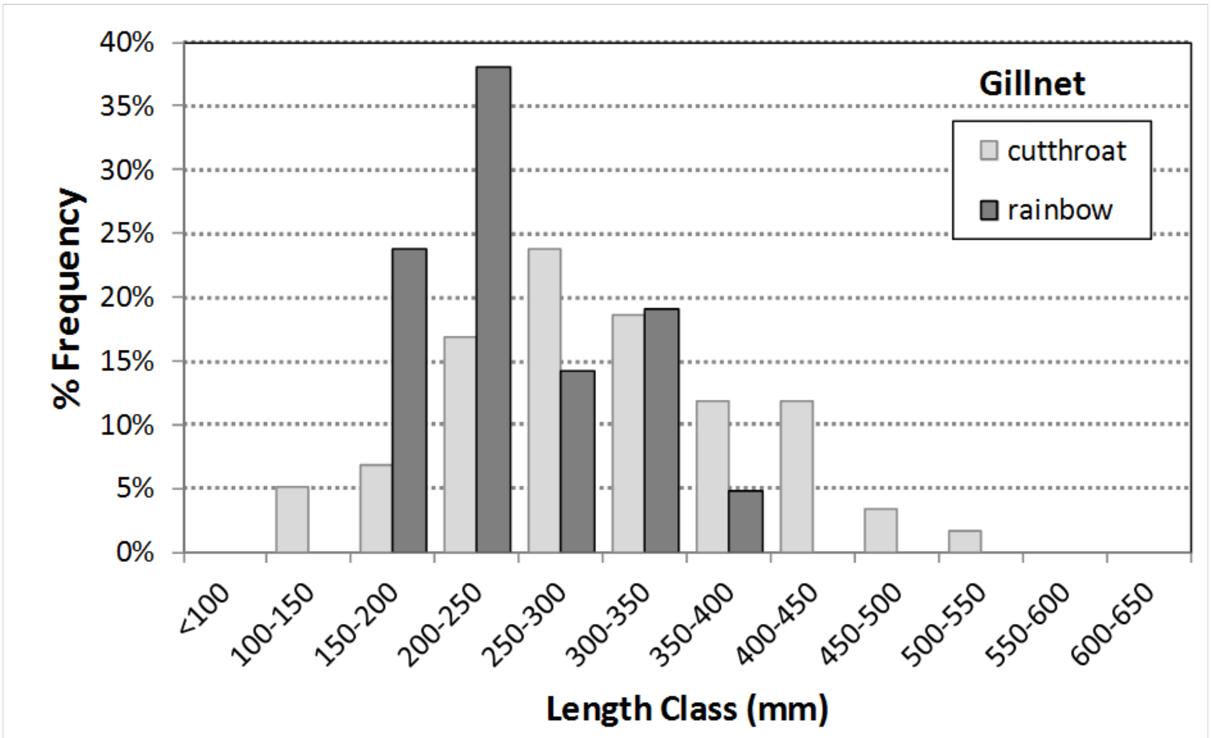


Figure 16. Percent of each length class of Cutthroat (n=59) and Rainbow (n=21) Trout sampled in gillnets in 2009 and 2011 (Source: Fish Inventory Summary System and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

Net Traps

The size of trout captured in net traps ranged from 82 to 390 mm (Figure 17). Cutthroat Trout were again larger than Rainbow Trout in both seasons and both species were smaller in the spring and larger in the fall. The smallest fish were captured in May and were 84 and 80 mm for Cutthroat and Rainbow Trout respectively. These fish were not aged but are likely to be age-1. When grouped into 10 mm bins, there is no sign of multi-modal age-class structure of either species captured in the May samples.

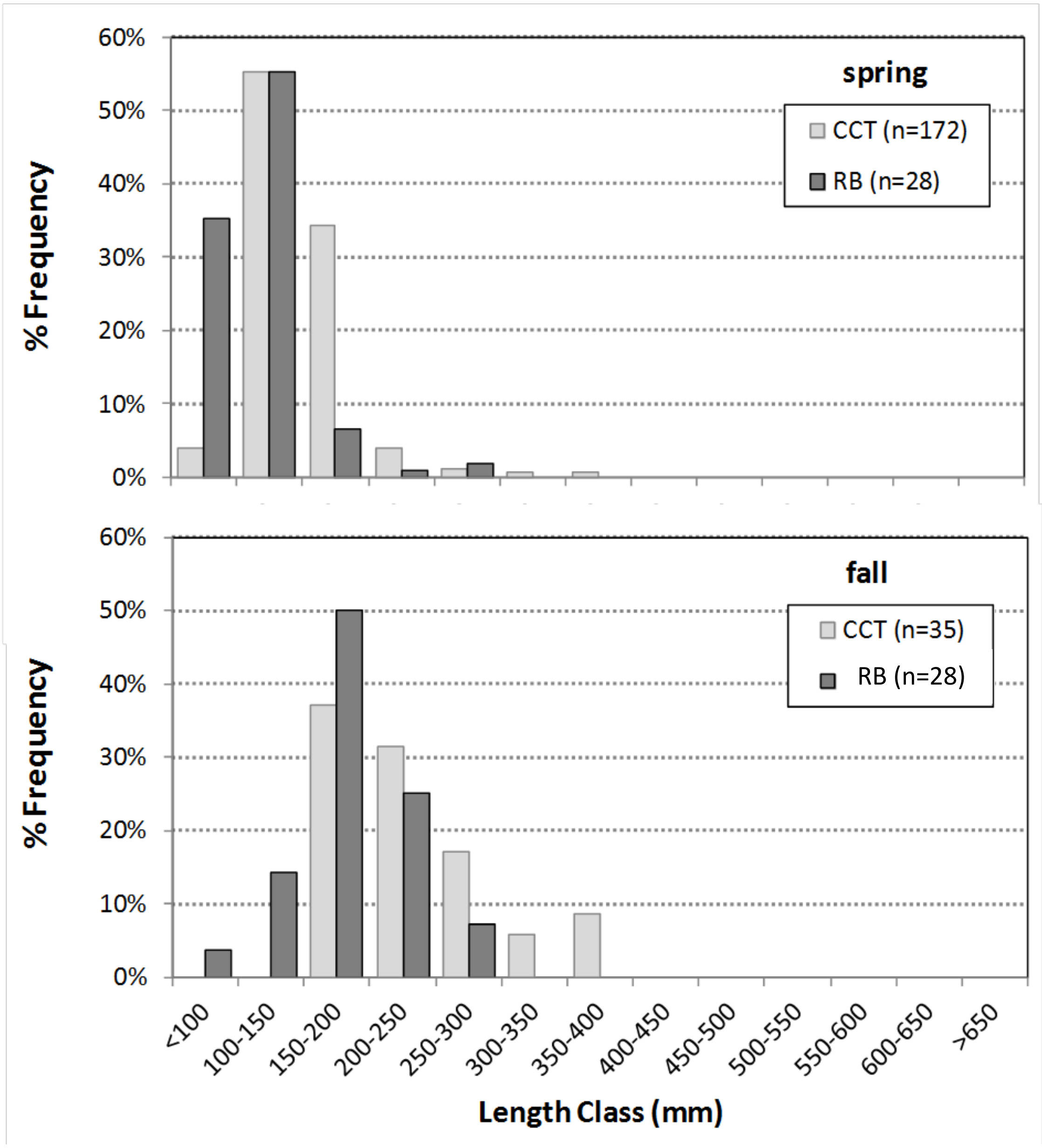


Figure 17. Percent of each length class of Cutthroat (CCT) and Rainbow (RB) Trout in samples collected in spring (May, June) and fall (November) using net traps in 1996 and 1998. The two panels share the same horizontal axis.

Condition Factor

I calculated the condition factor (K) for Cutthroat Trout sampled in gillnets in August 2009 and 2011 and compared the range and means to values provided by Carlander (1969, Table 13). The mean condition factor of Cowichan Lake Cutthroat is less than the mean of fish used in Carlander's analysis. The condition of Rainbow Trout captured in our gillnets in 2009/2011 is, however, comparable to the range and mean of condition factors reported by

Carlander for Rainbow Trout captured in Vancouver Island lakes (Carlander 1969, Table 13).

Table 13. Mean length, range and mean condition factor (K) of Cutthroat Trout, Rainbow Trout and Dolly Varden captured in gillnets in 2009 and 2011 (n=48) compared to range and mean of condition factor of 35 Cutthroat Trout captured from Oregon lakes reported in Carlander (1969). (Source: Fish Inventory Summary System and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

Species	N	Mean Length (mm)	Condition Factor Range	Condition Factor Mean	Carlander Condition Factor Range	Carlander Condition Factor Mean
Cutthroat	48	281.2	0.82 - 1.41	1.11	1.15 - 1.93	1.45
Rainbow	20	247.1	0.96 - 1.33	1.10	1.05 - 1.39	1.13
Dolly Varden	11	322.7	0.7 - 1.29	1.03		

Length Weight Relationships

Length-weight relationships were developed for Cowichan Lake Cutthroat and Rainbow Trout and Dolly Varden using gillnet data augmented with electrofishing data for age-0 trout from tributary streams (Figure 18). Combining the data sets was necessary to extend the length range and produce accurate estimates of the parameters. The exponents for both species were slightly greater than three, which suggests nearly allometric growth with individuals getting only slightly fatter as they grow longer.

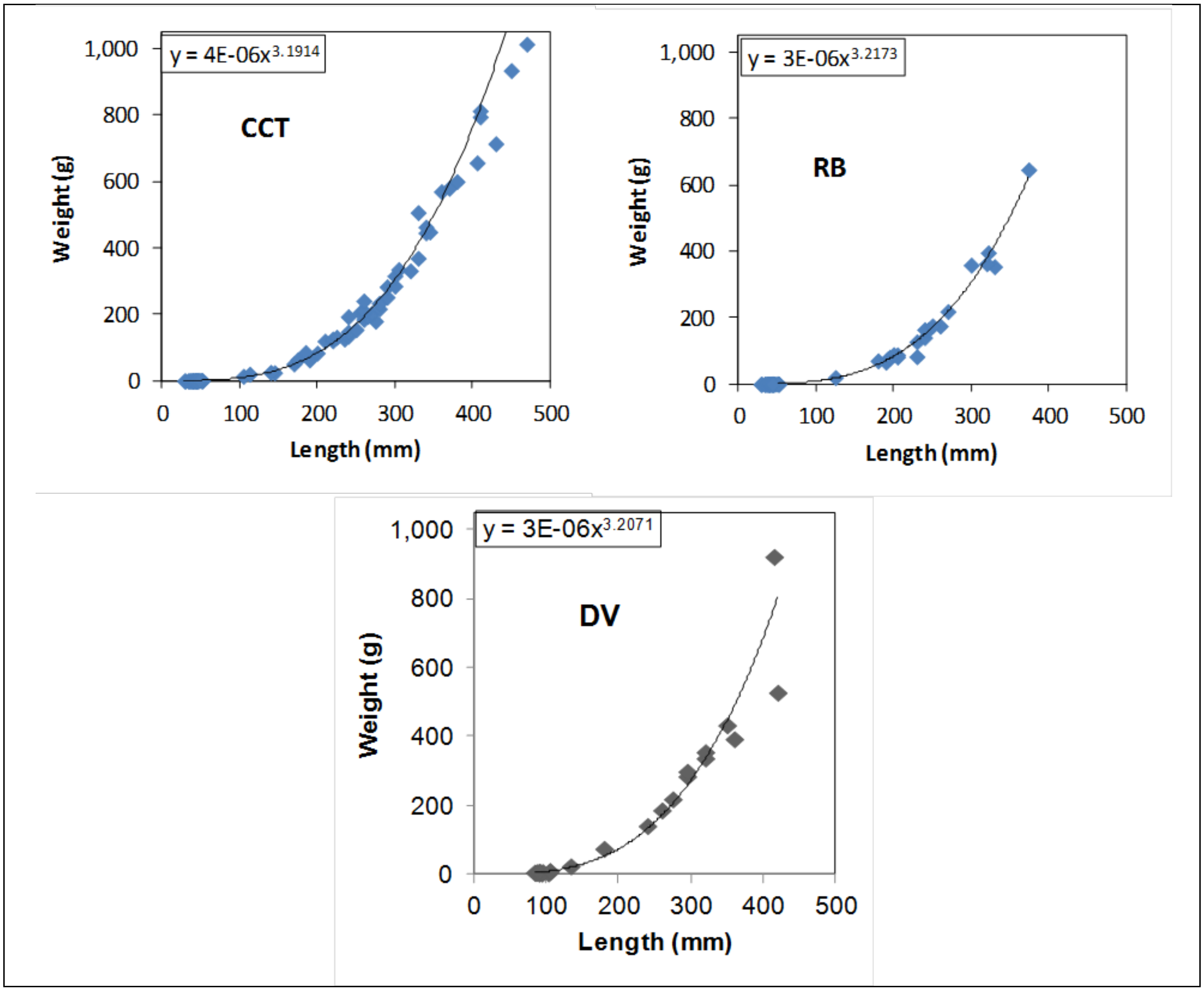
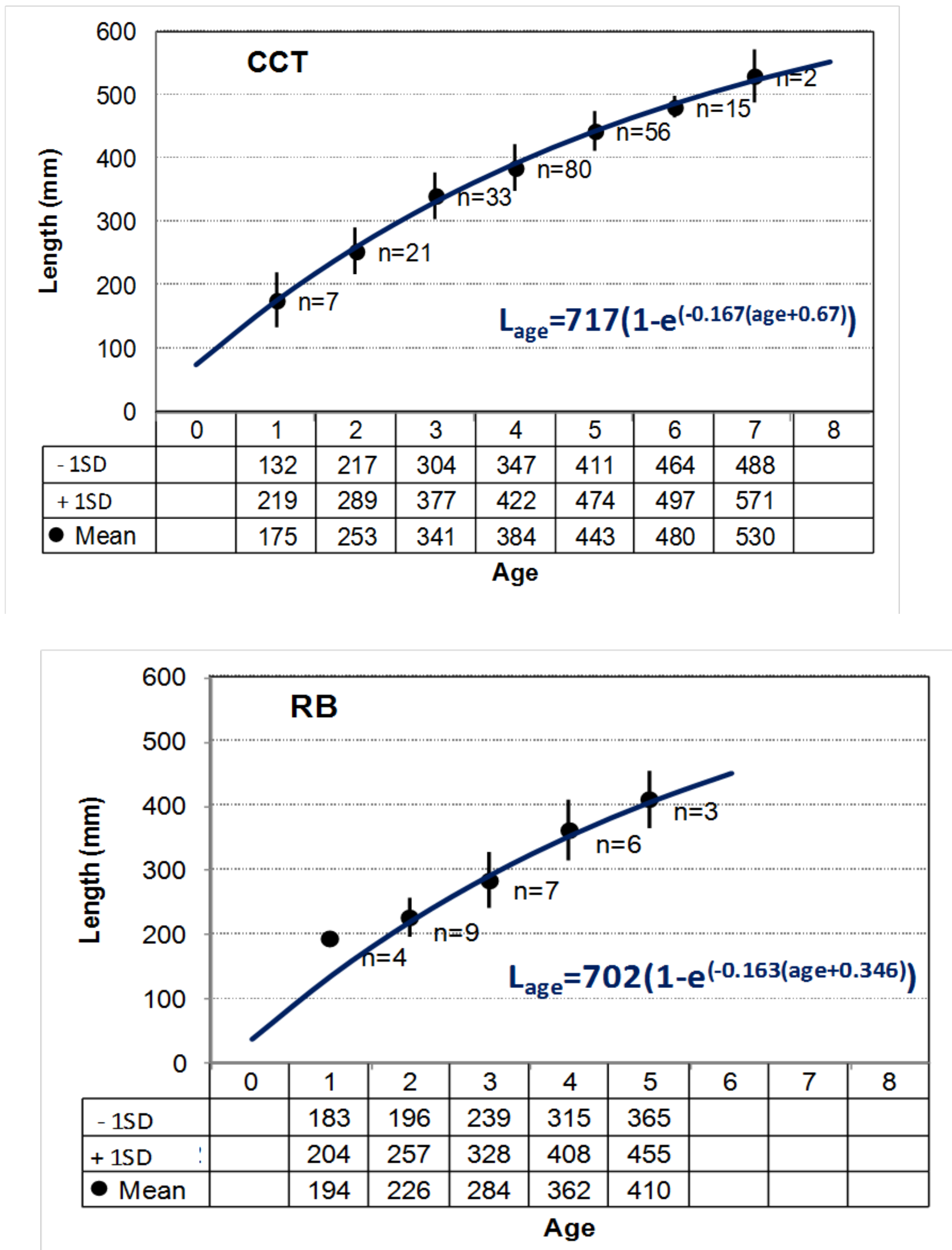


Figure 18. Length-weight relationship of Cutthroat and Rainbow Trout and Dolly Varden captured by gill-net in Cowichan Lake and by electrofishing in tributary streams (Source: Fish Inventory Summary System, Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

Age and Growth

Growth data from Cowichan Cutthroat Trout captured by gillnets and angling fitted to a von Bertalanffy growth model gives an asymptotic length of 717 mm (Figure 19). For Rainbow, the asymtotic length is poorly defined because the oldest fish are age-5. In both species, the von Bertalanffy k is about -0.165, indicating that the growth curve is relatively linear compared to other populations (e.g. Corsi et al., 2013). The von Bertalanffy k can be much higher in fast growing populations (e.g. Rainbow Trout, Blair et al., 2013), and generally much lower in long-lived species such as lake trout (e.g. Stafford et al., 2014).



CCT

	0	1	2	3	4	5	6	7	8
- 1SD		132	217	304	347	411	464	488	
+ 1SD		219	289	377	422	474	497	571	
● Mean		175	253	341	384	443	480	530	

RB

	0	1	2	3	4	5	6	7	8
- 1SD		183	196	239	315	365			
+ 1SD		204	257	328	408	455			
● Mean		194	226	284	362	410			

Figure 19. Length-at-age for Cutthroat (CCT) and Rainbow (RB) Trout caught by anglers in 2009-2012, and in gillnets in 2009 and 2011. The fitted growth curve is least squares fit of individual lengths to the von Bertalanffy growth curve which is shown on the inset; error bars indicate the data range for each mean datum fit to the curve. (Source: Fish Inventory Summary System, Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

I compared mean and maximum length-at-age of Cutthroat Trout captured in Cowichan Lake vs. Cutthroat Trout captured in all other large lakes on Vancouver Island and found the mean size-at-age for most age classes of Cowichan Cutthroat Trout was similar to that at other large lakes, but older age classes (6+ and 7+ fish) were generally smaller at Cowichan Lake (Table 14). The data from all other large lakes were likely skewed because of the large size of older Cutthroat Trout captured at Sproat Lake where Cutthroat >700 mm at age 6+ and 7+ have been captured.

Table 14. Number and maximum and mean length-at-age of Cutthroat Trout captured by electrofishing gillnetting and angling at large lakes on Vancouver Island (n=320) and at Cowichan Lake (n=302) 1951 – 2012. (Source: Fish Inventory Summary System, Ministry of Environment and files of Ministry of Forests, Lands and Natural Resource Operations, Nanaimo)

	Sample Size		Max. Fork Length (mm)		Mean Fork Length (mm)	
Age	Large Lakes	Cowichan	Large Lakes	Cowichan	Large Lakes	Cowichan
1	71	7	250	235	136.4	175.4
2	52	32	400	450	244.2	282.8
3	52	66	445	660	320.9	349.5
4	56	105	660	594	391.0	377.8
5	38	72	616	600	456.6	423.9
6	25	18	711	500	500.8	455.5
7	23	2	724	559	516.1	529.5
8	2	-----	489	-----	482.5	-----
9	1	-----	559	-----	559.0	-----

We aged 21 Dolly Varden captured at Cowichan Lake since 1989 (Figure 20). Age 2+ Dolly Varden ranged from 275 – 295 mm and averaged 285 mm, age 3+ Dolly Varden ranged from 240 – 480 mm and averaged 359 mm, age 4+ Dolly Varden ranged from 290 – 450, and averaged 363 mm and age 5+ Dolly Varden ranged from 350 – 480 mm and averaged 400 mm (Figure 20).

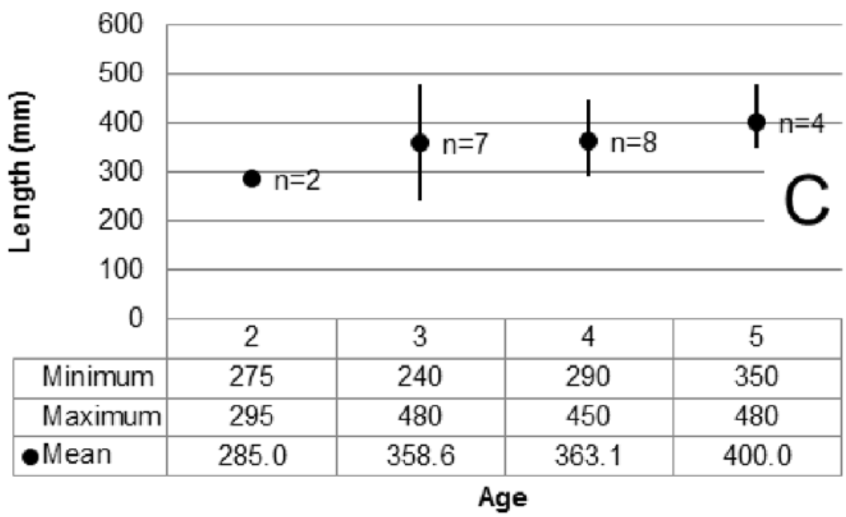


Figure 20. Length-at-age of Dolly Varden (N=21) caught by anglers in 1989 and 1990 and 2009 – 2012, and in gillnets in 2009 and 2011. (Source: Fish Inventory Summary System, Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo). Bars show min and max length of fish in each age class.

The mean length-at-age of Dolly Varden from Cowichan Lake was larger than that of Dolly Varden captured from other large lakes on Vancouver Island. For example, age 2+ Dolly Varden from Cowichan Lake averaged 285 mm while age 2+ Dolly Varden at other lakes averaged 230 mm; age 3+ Dolly Varden at Cowichan Lake were ~358 mm and at other large lakes were ~245 mm; age 4+ Dolly Varden at Cowichan Lake were ~360 mm and at other large lakes were ~300 mm while age 5+ Dolly Varden at Cowichan Lake averaged 400 mm and at other lakes averaged ~285 mm (Appendix 8).

Immature Fish

As with the ageing data, there is considerable variability in the sizes at which fish are judged as immature, maturing or mature. However, a review of maturity of Cutthroat Trout from large lakes on Vancouver Island suggests that Cutthroat commonly begin maturing at ~200 – 300 mm (Figure 21)

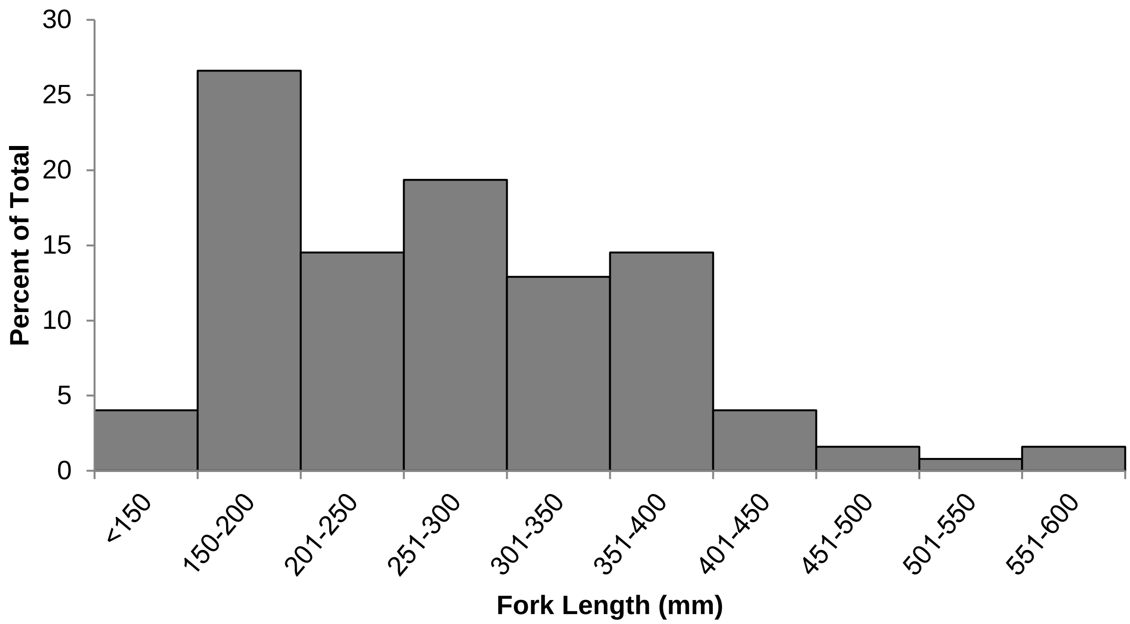


Figure 21. Length frequency distribution of maturing, mature and spawning Cutthroat Trout captured in gillnets, seines, trap nets and by anglers 1948 – 2011 (N=124) at Vancouver Island large lakes (Alice, Buttle, Comox, Cowichan, Great Central, Elsie, Henderson, Huaskin, Kennedy, Lower Campbell, Nimpkish, Nitinat, Sproat, Upper Campbell, Victoria and Woss) (Source: Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

Immature Cutthroat Trout ranged from 61 – 500 mm and averaged 282 mm, maturing Cutthroat ranged from 330 – 470 mm and averaged 410 mm and mature Cutthroat ranged from 340 – 530 mm and averaged ~450 mm (Table15). Immature Cutthroat were, on average, 2+ years old, maturing Cutthroat were 3+ years old and mature Cutthroat averaged 4+ years.

Table 15. Number, minimum, maximum and mean length and mean age of immature, maturing, and mature Cutthroat Trout (N=203), Rainbow Trout (N=92) and Dolly Varden (N=22) captured by electrofishing in 2012, gillnets (2009 and 2011) and by anglers (2009 – 2012) from Cowichan Lake. Note, all RB >500 mm have been removed as these are defined as Steelhead (Source: Fish Inventory Summary System, Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo).

				Length (mm)		Mean Age
Species	Maturity	n	Minimum	Maximum	Mean	
Cutthroat Trout	Immature	167	61	500	282.6	2.9
	Maturing	15	330	470	410.2	3.9
	Mature	21	340	530	448.5	4.8
Rainbow Trout	Immature	87	61	430	139.4	1.4
	Maturing	2	300	320	310.0	3.0
	Mature	3	335	460	385.0	4.3
Dolly Varden	Immature	15	60	320	142.7	1.4
	Maturing	4	275	350	310.0	3.5
	Mature	3	360	420	398.3	3.7

Immature Rainbow Trout captured at Cowichan Lake ranged from 61 – 430 mm and averaged ~140 mm, maturing Rainbow range from 300 – 320 mm and average 310 mm, and mature Rainbow Trout ranged from 335 – 460 mm and averaged 385 mm (Table 15). Immature Rainbow were, on average 1+ years old, maturing Rainbow were 3+ years old, and mature Rainbow were 4+ years old.

Immature Dolly Varden ranged from 60 – 320 mm and averaged ~143 mm, maturing Dolly Varden ranged from 275 – 350 mm and averaged 310 mm, and mature Dolly Varden ranged from 360 – 420 mm and averaged ~400 mm (Table 15). Immature Dolly Varden averaged 1+ years of age while maturing and mature Dolly Varden were, on average 3+ years of age.

Ageing – Anterior Scale Radius

Lough et al. (2011a) compared their ageing results with similar scale analysis studies for Cutthroat Trout from Vancouver Island Lakes (Narver, 1975; Lough 2010) and found some variability in the age-length relationship between studies especially in older fish. Older Cutthroat Trout are difficult to age precisely and some of variability among studies could be due to variations in growth conditions between years or even decades, or differences in the precise location of scale removal from the fish during sampling (see Lough et al. 2011a for more details).

Lough (2012) measured the anterior scale radius from Cutthroat and Rainbow Trout scales collected from Cowichan Lake. There was a close (R^2~0.81) relationship between the fork length of Cutthroat Trout and the anterior scale radius. In the future this metric can be used to back-calculate lengths of Cutthroat Trout sampled at Cowichan Lake to determine growth rates for all age classes (Figure 22).

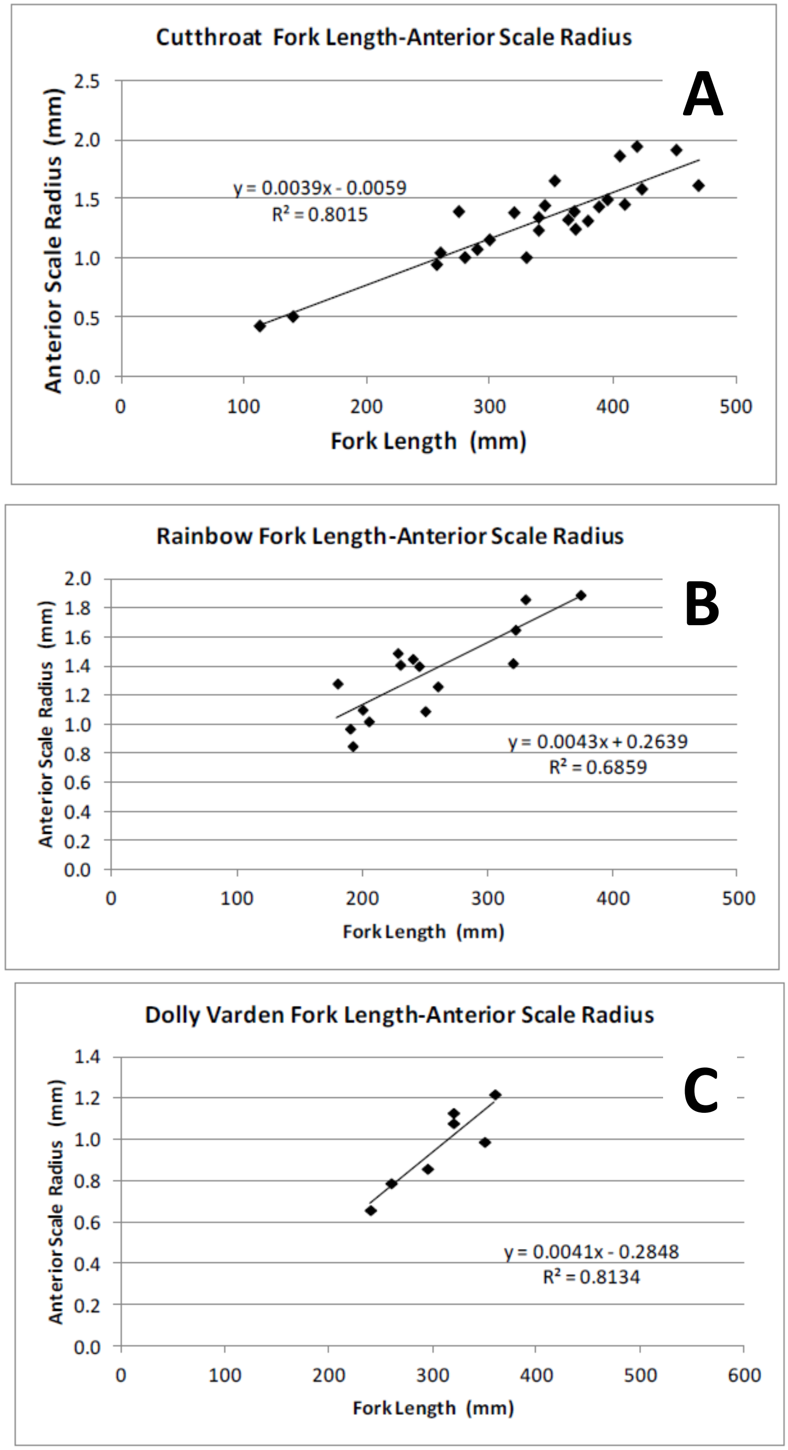


Figure 22. Fork length-anterior scale radius relationship for (A) Cutthroat Trout sampled from Cowichan Lake. Plot includes 21 gillnetted and 5 angler-caught Cutthroat Trout (B) Rainbow Trout; and (C) Dolly Varden sampled by gillnet at Cowichan Lake, August 26, 2011 (Reprinted from Lough, 2012).

Spawning

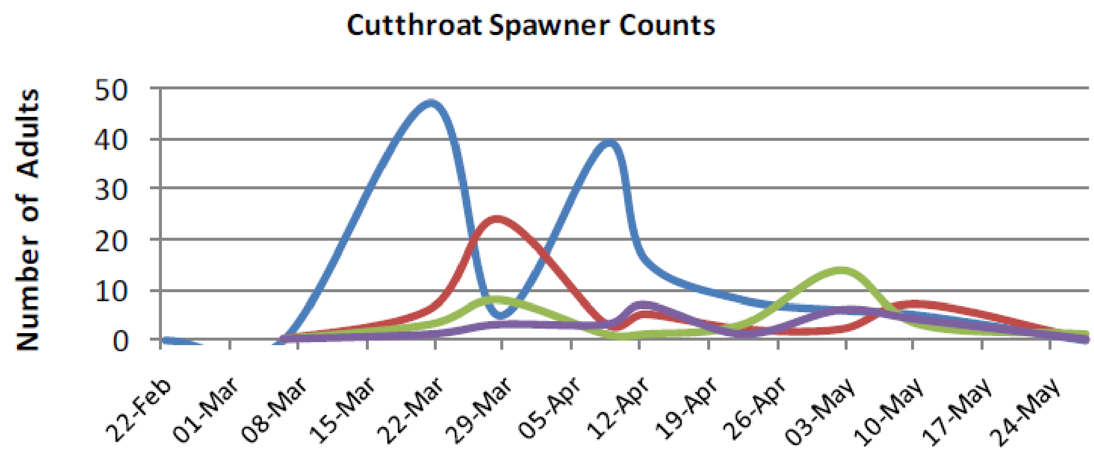
Cutthroat Trout

Lough et al (2011a) estimated the size of spawning Cutthroat during their 2011 snorkel survey of four Cowichan Lake tributaries. Spawners ranged in length from 300 mm to 650 mm, with males averaging 450 mm and females averaging 410 mm (Table 16). The overall mean fork length for both sexes was 430 mm. Lough et al (2011a) also estimated that the smallest spawning Cutthroat observed was 300 mm which they suggest is a good approximation of the size of sexual maturity for the Cowichan population. This is in keeping with our findings from Vancouver Island large lakes (Figure 21) (Figure 23)and a similar study conducted at Comox Lake (Lough et al. 2011b).

Table 16. Total number and mean length (mm) of spawning male and female Cutthroat Trout observed during snorkel surveys conducted in the Robertson River and Sutton, Nixon and Shaw Creeks February 22 – May 27, 2011 (Reprinted from Lough et al. 2011a).

Stream	Males		Females	
	n	Mean Length (mm)	n	Mean Length (mm)
Robertson	34	420	33	390
Sutton	16	500	14	420
Nixon	14	440	11	410
Shaw	12	460	8	410
All	76	450	66	410

I have provided the number of adult Cutthroat Trout observed in weekly snorkel surveys in Figure 23 (Lough et al. 2011a). These counts include gravid, unspawned fish, actively spawning fish and kelts. Over the ~3 month survey period a total of 126 Cutthroat were counted in the Robertson River, 49 were counted in Sutton Creek, 34 were observed in Nixon Creek, and 25 were observed in Shaw Creek.



	22-Feb	06-Mar	21-Mar	28-Mar	08-Apr	12-Apr	22-Apr	02-May	10-May	27-May
Robertson	0	0	47	5	39	16	8	6	5	0
Sutton		0	6	24	3	5	2	2	7	0
Nixon		0	3	8	1	1	3	14	3	1
Shaw		0	1	3	3	7	1	6	4	0

Figure 23. Number of Cutthroat Trout spawners counted each snorkel survey at the Robertson River and Sutton, Nixon and Shaw Creeks between February 26 – May 27, 2011 (Reprinted from Lough et al. 2011a).

Spawner counts are used by the BC FLNRO to confirm species characteristics and size and to monitor spawning populations of Steelhead, Rainbow Trout, and Cutthroat Trout. Snorkeling has been demonstrated to be an efficient method for estimating fish number and lengths and snorkeling numbers have been validated by other researchers (e.g. Mullner et al. 1998). In addition to spawning numbers, however, we also wanted an estimate of average residence time and proportion observed to confidently estimate spawner abundance. Accordingly, Lough et al (2011a) relied on redd counts to determine spawning activity in index sites.

A total of 266 Cutthroat Trout redds were counted in the index sites between February 22 and May 27, 2011 in the four study streams (Lough et al. 2011a). Of these, 63 redds were counted in the Robertson River, 60 redds were counted in Sutton Creek, 97 were counted in Nixon Creek and 46 redds were found in Shaw Creek. Of the four sites, Nixon Creek had the highest number of redds and the highest number of redds/km (Lough et al. 2011a) (Table 17).

Table 17. Total number and total number per km of redds counted in Robertson River and Sutton, Nixon and Shaw Creeks February 22 – May 27, 2011 (Reprinted from Lough et al. 2011a).

Parameter	Robertson River	Sutton Creek	Nixon Creek	Shaw Creek
Total Number of Redds	63	60	97	46
Total Number of Redds/Km	17	21	29	18

Spawning activity started between March 21 and March 28 in the Robertson River, Nixon and Shaw Creeks, and between March 28 and April 8 in Sutton Creek (Lough et al. 2011a). Spawning continued until May 27 by which time the presence of new redds had declined to near 0 suggesting that minimal spawning occurred after this time. Peak spawning occurred between April 8 and April 12 in the Robertson River and Shaw Creek, and between April 22 and May 2 in Sutton and Nixon Creeks (Table 18). Lough et al (2011a) suggested the difference in timing among these streams could be related to water temperature and flow pulses during the spawning period.

Table 18. Spawning period, peak spawning period, water temperature during spawning period and water temperature during peak spawning in Robertson River and Sutton, Nixon and Shaw Creeks March 21 – May 27, 2011 (Reprinted from Lough et al. 2011a).

Parameter	Robertson River	Sutton Creek	Nixon Creek	Shaw Creek
Spawning Period	Mar 21/28-May 27	Mar 28/Apr 8-May 27	Mar 21/28-May 27	Mar 21/28-May 27
Peak Spawning	Apr 8-12	Apr 22-May 2	Apr 22-May 2	Apr 8-12
Water Temp. during Spawning	3.4-9.2 °C	4.0-6.0 °C	4.0-6.0 °C	4.0-6.0 °C
Water Temp. during Peak Spawning	3.5-5.9 °C			

Spikes in spawning activity generally followed spikes in stream flows that were related to either rain, or snow run-off events (Lough et al. 2011a). Small groups of fresh spawners moved into the study streams on declining flows immediately following peak water levels, and fish appeared to remain together for only 1 or 2 days before dispersing through the index section.

Water temperature ranged from 3.4 °C to 9.2 °C during the overall spawning period and from 3.5 °C to 5.9 °C during the peak of the spawning period in the Robertson River (Lough et al. 2011a). The Robertson River was the only stream with a data logger but spot temperatures taken at the other survey streams indicated that, in general, the peak spawning at all streams occurred between ~ 4.0 °C and 6.0 °C (Table 18).

To provide a rough estimate of the total number Cutthroat Trout redds in each of the four study streams, Lough et al. (2011a) expanded the data collected at the index sites by applying the mean redds/km in the index sites to the total Cutthroat-Trout accessible mainstream length (Table 19). Lough et al. (2011a) estimated the total number of redds in the surveyed streams at 763 with the highest estimates in Nixon (319 redds) and Sutton (220 redds) Creeks.

Table 19. Index site length (km), total red count during surveys, redds/km, Cutthroat accessible stream length (km) and estimated total redds in Robertson River and Sutton, Nixon and Shaw Creeks March 21 – May 27, 2011. Estimated total redds in stream is calculated as redds/km * Cutthroat accessible stream length (Reprinted from Lough et al. 2011).

Stream	Index Site Length (km)	Total Redd Count	Redds/km	Cutthroat Accessible Stream Length(km)[1]	Estimated Total Redds in Stream
Robertson	3.7	63	17	10.0	170
Sutton	2.8	60	21	10.5	220
Nixon	3.4	97	29	11.0	319
Shaw	2.5	46	18	3.0[2]	54
Total					763

[1] Burns and Tutty, 1999
[2] Not clear if obstruction at km 3 is a total barrier to Cutthroat Trout spawner migration.

Gallagher et al. (2010) found that redd counts were reliable indices for monitoring spawning escapements (*in* Lough et al. 2011a). Using an estimate of ~1.2 redds/female during the 2011 survey, which is consistent with the observations of other investigators (e.g. Duffy, 2005), and assuming a 1:1 sex ratio, Lough et al. (2011a) estimated the total spawning escapement as:

- 763 redds/1.2 redds/female = 636 females
- 636 * 2 (i.e. 1:1 sex ratio) = 1,272 total spawning escapement

Rainbow Trout

Fisheries staff has conducted annual mid-summer snorkel surveys of the Cowichan River since 1976. Overall, the average number of Rainbow Trout observed during these mid-summer surveys has been between 50 - ~450 fish and has averaged ~215 fish over the ~7 km stretch between the village of Cowichan Lake to Skutz Falls (Figure 24). More Rainbow Trout are observed in snorkel counts early in July *vs*. later in the month. Unfortunately, there is no information in the files on whether these are adfluvial or fluvial Rainbow Trout, or a mixture of life-history types.

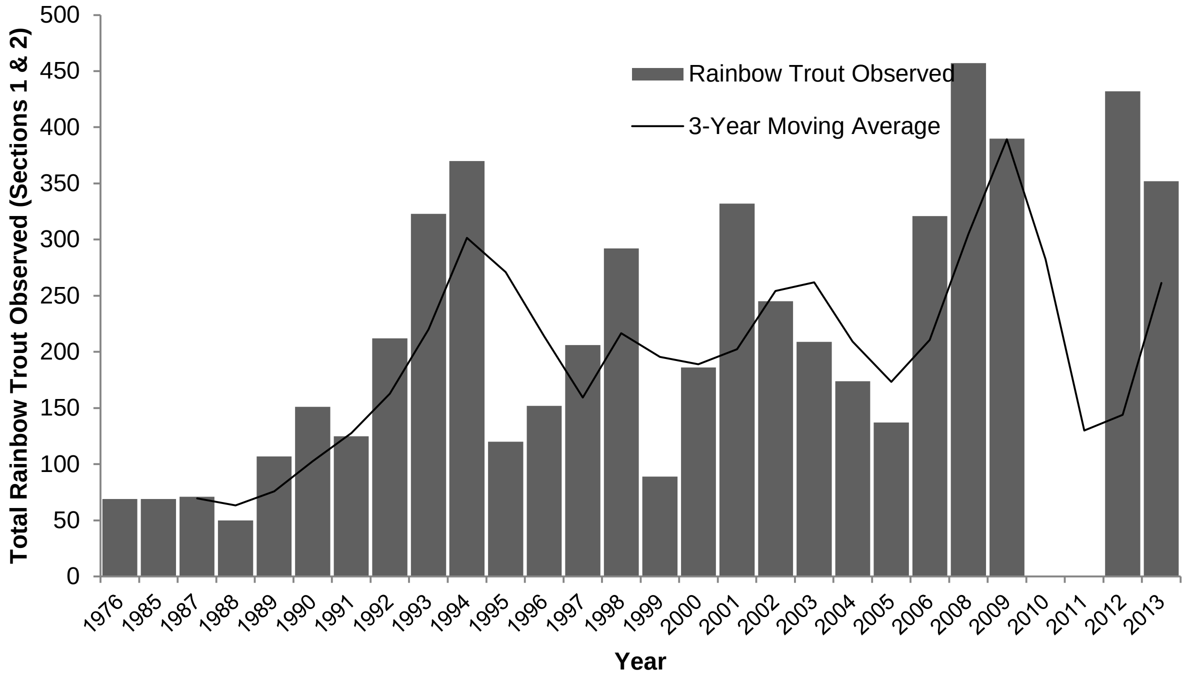


Figure 24. Total number of Rainbow Trout observed in snorkel surveys of Section 1 and 2 (Village of Lake Cowichan to Skutz Falls) of the Cowichan River 1976 - 2012. All swims were conducted during the month of July, except for in 1995, 2011 and 2012 when the swim took place in No swim was conducted in 2011. (Source: files of Ministry of Forests, Lands and Natural Resource Operations, Nanaimo).

Juveniles Egg Incubation, Fry Emergence and Juvenile Recruitment

Cutthroat Trout

Lough et al. (2011a) used water temperature data from the data logger in the Robertson River and mean daily water temperature data to determine the Accumulated Thermal Units (ATU's) to approximate fry emergence periods. These investigators used 520 ATU's as the threshold for Cutthroat Trout fry emergence (Lough et al. 2011a).

Given the earliest spawning activity was March 21/28, and the latest documented spawning activity was May 26, fry emergence would have taken place from June 7 until July 15 (Lough et al. 2011a). It's likely the incubation period in Sutton, Nixon and Shaw Creeks is longer as these streams are generally cooler than the Robertson River.

Lough et al. (2011a) used assumptions provided in Slaney and Roberts (2005)[6] and the number of redd counts observed in index sites to estimate that the fry recruitment in the study streams could range from 2,040 fry/km of stream in the Robertson River, to 3,480

[6] Fecundity of 400 mm spawners is ~1,200 eggs/female; 10% egg-to-fry survival; 20% fry-to-parr survival.

fry/km of stream in Nixon Creek and the abundance of Cutthroat Trout parr could range from 408 to 696 par/km (Table 20).

Table 20. Total number of redds/km in index sections of Robertson River and Sutton, Nixon and Shaw Creeks March 21 – May 27, 2011 and estimated number of eggs, fry and parr per km of stream in each of the 4 study streams. Fecundity is estimated as 1,200 eggs/400 mm female, egg-to-fry survival is estimated at 10% and fry-to-parr survival is estimated at 20% (from Slaney and Roberts, 2005) (Reprinted from Lough et al. 2011a).

Parameter	Robertson	Sutton	Nixon	Shaw
Redds/km	17	21	29	18
Eggs/km	20,400	25,200	34,800	21,600
Fry/km	2,040	2,520	3,480	2,160
Parr/km	408	504	696	432

Lough et al (2011a) observed few trout parr during their snorkel surveys even during May when water temperatures >7^{0}C. This is comparable to findings in a similar study in the Comox Lake watershed (Lough et al. 2011b), and to previous snorkel survey observations in the Robertson River by BC Fish and Wildlife staff. Lough et al. (2011a) point out their findings of low juvenile abundance is inconsistent with the relatively high levels expected from the redd counts and the resulting estimated juvenile production, but could possibly be explained if fry move directly into Cowichan Lake after emergence. This is possible based on the electrofishing data collected in 2012 in Cowichan Lake tributaries, and net trap data collected by the Cowichan Lake Educational Centre in 1996 and 1998 and which found Cutthroat fry and Cutthroat parr on the shoals of Cowichan Lake (Table 21).

Table 21. 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: Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo, BC).

			Length (mm)		
Month	Life Stage[1]	n	Minimum	Maximum	Mean
		Electrofishing			
August	Fry	25	40	89	47.6
August	Parr	2	98	150	124.0
		Net Trap			
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] I estimated size of Cutthroat Trout at emergence ~25mm; growth of 0+ up to ~85 mm growth of 1+ up to ~145 mm (Carlander,1969).

Estimates of Juvenile Population

I've provided summaries of the population estimates, minimum and maximum lengths and weights and condition factors for all juveniles captured by electrofishing in Nixon and Sutton Creeks in Table 22. In summary, the population for Coho at Nixon Creek was estimated at 121 individuals at Site 1 and 234 at Site 2. Trout population estimates were substantially lower at 12 individuals at Site 1 and six at Site 2. The population of Coho at Sutton Creek was estimated at 229 at Site 1 and 212 at Site 2. Again, trout were estimated lower at only 21 individuals at Site 1 and 13 at Site 2. Population estimates for all species were likely underestimated because of the higher than ideal discharge during sampling and this is reflected in the capture probabilities.

Table 22. Population estimates, 95% Confidence Intervals, capture probability, percent of total catch, length, weight minimums, maximums and averages, and condition factors for Coho, trout and Dolly Varden captured by electrofishing at two sites in Nixon and Sutton Creeks, August, 2012. Population estimates calculated by Microfish 3.0 (Van Deventer, 2013)[7].

Nixon Creek Site 1 (site area = 401 m^2); Total Fish/100m^2 = 33

	Coho	Trout	Dolly Varden
Total catch	118	12	1
Population estimate	121	12	1
95% Confidence Interval	116-126	15-Sep	n/a
Capture Probability	0.686	0.63	0.5
Percent of Total Catch	90	9	1
Length Range (mm)	43-90	35-150	----
Mean Length (mm)	56.2	56.3	86
Weight Range (g)	0.8-8.1	0.2-37.2	----
Mean Weight (g)	1.9	4.4	5.2
Condition Factor	1.031	0.861	0.818

Sutton Creek Site 1 (site area = 263 m^2); Total Fish/100m^2 = 65

	Coho	Trout	Dolly Varden
Total catch	145	14	11
Population estimate	229	21	16
95% Confidence Interval*	145-315		11-37
Capture Probability	0.283	0	0.306
Percent of Total Catch	85	8	6
Length Range (mm)	36-84	29-89	84-134
Mean Length (mm)	47.2	44.5	98.1
Weight Range (g)	0.1-4.6	0.1-2.3	3.4-24.3
Mean Weight (g)	1.1	0.72	8.4
Condition Factor	0.934	0.761	0.831

Nixon Creek Site 2 (site area = 510 m^2); Total Fish/100 m^2 = 31

	Coho	Trout	Dolly Varden
Total catch	156	4	0
Population estimate	234	6	---
95% Confidence Interval*	234-234	06-Jun	---
Capture Probability			---
Percent of Total Catch	98	3	---
Length Range (mm)	49-69	44-69	---
Mean Length (mm)	52.3	52.5	---
Weight Range (g)	0.6-3.7	0.5-3.5	---
Mean Weight (g)	1.6	1.5	---
Condition Factor	1.072	0.845	---

Sutton Creek Site 2 (site area = 384 m^2); Total Fish/100m^2 = 36

	Coho	Trout	Dolly Varden
Total catch	131	8	0
Population estimate	212	13	---
95% Confidence Interval	131-301	8-40	---
Capture Probability	0.274	0.258	---
Percent of Total Catch	94	6	---
Length Range (mm)	28-83	34-47	---
Mean Length (mm)	47.2	40	---
Weight Range (g)	0.2-5.1	0.2-0.9	---
Mean Weight (g)	1.1	0.6	---
Condition Factor	0.917	0.882	---

*adjusted lower Confidence Interval = Total Catch

[7] Microfish 3.0 was developed at Washington State University with technical advice from Microsoft, and a number of government agencies including the US Forest Service and the Tennessee Wildlife Resources Agency, and Virginia Department of Game and Inland Fisheries. Microfish 3.0 is a software program that calculates the maximum-likelihood population estimates, length statistics and weight statistics from removal-depletion sampling.

The size of Coho salmon captured ranged from 28 mm in Sutton Creek to 90 mm in Nixon Creek while trout ranged from 29 mm to 89 mm for 0+ fish. Overall, the average Condition Factor was higher for Coho (0.985) than for trout (0.84) (Table 22). In addition, we caught far more Coho than trout at all sites sampled. For example, Coho comprised almost 100% of our catch at Site 2 of Nixon Creek, and 94% of our catch at Site 2 of Sutton Creek (Figure 25).

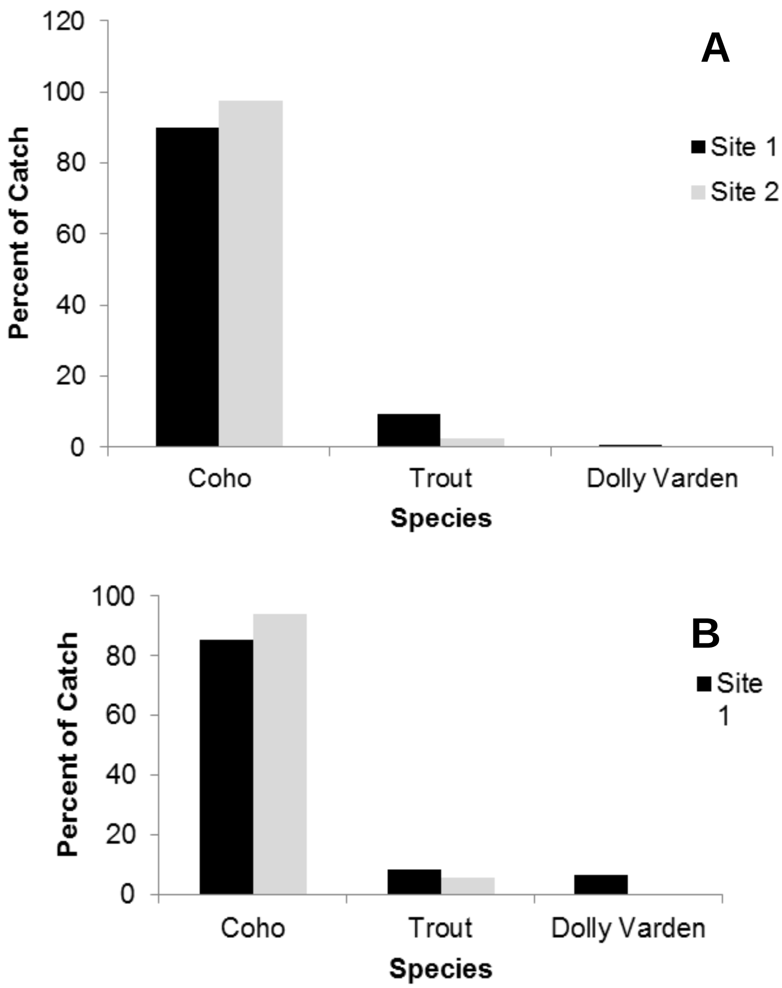


Figure 25. Percent of total catch comprised of Coho Salmon, trout and Dolly Varden captured at Sites 1 and 2 by electrofishing at (A) Nixon Creek and (B) Sutton Creek August, 2012.

3.7 Kokanee Salmon

I have summarized the results of the hydro acoustic survey conducted in 2011 below, while complete results can be found in Johner and Sebastian (2011). Kokanee Salmon comprised 99% of the trawl catches (518 Kokanee) with the remaining 1% of fish consisting of six lamprey, one Sculpin and one- Threespine Stickleback (Table 23).

Table 23. Number of Kokanee Salmon, Lamprey, Sculpin and Threespine Stickleback captured in 4 trawls conducted at Cowichan Lake July 6-8, 2010 (Reprinted from Johner and Sebastian, 2011).

Catch in Trawls	Species Kokanee	Lamprey	Sculpin	Stickleback
Total	518	6	1	1

Most Kokanee captured (~82%) were age 0+ with ~9% aged 1+ and 9.5% aged 2+ (Table 24). Kokanee ranged from 24 - 163 mm and both age 1+ and age 2+ fish showed some bimodality in their length frequency distributions. The average length of 0+ Kokanee was 34.5 mm, of age 1+ Kokanee was 92.1 mm, and of age 2+ Kokanee was 143.1 mm (Johner and Sebastian 2011).

Table 24. Number, range and mean size of 0+, 1+ and 2+ Kokanee Salmon captured in 4 trawls conducted at Cowichan Lake July 6-8, 2010 (Reprinted from Johner and Sebastian 2011).

		Size (mm)	
Age	n	Range	Mean
0+	258	24 - 32	34.5
1+	47	64 - 119	92.1
2+	49	128 - 163	143.2

Johner and Sebastian (2011) estimated the abundance of fish in pelagic habitat[8] at 8.1 million fish (6.9 – 9.2 million) with an average areal[9] density of 1,514 fish/ha based on Department of Fisheries and Oceans (DFO) estimate of 5,389 ha for pelagic habitat area for Cowichan Lake. Based on their acoustic size, the fish population was partitioned into 0+, 1+, and 2+ fish assumed to be mostly Kokanee, and fish too large to be Kokanee that may have been predators such as Cutthroat Trout. The combined estimated density of age 1+ and 2+ Kokanee (because acoustics cannot distinguish age 1+ from 2+) was 1.2 million (223/ha) (Figure 26) (Figure 27) (Johner and Sebastian 2011).

[8] Pelagic habitat is defined as $\geq$ 20 m depth.
[9] A roughly bounded part or section.

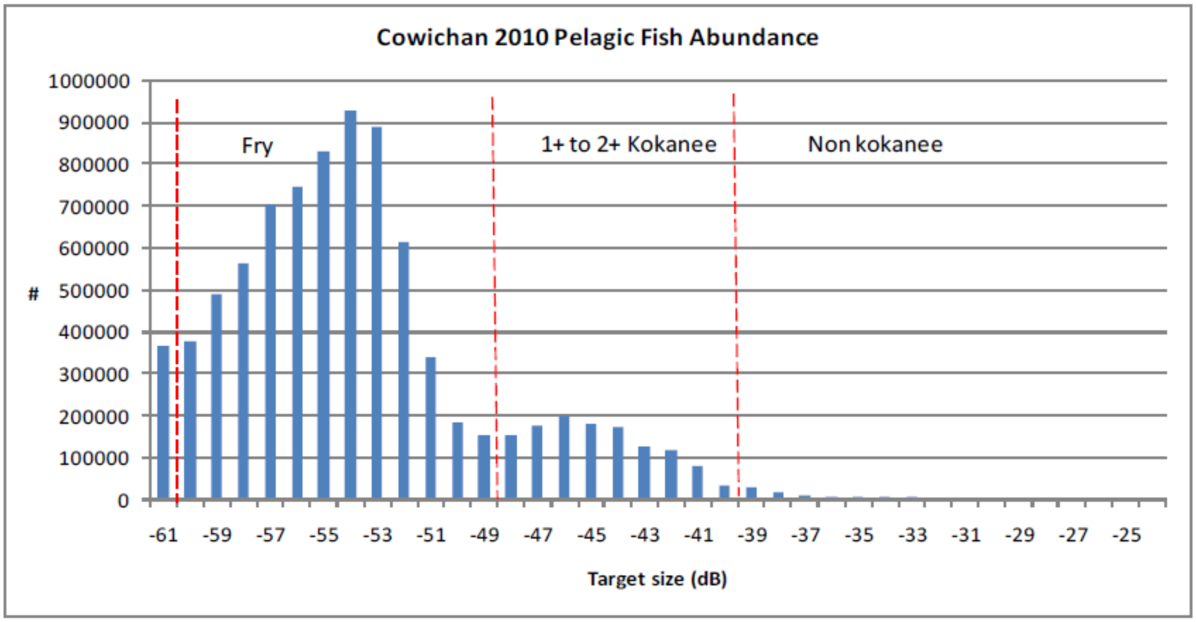


Figure 26. Acoustic size distribution of pelagic fish captured in four trawls conducted at Cowichan Lake July 6-8, 2010 (Reprinted from Johner and Sebastian 2011).

The large majority of fish were at 10 – 20 m depth at night with the highest densities of fry at 10 – 15 m and highest densities of age 1+ – 2+ Kokanee found slightly deeper at 15 – 20 m depth. The higher densities of fish coincide with the thermocline where temperatures were between 10^0C and 15^0C (Figure 27).

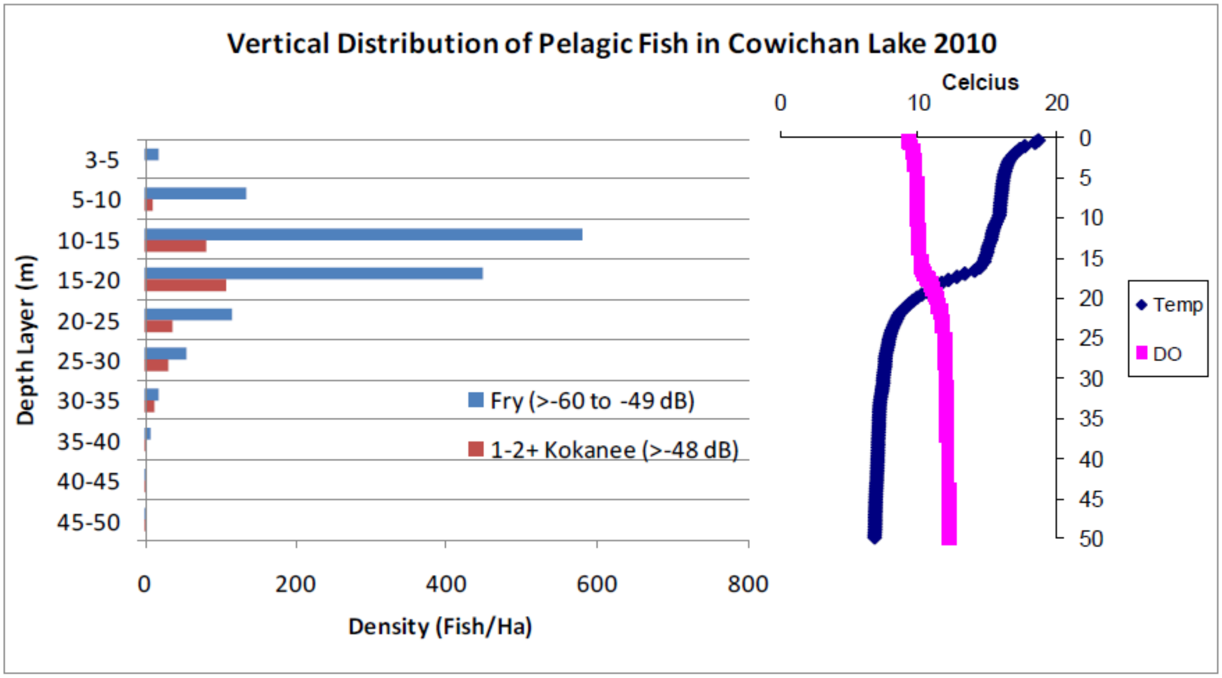


Figure 27. Comparison of the vertical distribution of Kokanee salmon in the water column with vertical profiles of water temperature (0C) and oxygen concentration (ppm) (Reprinted from Johner and Sebastian 2011).

Population Abundance and Status

The abundance of pelagic fish estimated at 8.1 million in 2010 appears to be a substantial increase over the population of 3.4 – 5.1 million reported by DFO in the mid-1980's (Rutherford et al. 1988). Johner and Sebastian (2011) suggest that differences in abundance estimates could be because of timing differences in surveys (July in 2010; October in the 1980's), natural fluctuations in fish populations over the 2 decades, and/or improvements in hydro acoustic equipment that minimize the loss of data.

One important finding by Johner and Sebastian (2011) is the lack of age 3+ spawners and the similarity of size of age 2+ Kokanee salmon with age 3+ Kokanee identified by DFO. Rutherford et al. (1988) suggest that Cowichan Kokanee mature at age 3+ at 153 – 172 mm. However, Johner and Sebastian (2011) suggest that Cowichan Kokanee spawn at age 2+ which is a marked difference from interior Kokanee stocks which tend to spawn at age 3+ (Schindler et al. 2010; Schindler et al. 2011). Long term studies from the interior suggest the only time interior Kokanee Salmon switch to age 2+ spawning is following good growing conditions resulting in very low densities or increased lake capacity (e.g. through nutrient enrichment) (Johner and Sebastian 2011). These researchers speculate that the size of Kokanee Salmon in Cowichan Lake may be limited by the densities of large zooplankton, however, they note that more sampling is needed to verify this.

Johner and Sebastian (2011) suggest that due to small size and low fecundity of Cowichan Lake Kokanee, egg-to-fry survival must be very good (~15%) to achieve the 6.9 million fry estimated observed in 2010. This suggests that spawning habitat is most likely not limiting this population. In addition, the Kokanee Salmon are dense and stunted, and likely are not under high mortality stress from predation. Note, however, these authors point out that more data is required to rule out the possibility of highly variable population abundance between successive years as indicated by DFO's sampling.

3.8 Cowichan Lake Lamprey

The Cowichan Lake Lamprey is globally unique as it is endemic to only Cowichan and Mesachie Lakes. The species was designated as a Threatened Species in 2008 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is protected by the *Species at Risk Act* (*SARA*) which prevents individuals from killing, harming, harassing, capture or taking individuals, or destroying their critical habitat.

Sean MacConnachie[10] provided the Valley Fish and Game sub-committee with an overview of the biology and ecology of the Cowichan Lake lamprey. MacConnachie noted that the Cowichan Lamprey probably evolved from Pacific lamprey in the last 10 – 15,000 years and because this species evolved with the existing fish community it plays a valuable role in the ecology of Cowichan Lake. He also noted that these lampreys die after spawning and the larvae burrows into the sediment for an unknown number of years and feeds on organic material and detritus.

Although Beamish (2007) provided a population estimate of 1,000 – 2,000 individuals in Cowichan Lake, this estimate was an educated guess and provided only as a starting point for recovery planning (MacConnachie pers. comm. 2012). MacConnachie stated that his recent discussions with Beamish suggest there are likely <100 adult lamprey in Mesachie Lake, and recent trapping results indicate it's unlikely there are >2,000 in the entire Cowichan Lake system.

Carl (1952) cites Cutthroat Trout as the observed prey of the Cowichan Lake lamprey and MacConnachie (pers. comm. 2012) noted that lampreys are generally believed to target salmonids. However, he also stated there are uncertainties regarding the spatial distribution of the species and it's possible that fish in an area of high lamprey concentration may have a higher incidence of lamprey scarring which would suggest a higher population of lamprey than actually exists. In 1982, Beamish suggested that young Coho Salmon are a preferred prey source by Cowichan Lake lamprey (Beamish, 2007). However, this observation was specific to Mesachie Lake and during the period when people were relocating Coho stranded in drying tributaries into Mesachie Lake. MacConnachie (pers. comm. 2012) suggested this practice may have acted as a lamprey enhancement program.

Lough et al (2011a) found that Cowichan Lake lampreys were attached to ~10% of the spawning Cutthroat Trout they observed and that the lampreys were generally ~200 mm in length. These researchers also estimated that ~80% of Cutthroat Trout spawners had one or multiple lamprey scars, but no lamprey attached. Since lampreys are not good swimmers, it seemed unlikely they could catch adult Cutthroat Trout. And when we discussed

[10] MacConnachie, S., Species at Risk Biologist, Department of Fisheries and Oceans. Nanaimo, BC.

Lough's findings with MacConnachie, he suggested that lamprey may attach to smaller fish when they are in shallower or littoral zones of the lake.

With respect to the impacts to Cutthroat Trout, MacConnachie pointed out that while fish with attached lamprey or lamprey scars can be sick looking and very thin, the Cowichan Lake lamprey is a parasite which evolved within the Cowichan lake system. As a result, while these parasites may weaken their hosts and make them more vulnerable to predators or other sources of mortality, the lamprey likely do not kill their hosts directly.

4.0 Discussion

Fisheries data are collected to evaluate the need for changes in management that affect harvest regulations, habitat protection, hatchery intervention and the need for monitoring. In this section of the report I discuss the results of our stock and fisheries assessments including whether the data suggest approaches that may enhance conservation or fisheries values at Cowichan Lake. I also provide suggestions for monitoring, and additional studies to fill data gaps relating to Cowichan Lake fish stocks and fisheries.

4.1 Fisheries Management

I have estimated between 6,500 ± 1,500 angler days per year at Cowichan Lake with almost 80% of the angler catch being Cutthroat Trout. The fact that anglers catch more Cutthroat than Rainbow Trout may simply reflect the relative abundance of the two species. In many coastal BC lakes Rainbow are more common than Cutthroat Trout (Cutthroat: Rainbow = 0.78:1 to 0.18:1) (Nilsson and Northcote 1981). In Cowichan Lake, however, we found Cutthroat were more common than Rainbow Trout over all capture methods (i.e., floating traps (1.7:1); gillnets (2.4:1); and angler catches (4.7:1)).

The prevalence of Cutthroat Trout in angler catches suggests that Cowichan Lake anglers may target Cutthroat Trout. In a sample of 10 Coastal BC lakes that support sympatric populations of Cutthroat and Rainbow Trout, the two species occupied different feeding and habitat niches (Nilsson and Northcote 1981). This finding suggests that anglers can differentially target the two species.

In addition to occupying different habitats, on Vancouver Island, Cutthroat Trout grow to larger sizes than Rainbow Trout (Table 15). The larger size of Cutthroat *vs*. Rainbow Trout may produce higher catchability for Cutthroat Trout. In fact, a positive relationship between catchability and fish size is common in a variety of species (e.g. Rieman and Maiolie 1995). Larger fish are generally preferred by anglers and, in general at Cowichan Lake, anglers catch large (>40 cm) Cutthroat. Recruitment to angling gear takes place at 20 – 30 cm but Cutthroat Trout age structure in the angler catch includes many fish that are >40 cm and 5 and 6 years old.

Harvest rates are also higher on Cutthroat than on Rainbow Trout. Again, the fact that anglers are more likely to harvest, rather than release Cutthroat Trout is likely because of a preference for larger fish. Having said that, ~50% of the Cutthroat Trout harvested at Cowichan Lake are <35 cm.

High levels of harvest of immature relative to mature Cutthroat Trout (see Section 3.3) may be a concern over extended time periods. In addition, angler effort during the derby period, the last 2 months of which overlaps the Cutthroat Trout spawning period (Table 18), accounts for close to 50% of the angler effort, almost 70% of the total catch, and almost 40% of the annual harvest at the lake. It is likely the lure of catching large fish that attracts serious anglers from around Vancouver Island to these events. In contrast to anglers in the general fishery, derby anglers have higher catch success rates (>1.3 fish/day), and catch larger fish with ~50% of the Cutthroat Trout harvested averaging ~40 cm. The cumulative effect of potential concerns raised by a high level of fishing of immature fish, along with the overlap of the derby season with the spawning season may be worth monitoring.

The maximum size regulation of 50 cm for Cutthroat Trout was introduced at Cowichan Lake in the 1990's (George Reid, pers. comm. 2012)[11] as a result of concerns over the extensive derby fisheries. Maximum size limits have been implemented in a variety of stocks and are typically successful in increasing the abundance of large fish (Eric Parkinson pers. comm. 2015). This is a key regulation on Cowichan Lake and it differs from the 1 >50 cm, 1< 50 cm and annual limits implemented on similar stocks in other BC lakes (Eric Parkinson pers. comm. 2015). Our data suggest the modal length of Cutthroat Trout captured by anglers has increased since the 1980's as has the proportion of each length class of Cutthroat Trout caught. Data cited here suggest that, in the 1980's, most Cutthroat caught were <35 cm, whereas now most Cutthroat are 35 – 50 cm, and 10% are >50 cm including some fish 70 cm+.

In contrast to management of Cutthroat Trout, no size regulation was introduced for Rainbow Trout. Our data suggest the average size of Rainbow caught by anglers has declined over the past 3 decades. Data reviewed here indicate that in the 1980's, anglers caught Rainbow Trout ranging from ~20 – 50 cm and averaging ~32 cm. Approximately 35% of the catch was >35 cm. Currently, Rainbow range up to 46 cm and average <30 cm with only ~20% of the angler catch >35 cm (Table 4). Rainbow Trout begin maturing at ~33 cm; consequently, most of the Rainbow Trout harvested at Cowichan Lake are immature.

According to our studies, prey abundance for predaceous fish does not appear to be limiting the trout populations in Cowichan Lake, and our data provide little evidence of overfishing. Our data suggest CPUE is increasing, not decreasing; however, declining angler effort (VILQ; unpublished data), or higher angler efficiency (i.e. higher catchability) may contribute to this apparent trend and should be evaluated further. The age structure of Cutthroat Trout includes fish that are up to 3 years older than the age of recruitment to the fishery at 25 cm. The downward trend in angler effort derived from the mail survey is substantial but not statistically significant. The current effort density (4.2 angler-hour/ha) appears to be slightly less than at Kootenay Lake (5.2 rod-hours/ha, Andrusak and Andrusak 2012) and the corresponding harvest rates on Kootenay Lake Rainbow and Bull Trout (*Salvelinus confluentus)* appear to be sustainable (Andrusak and Thorley 2014). In addition, growth rates and age structures of Cowichan Lake Cutthroat and Rainbow Trout are similar to other Vancouver Island sympatric trout populations (Nilsson and Northcote 1981).

[11] Reid, G. Retired; former Fisheries Section Head Fish and Wildlife Branch; Ministry of Environment, Nanaimo, BC.

The high level of harvest of immature Cutthroat and Rainbow is; however, worth further study to assess the potential impact of pressure on these age classes and the fishery if fish are not able to spawn at least once. High harvest pressure on these trout while they are immature and growing rapidly may also be a concern given the heavy angler effort on Cutthroat Trout during the derby period. Wild fish stocks at Cowichan Lake may have already been compromised (Figure 3), and there may be insufficient recruitment of wild fish to provide anglers with opportunities and adequate catch rates to ensure angler satisfaction. This is of particular concern given that angler effort at Cowichan Lake is the 2nd highest of any lake on the Island (VILQ; unpublished data).

Anglers at Cowichan Lake have an average success rate of ~0.3 fish/angler day which is among the lowest angler success of any large lake in the region (Michalski and Schlag 2013). In fact, almost 40% of anglers we canvassed said the angling at Cowichan Lake is poor (Table 5). A related issue is the variability in efficiency among anglers (Ward et al., 2013). Efficient anglers are able to deplete the pool of vulnerable fish leaving less efficient anglers with very poor catch rates (Cox and Walters, 2002a; 2002b). This may in part explain why quantitative data on fish numbers caught indicate an increasing CPUE, but the survey of anglers still points to dissatisfaction of the angling experience for many.

I list below management activities that, based on the above analysis, could be considered to promote conservation of wild stocks and enhance sustainable fishing opportunities for the wild stocks which comprise the Cowichan Lake fishery.

1. Implement a minimum size limit of 30 cm for Cutthroat and Rainbow Trout.

   Ricker (1945) emphasized the need for legal minimum size limits to ensure optimum recruitment and permit sufficient survival of mature fish for adequate reproduction. A minimum size limit of 30 cm will ensure fish have the opportunity to spawn at least once before entering this high effort fishery. According to our angler survey, ~30% of anglers support size limits to conserve fish stocks (Table 6). This size limit would cut angling mortality of small Cutthroat Trout which have high natural rate of survival and, as larger fish, may provide more angler satisfaction.

2. Focus on trophy fish management to provide anglers with an opportunity to keep a large Cutthroat Trout.

   This study suggests the current fishery is sustainable and some harvest of >50 cm fish could be permitted if harvest of smaller fish is reduced (Parkinson pers. comm. 2015). Cowichan Lake can produce large fish and large fish are both unusual and important to anglers. In fact, length of fish appears to be slightly more important to angler satisfaction than catch rates (McCormick and Porter 2014, Hunt et al. 2012, Petering et al. 1995).

   Cutthroat Trout at Cowichan Lake are large which suggests these fish can provide an angling experience of higher than average quality. Higher than average angling quality tends to attract more angler effort which drives the quality back down as fish size and catch rates decline. In this situation, the an appropriate approach is to maximize the quality of the fish harvested, or caught in a Catch-&-Release fishery, and to closely monitor average fish size and the response of anglers. One of the two following approaches could be considered:

a. Implement a 1 >50 cm, 1< 50 cm regulation for Cutthroat Trout. Rainbow Trout are available for non-trophy anglers and annual growth rates (and presumably natural survival) are high for Cutthroat in the 30 – 50 cm range (Andrusak and Thorley 2014); or,
b. Implement a tag system or annual limit for Cutthroat Trout. There is a 5/year quota system on Shuswap and Kootenay Lakes which could be a possible model for Cowichan Lake.

4.2 Stock and Fishery Monitoring

Cowichan Lake is one of the most important fisheries in the region and regular monitoring of fish stocks and fisheries will provide valuable information for understanding stock status and relationships among angler effort in the general, versus derby fisheries. A comprehensive, ongoing, and consistently-implemented habitat and stock monitoring program will help detect changes in fish populations, and ideally tease apart the impacts of habitat, prey-availability and fishing pressure. It is important this monitoring program be multi-faceted and designed to ensure a high probability of detecting ecologically significant effect sizes. The following suggestions are aspects of a monitoring program that may provide important trend information, as well as scientific understanding of the interrelationships among factors influencing population sizes of Cutthroat Trout within the Cowichan Lake system (see Appendix 9 for suggested schedules).

1. Monitor Cutthroat Trout stock status through ongoing spawner surveys.

   Because declines in spawning escapement or the average size of spawners could be indicators of problems such as excessive harvest rates (Parkinson pers. comm. 2014), consider counting redds, and assessing size and numbers of spawners during peak spawning at the index sites identified by Lough et al (2011a) every 3 years. These data should be reviewed in concert with angler catch data from creel surveys or the VILQ, which was also designed to be implemented every 3 years (Law, pers. comm. 2012[12]).

2. Conduct gillnet assessments every 3 years to monitor stock status.

   Consider monitoring length-at-age and length-at-maturity and other stock status indicators to identify changes to Cutthroat Trout stocks especially if regulations are changed at Cowichan Lake. Additional details regarding fish stock monitoring at Vancouver Island large lakes is provided in Michalski and Schlag (2013).

[12] Law, P. retired; former Small Lakes Biologist, Fish and Wildlife Branch, Ministry of Environment; Nanaimo, BC.

3. Monitor the Cowichan Lake derby fishery

   The most informative monitoring of the Cowichan Lake fishery would likely focus on the derby fisheries which constitute most of the angler effort, catch, and harvest at the lake. I recommend instantaneous angler counts and creel surveys and monitoring at weigh-ins be considered. Monitoring should concentrate on derbies held during April and May which coincides with the peak Cutthroat Trout spawning period and when almost 30% of the annual angling effort occurs (Figure 6) and the harvest rate increases (Table 3).

   In addition to targeted monitoring during derbies, I suggest considering monitoring the general fishery using the VILQ. The objectives of the VILQ are to monitor trends in the regional fisheries and identify concerns including drops in angler effort, catch and/or success so more detailed assessments can be implemented (Reid pers. com. 2012). According to the VILQ, the average angler success at large lakes in the Vancouver Island region is 1.7 fish/angler day, and the angler success at Cowichan Lake 1.2 fish/angler day (Michalski and Schlag 2013). Part of the reason for this discrepancy may be that the fish are bigger at Cowichan Lake which attracts more angler effort which, in turn drives angler quality back down (Parkinson pers. com. 2015). The VILQ could be used to monitor angler success and, if success drops to one fish/angler day, support consideration of additional management actions including:

   a. Reducing the harvest quota to one fish/day. This regulation allows for a harvest of fish, and anglers would be likely to throw back smaller fish, hoping for a big one. In addition, our angler survey found some support (16%; Section 3.4) for reduced harvest if the result would be an improvement in fishing.

   b. Implementing Catch-&-Release regulations. In certain fisheries, angler effort can go up if the abundance of large fish goes up but the increase in large fish has to be substantial (e.g. 2 – 3 times the current abundance of large fish) unless there is either a large population pool (i.e. Victoria), few other opportunities to catch large fish, and/or a specialized group of anglers who like large fish and do not strongly prefer to harvest (Parkinson pers. com. 2015). Angler surveys would have to be implemented to determine if this is the case at Cowichan Lake as this approach could result in a loss of angler effort.

4.3 Recommendations for additional study and assessment and communication to support science and management of trout populations in Cowichan Lake

1. Address data gaps regarding Cutthroat Trout fecundity and anthropogenic mortality

   Two data gaps were suggested by our work: fecundity of Cutthroat Trout, which should be included as part of the next gillnetting assessment; and level of anthropogenic mortality of trout. Regulations to control fishing mortality are an important management tool and, therefore, estimating fishing mortality and the effect of harvest regulations on this mortality is essential for the management of most fisheries (Walters and Martell 2004).

2. Consider conducting assessments to determine juvenile fish densities and carrying capacity for Cowichan Lake tributaries and determine if Coho Salmon stocking is necessary.

   During our electrofishing survey, we found high numbers of Coho Salmon fry compared to Cutthroat Trout (Table 22). Ptolemy (1990) also commented on the high abundance of Coho fry in Cowichan tributaries sampled by Griffith (1989) and expressed concern over the impact of these densities on maximum growth performance and survival, as well as the increased mortality of Cutthroat Trout fry.

   It is unknown what proportion of the Coho Salmon in streams is wild, however, it appears the proportion of Coho Salmon and Cutthroat Trout sampled in streams has changed over the past 20 years with Cutthroat and Rainbow Trout and Dolly Varden dominating samples in last decade, and Coho dominating in 2012.

3. Discuss with the DFO the potential utility of re-instating the use of their biostandard of 0.5 Coho/m^2 of stream habitat (Envirowest Environmental Consultants, 1990) to guide stocking efforts until fish density and carrying capacity assessments are completed and can effectively inform management decisions.

   Juvenile Coho Salmon and coastal Cutthroat Trout are potential competitors for food and space during the summer low-flow season (Glova and Mason 1977). Cutthroat Trout populations, both young-of-the year and older fish are adversely affected by the stocking of Coho fry and those effects include reduced survival, growth and production (Tripp and McCart 1983). Not only is the survival of wild Cutthroat Trout fry in the Cowichan system compromised if Coho stocking is excessive, new regulations to increase spawning numbers of Cutthroat Trout could be undermined if fry produced from additional spawners are outcompeted by introduced Coho Salmon. The Alkalinity Model (Ptolemy et al. 1991) could be refined and used to identify carrying capacity of Cowichan Lake tributaries to assist with supporting discussions with DFO.

4. Determine the extent of Coho Salmon salvaging in the Cowichan watershed.

   Salvaging Coho Salmon from drying habitats and moving these fish to wetted areas is common in many watersheds along the East Coast of Vancouver Island. Unfortunately, the carrying capacity and abundance of fish in the receiving habitats is rarely, if ever, determined before the salvaged fish are introduced. I suggest evaluation of the extent of Coho Salmon salvaging in the Cowichan watershed, further study of the ecological implications of this practice, and discussion of this practice with stakeholders. Results from the juvenile assessments and carrying capacity studies suggested above will be important in these discussions.

5. Develop an improved method for determining productivity of Cowichan Lake Kokanee Salmon.

   The Large Lakes Kokanee Model (LLKM) was an interactive computer model that facilitated the process of tying lake specific data to a series of functional relationships (Parkinson and Korman 1994). Specifically, the model predicted the number of predaceous fish that could be supported based on the availability of their prey. The LLKM was extremely useful in identifying management actions for large lakes which are difficult and expensive to assess and monitor. However, the model was developed on data from some of BC's more productive Interior lakes and did not account for the occurrence of other piscivorous species or other significant prey species which limited its applicability for Vancouver Island large lakes (e.g. Russell 1990).

   I recommend the development of a revised LLKM specifically for Vancouver Island to support future management decisions. This model should incorporate methods and understanding derived from the newer predator-prey models that have become standard methods of evaluating the role of forage fish density, and angler harvest on the dynamics of piscivorous salmonids in large lakes (e.g. Hansen et al. 2010, Post et al. 2003).

6. Collect additional baseline data for Kokanee Salmon

   Additional baseline data may be required to develop a LLKM as we have an incomplete understanding of the Kokanee resources on the Island. Johner and Sebastian (2011) suggest completing successive years of hydro acoustic surveys to reflect the natural fluctuations in Kokanee abundance between Cohorts, size-at-age, growth rates, and species composition. For Cowichan Lake and other Island large lakes the production of higher resolution and more complete bathymetric maps may also be required to increase the accuracy of habitat and species abundance and biomass estimates.

7. Determine the need for more information on life history strategy of Cowichan River/Lake Rainbow Trout

   The objective of the annual Cowichan River snorkel surveys is only to count Rainbow Trout and Brown Trout and estimate fish size. Consequently, there is no information in the ministry files regarding whether the Rainbow Trout observed in these annual surveys are fluvial or adfluvial populations. If the Rainbow Trout observed during these assessments are returning to Cowichan Lake after spawning these fish should be available to the angler. Information on the life history of these fish will provide a better understanding of the fisheries resources of Cowichan Lake, and contribute to the development of appropriate fishery management strategies for this stock.

8. Erect regulations signs at Cowichan Lake

   Anglers in both the general fishery and at derbies report harvesting Cutthroat Trout >50 cm despite the maximum size regulation. Signs outlining the fisheries regulations could help anglers and enforcement staff, and could be erected at the Cowichan Lake and Gordon Bay Provincial Park boat launches, and the Heather Campsite.

9. Conduct habitat enhancement assessments and identify priority projects

   An extension of habitat carrying capacity studies is habitat enhancement and restoration work. Some habitat assessments have been conducted in the Cowichan Lake watershed (e.g. Michalski and Jancowski 2006, Griffith 1989) and I recommend these be reviewed as Level 2 habitat assessments and priority habitat enhancement projects may already be identified. Many habitat enhancement projects are ideally suited for implementation by volunteers and not only do these projects result in additional habitat to support juvenile life history phases of wild stocks, they are positive alternatives to fish stocking in tributaries and/or salvage efforts.

10. Address data gaps relating to the Cowichan Lake lamprey

   There are data gaps regarding the Cowichan Lake lamprey and the relationship between this species and Cutthroat Trout. In addition, many anglers are concerned about the appearance of lampreys attached to Cutthroat Trout and the fact that Lamprey appear plentiful, and yet are protected under *SARA*. More information on the Cowichan Lake Lamprey and its potential impacts on Cutthroat Trout, and a public awareness program regarding this little-known species, and its relationship to Cutthroat Trout would be useful for anglers and could help managing the Cowichan Lake system.

11. Work in partnership with public stakeholders and volunteers to identify stock and fisheries studies and monitoring programs at Cowichan Lake

   The guiding principles of the Fisheries Program Plan (Ministry of Environment 2007) include clear, collaborative and productive relationships among governments, First Nations, partners and stakeholders, and a strong shared stewardship of the fisheries resource which is dependent on increasing awareness and accountability for fish and fish habitat among all British Columbians (Ministry of Environment 2007). One of the objectives of FLNRO is sustainable natural resource management through effective policy, legislation and external relationships (Ministry of Forests, Lands and Natural Resource Operations, 2015). There are many enthusiastic volunteers in the Cowichan Valley interested in providing their time to assist with studies and monitoring of Cowichan Lake stocks and fisheries, and I recommend consideration of implementation of future projects in partnerships with these stakeholders.

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Appendix 1.
Cowichan Lake Creel Survey Calendars 2010, 2011

2010 Creel Survey Calendar

January '10

Su	M	Tu	W	Th	F	Sa
					1	9:00
3	4	5	###	7	8	9
10	11	8:00	13	14	15	16
###	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

February '10

0.42	M	Tu	W	Th	F	Sa
	1	2	3	4	9:00	6
7	8	9	10	11	12	###
14	15	16	17	18	19	20
###	22	23	24	###	26	27
28						

March '10

0.42	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
###	###	9	10	11	12	13
###	15	16	9:00	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

April '10

0.42	M	Tu	W	Th	F	Sa
				1	2	###
4	5	6	7	9:00	9	10
11	12	13	14	15	16	17
18	19	###	21	22	23	24
###	26	27	28	29	30	

May '10

0.42	M	Tu	W	Th	F	Sa
						###
2	3	4	5	###	7	8
###	10	11	###	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	###
30	31					

June '10

0.42	M	Tu	W	Th	F	Sa
		1	###	3	4	5
6	7	8	9	10	11	###
13	14	15	###	17	18	19
20	21	22	23	24	25	26
27	###	29	30			

July '10

0.42	M	Tu	W	Th	F	Sa
				1	2	###
4	5	###	7	8	9	10
11	12	13	14	15	16	###
18	###	20	21	22	23	24
25	26	27	28	29	30	31

August '10

0.42	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
###	8:00	17	18	19	20	21
###	23	24	25	26	27	28
29	###	31				

September '10

0.42	M	Tu	W	Th	F	Sa
			1	2	3	4
9:00	6	7	###	9	10	11
12	13	14	15	16	17	18
###	20	21	22	23	24	25
26	27	28	###	30		

October '10

0.42	M	Tu	W	Th	F	Sa
					1	2
###	4	5	6	7	8	9
###	11	12	13	14	15	###
17	###	19	20	21	22	23
24	25	26	27	28	29	30
31						

November '10

0.42	M	Tu	W	Th	F	Sa
	1	2	3	4	###	6
7	8	###	10	11	12	13
14	15	16	17	18	19	###
21	22	23	24	25	26	27
###	29	30				

December '10

0.42	M	Tu	W	Th	F	Sa
			1	2	3	###
5	6	7	8	9	10	11
###	13	14	15	16	###	18
19	20	21	9:00	23	24	25
26	27	28	29	30	31	

2011 Creel Survey Calendar

January '11

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	9:00	6	7	13:00
9	10	11	12	12:00	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	11:00
30	31					

February '11

Su	M	Tu	W	Th	F	Sa
		10:00	2	3	4	5
11:00	7	8	13:00	10	11	12
13	14	15	16	17	18	19
10:00	21	22	23	24	25	26
27	28					

March '11

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
14:00	7	8	9	11:00	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
14:00	28	15:00	30	31		

April '11

Su	M	Tu	W	Th	F	Sa
					1	2
15:00	4	5	11:00	7	8	9
10:00	11	12	13	14	15	16
17	18	19	20	21	22	23
24	12:00	26	27	28	29	30

May '11

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
12:00	9	10	11	15:00	13	14
15	16	17	18	19	20	21
15:00	13:00	24	25	26	27	28
29	30	31				

June '11

Su	M	Tu	W	Th	F	Sa
			1	16:00	3	4
5	6	7	8	9	10	11
13:00	13	14	15	16	17	18
15:00	20	21	22	23	24	25
26	27	13:00	29	30		

July '11

Su	M	Tu	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	13:00	12	13	14	15	16
17	18	9:00	20	21	22	23
13:00	25	26	27	28	29	30
9:00						

August '11

Su	M	Tu	W	Th	F	Sa
	1	2	10:00	4	5	10:00
7	8	9	10	11	12	13
14	15	16	17	18	19	20
13:00	22	23	24	25	26	27
28	29	30	8:00			

September '11

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	11:00	10
15:00	9:00	13	14	15	16	17
18	19	20	21	22	23	24
13:00	26	27	28	29	30	

October '11

Su	M	Tu	W	Th	F	Sa
						1
11:00	3	4	5	6	7	8
9	10	13:00	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
10:00	12:00					

November '11

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	11:00	11	12:00
13	14	15	16	17	18	19
9:00	21	22	23	12:00	25	26
27	28	29	30			

December '11

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	9:00	13	14	15	16	11:00
13:00	19	20	21	22	12:00	24
25	26	27	28	29	30	31

Appendix 2.
Cowichan Lake Creel Survey Instructions

Cowichan Lake Assessment

On Water Angler Survey Procedure

The two parts of the survey are the angler count and angler interviews. The goal of the procedure is to achieve an accurate as possible "snapshot" of the anglers on the water at a single point of time. To achieve this goal the following procedure applies. Use the following route that applies to your start point. It is important that both North and South arms are covered on the outbound leg so as to capture maximum lake area in the initial angler count. You may find having passengers utilize binoculars will assist in spotting shore anglers. On the outbound leg you will be counting anglers only. Interviews will be conducted on the return trip.

Routes

Starting at Weir

From Put-in point at Weir, follow north shore west through South arm and complete a pass of the North arm. Follow north shore to West end of lake in vicinity of Heather Campsite. During this time count all boats and anglers on the lake and the shore. This should capture almost all boats on the water and all North Shore anglers.

Return to your start point following the South Shore to count any missed anglers on the South side of the lake and Gordon Bay.

Starting in North Arm

Complete pass of North Arm and South arm. Then follow south shore west through Gordon bay to west end in vicinity of Heather Campsite. During this time conduct angler count. This count will capture most of the boats and shore anglers.

Return to your start point following North shore counting any missed anglers on the North side of the Lake. Enter all your counts into Part A of your field book.

Angler Interviews

On the return trip select at random a minimum 10% of anglers counted in Part A for interview. If there are few anglers on the water greater than 10% can be surveyed. It is important that the locations of anglers surveyed are randomly distributed. This may require cutting back to the opposite shore or into the North arm, on the return trip. Where possible some shore anglers should be interviewed as well.

Note the location of the anglers interviewed and whether they were shore or boat fishing. Enter all your interview data into your fieldbook, and all angler preference data into the separate questionnaire sheets provided.

Appendix 3.
Angler Effort and Total Catch Reported in Creel Surveys at Cowichan Lake July, 2009 – June, 2011

Table 1. Expanded angler effort (angler hours) for creel surveys at Cowichan Lake July, 2009 – June, 2011.

Year and Month	Fishable Hours	Days in the Month	Instantaneous Count	Expanded Angler Effort (angler hours)
Jul-09				
weekdays	16	22	0.00	0
weekends	16	9	5.36	771
total		31	5.36	771
09-Aug				
weekdays	14	20	3.57	1,000
weekends	14	11	6.43	990
total		31	10.00	1,990
09-Sep				
weekdays	12	21	2.50	630
weekends	12	9	12.86	1,389
total		30	15.36	2,019
09-Oct				
weekdays	11	21	12.14	2,805
weekends	11	10	20.36	2,239
total		31	32.50	5,044
09-Nov				
weekdays	9	20	1.07	193
weekends	9	10	8.21	739
total		30	9.29	932
09-Dec				
weekdays	8	22	5.71	1,006
weekends	8	9	5.36	386
total		31	11.07	1,391

Table 1. Expanded angler effort (angler hours) for creel surveys at Cowichan Lake July 2009 – July 2011 (continued).

Year and Month	Fishable Hours	Days in the Month	Instantaneous Count	Expanded Angler Effort (angler hours)
10-Jan				
weekdays	8	20	1.43	229
weekends	8	11	5.00	440
total		31	6.43	669
10-Feb				
weekdays	10	20	0.00	0
weekends	10	8	3.93	314
total		28	3.93	314
10-Mar				
weekdays	12	23	0.71	197
weekends	12	8	2.50	240
total		31	3.21	437
10-Apr				
weekdays	14	20	0.71	200
weekends	14	10	5.71	800
total		30	6.43	1,000
10-May				
weekdays	15	20	1.43	429
weekends	15	11	10.00	1,650
total		31	11.43	2,079
10-Jun				
weekdays	16	22	1.43	503
weekends	16	8	1.07	137
total		30	2.50	640
10-Jul				
weekdays	16	21	0.00	0
weekends	16	10	7.86	1,257
total		31	7.86	1,257
10-Aug				
weekdays	14	21	10.36	3,045
weekends	14	10	2.86	400
total		31	13.21	3,445
10-Sep				
weekdays	12	21	1.07	270
weekends	12	9	15.36	1,659
total		30	16.43	1,929
10-Oct				
weekdays	11	20	1.43	314
weekends	11	11	20.71	2,506
total		31	22.14	2,821
10-Nov				
weekdays	9	21	0.00	0
weekends	9	9	2.86	231
total		30	2.86	231
10-Dec				
weekdays	8	23	1.79	329
weekends	8	8	0.71	46
total		31	2.50	374

Table 1. Expanded angler effort (angler hours) for creel surveys at Cowichan Lake July, 2009 – June, 2011 (continued).

Year and Month	Fishable Hours	Days in the Month	Instantaneous Count	Expanded Angler Effort (angler hours)
11-Jan				
weekdays	8	21	0.71	120
weekends	8	10	4.64	371
total		31	5.36	491
11-Feb				
weekdays	10	20	0.71	143
weekends	10	8	3.21	257
total		28	3.93	400
11-Mar				
weekdays	12	23	0.00	0
weekends	12	8	0.00	0
total		31	0.00	0
11-Apr				
weekdays	14	19	0.00	0
weekends	14	11	0.00	0
total		30	0.00	0
11-May				
weekdays	15	21	8.93	2,813
weekends	15	10	4.64	696
total		31	13.57	3,509
11-Jun				
weekdays	16	22	1.79	629
weekends	16	8	6.43	823
total		30	8.21	1,451

Table 2. Total catch reported by anglers participating in creel survey interviews at Cowichan Lake July, 2009 – June, 2011.

Year	Total Catch			
	Cutthroat	Rainbow	Trout	Dolly Varden
2009	42	10	6	-----
2010	71	18	-----	1
2011	26	2	3	-----
Total	139	30	9	1
Percent of Total Catch	77.7	16.8	5.0	0.6

Appendix 4
Cowichan Lake Derby Schedule 2009 - 2012

Table 1. List of Cowichan Lake Derbies Attended by Volunteers, Ministry Staff and Contractors October, 2009 – March, 2012.

Year	Month	Day	Derby Name
2009	10	10-11	Lubin Annual
2009	10	17	Youbou Pub
2009	10	24	Witty Derby
2009	11	21	Barber Annual/Down & Dirty
2010	1	30	Blue Balls Derby
2010	2	19-20	Frost Bite Derby
2010	3	6	Legion Derby
2010	4	2	Caycuse Family Derby
2010	4	2	Valley Fish and Game Derby
2010	5	22	Private Derby
2010	10	9-10	Lubin Annual
2010	10	23	Private Derby
2010	11	12	Lakeview Derby
2010	11	13	Caycuse Derby
2010	11	13-14	Lakeview Derby
2010	11	27	Private Derby
2011	2	26-27	Blue Balls Derby
2011	3	19	Frost Bite Derby
2011	4	22-24	Private Memorial Derby
2012	1	21	Blue Balls Derby - Take 1
2012	1	29	Private Derby
2012	3	3	Legion Frost Bite Derby
2012	3	3	Legion Frost Bite Derby
2012	3	3-4	Blue Balls Derby - Take 2

Appendix 5.
Gillnet Catch Summary for August 2009 and August 2011.

Table 1. Summary of gillnet catch from sinking and floating nets set at mouths of Nixon and Shaw Creeks, August, 2009 and August, 2011.

Gillnetting Summary - 2009							Gillnetting Summary - 2011					
Nixon Creek - Floating Net							Nixon Creek Floating Net					
Net Set	18:00	Aug 25/09		Catch			Net Set	19:45	Aug 25/11		Catch	
Net Pulled	8:30	Aug 26/09		Rainbw	5		Net Pulled	8:30	Aug 26/11		Rainbw	9
Soak Time	14.5 hrs			Coho	1		Soak Time	12.75 hrs			Cutthroat	3
temp-surface	18.1			**Total**	**6**		temp-surface	19.4			Rainbow/(	1
Secchi	10.5 m										Coho	1
Nixon Creek - Sinking Net							Nixon Creek - Sinking Net					
Net Set	17:30	Aug 25/09		Catch			Net Set	19:00	Aug 25/11		Catch	
Net Pulled	8:30	Aug 26/09		Cutthroat	13		Net Pulled	8:00	Aug 26/11		Cutthroat	11
Soak Time	15 hrs			Salmon	1		Soak Time	13 hrs			Dolly Var	9
temp-surface	18.1			**Total**	**14**		temp-surface	19.4			**Total**	**20**
Shaw Creek - Floating Net												
Net Set	18:30	Aug 25/09		Catch			Shaw Creek - Floating Net					
Net Pulled	8:00	Aug 26/09		Cutthroat	2		Net Set	21:00	Aug 25/11		Catch	
Soak Time	14.5 hrs			Dolly Varden	1		Net Pulled	7:30	Aug 26/11		Rainbow	5
temp-surface	18.1			**Total**	**3**		Soak Time	10.5 hrs			Cutthroat	2
							temp-surface	19.4			**Total**	**7**
Shaw Creek - Sinking Net							Shaw Creek Sinking Net					
Net Set	19:00	Aug 25/09		Catch			Net Set	20:30	Aug 25/11		Catch	
Net Pulled	7:30	Aug 26/09		Cutthroat	20		Net Pulled	7:00	Aug 26/11		Cutthroat	8
Soak Time	12.5 hrs			Rainbw	1		Soak Time	10.5 hrs			Rainbow	1
temp-surface	18.1			Dolly Varden	5		temp-surface	19.4			Dolly Var	7
Comments:				Trout	2						Kokanee	1
Lots of crayfish in net, 4 sculpins				**Total**	**28**						**Total**	**17**

Appendix 6.
Terms of Reference for the Cowichan Lake Fisheries Subcommittee – November, 2011

Committee Composition

1. The subcommittee is formed to study wild stocks and fisheries at Cowichan Lake.
2. Subcommittee members are approved by the Valley Fish and Game Club.
3. Sub-committee members may be appointed or removed at the discretion of the Valley Fish and Game Club.
4. The subcommittee reports to the Valley Fish and Game Club.
5. Decisions will be reached by consensus. Consensus is defined by Merriam Webster as general agreement, or the judgment arrived at by most of those concerned.

Members
Gilles Gaudreau
Larry Williams
Howard Smith
Rick McPhail
Wally Baas
George Reid
Tracy Michalski

Term of Membership
1. The subcommittee will meet as required until the Operational Management Plan is complete.
2. The completed Plan will be presented to the Valley Fish and Game Club for ratification.
3. Once the Plan is ratified, the subcommittee will be disbanded or serve at the discretion of the Valley Fish and Game Club.

Guiding Principles

The following principles will guide the subcommittee:

1. Conservation of wild stocks will be our overarching principle.
2. Providing sustainable fishing opportunities for wild[13] stocks which comprise the Cowichan Lake fishery (i.e. Cutthroat Trout, Rainbow Trout, and Dolly Varden) is a priority.
3. Monitoring and adaptive management will be supported.
4. Enhancing habitat for wild stocks is a priority.

[13] The definition of "wild" is "completes its life cycle without the direct assistance of people." This definition is from the Conservation Policy (November 1, 1993) from the Ministry of Environment Policy Manual, Fisheries Branch Section.

5. Limiting factors for Cowichan Lake tributaries will be identified before developing habitat restoration or enhancement prescriptions, and habitat prescriptions will address limiting factors.
6. Habitat parameters and limiting factors will be identified based on field assessments conducted according to established scientific standards (e.g. Resource Inventory Standards Committee (RISC) methods; American Fisheries Society supported methods etc.).
7. Restoration plans will identify projects in priority order according to factors limiting production of wild stocks.
8. Under-seeded reaches will be high priority areas for restoration.
9. Tributaries and tributary reaches where hatchery salmon have been introduced will be a low priority.
10. Reaches where there is an incomplete list of habitat parameters or limiting factors will be priority areas for the completion of habitat assessments.
11. All management strategies will be based on data collected during the Cowichan Lake Fish and Fisheries Assessment Project (2009 – 2012), and related scientific and technical data.
12. The pros and cons of wild-stock hatchery programs will be reviewed and the sub-committee will recommend whether this is an option to be pursued to enhance fisheries stock levels.
13. Public education and awareness projects associated with any management or recovery strategies will be a part of the Plan.

Terms of Reference for the Cowichan Lake Fisheries Subcommittee – November, 2011

Goals and Objectives

Goals	***Objectives***
Provide a diversity of sustainable angling opportunities for Cowichan Lake wild fish stocks.	1. Review fish stock and fisheries data collected during the 2009-2012 Cowichan Lake Fish and Fisheries Assessment project and related studies, and identify concerns regarding conservation of wild stocks and provision of sustainable fisheries opportunities. 2. Identify potential opportunities and related regulations to conserve wild fish stocks, while maintaining angling opportunities. 3. Outline a program to monitor fisheries and angler satisfaction before and after implementation of management strategies including new regulations. 4. Develop programs to inform anglers of changes to regulations if implemented.
Enhance wild fish stocks and their habitat.	1. Identify ecological and fish stock data gaps (e.g. life history, population status etc.) and identify projects for filling data gaps. 2. Identify and prioritize reaches for habitat enhancement where data for limiting factors exists and prescriptions can be identified. 3. Identify reaches where further biophysical habitat work must be undertaken. 4. Develop a monitoring plan to accompany habitat recovery and enhancement projects. 5. Develop a program to inform the public of habitat enhancement projects.
Investigate pros and cons of a wild stock hatchery program.	1) The pros and cons of a wild-stock hatchery program will be reviewed and the sub-committee will recommend whether this is an option to be pursued to enhance fisheries stock levels.

Deliverables and Timeframe

The study will result in a final report that will outline fish stock and fishery status and recommendations for future activities. The timeframe will correspond to the HCTF funding and reporting schedule.

Appendix 7.

Size of Cutthroat and Rainbow Trout in Vancouver Island Large Lakes

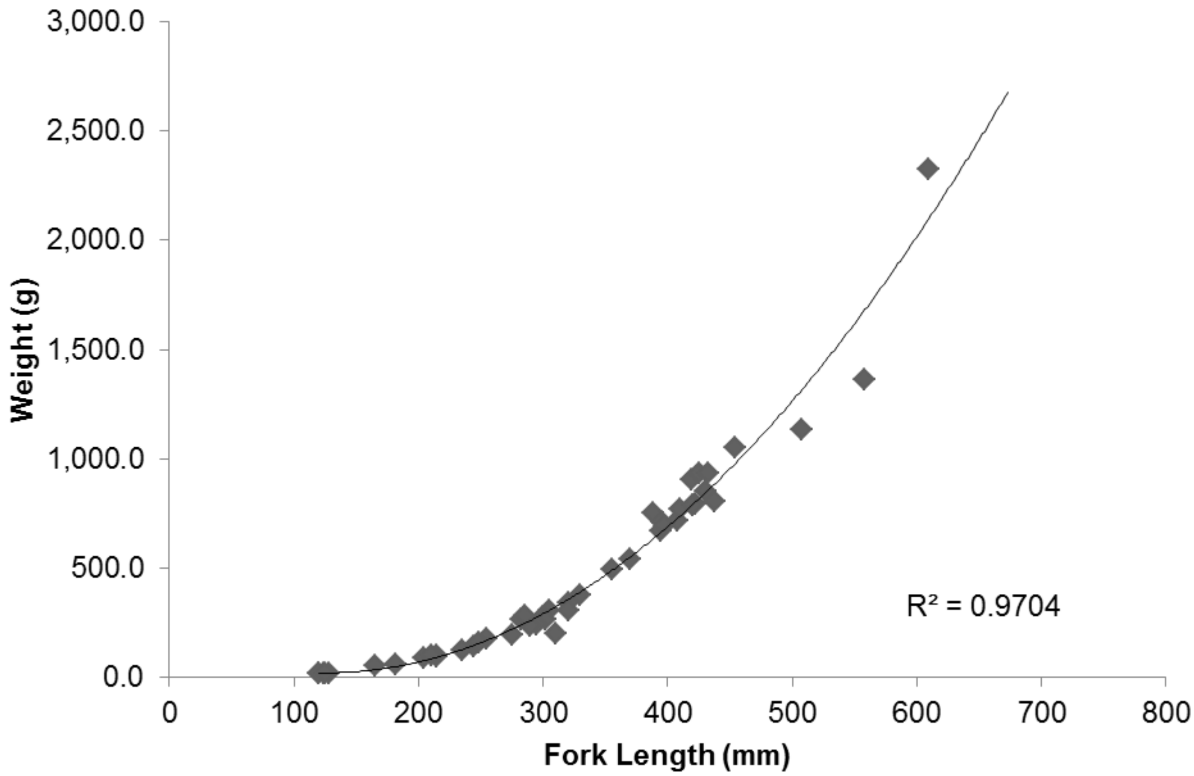

Figure 1. Length vs. weight relationship for Cutthroat Trout captured by angling, gillnetting, net trap and electrofishing in Vancouver Island large lakes 1948 – 2010 (N=1,471). (Source: Ministry of Forests, Lands and Natural Resource Operations files, Nanaimo, BC.)

Appendix 8.

Length-at-Age of Rainbow Trout and Dolly Varden Char Captured in Vancouver Island Large Lakes1948 – 2010.

Table 1. Mean length-at-age of Rainbow Trout captured by angling, gillnetting and electro-fishing in Vancouver Island large lakes not including Cowichan Lake (N=505) 1948 - 2010. (Source: FLNRO files, Nanaimo, BC.)

Age	N	Mean Length (mm)
0	64	53.3
1	51	118.5
2	94	173.0
3	94	227.0
4	66	267.0
5	21	366.1
6	18	378.5
7	34	419.9
8	43	459.9
9	20	475.1

Table 2. Mean length-at-age of Dolly Varden captured by angling, gillnetting and electrofish-ing in Vancouver Island large lakes not including Cowichan Lake (N=103) 1948 - 2010. (Source: FLNRO files, Nanaimo, BC.)

Age	N	Mean Length (mm)
0	15	55.7
1	35	116.0
2	28	230.1
3	15	245.8
4	5	306.6
5	4	285.0
6	1	58.0

Appendix 9
Stock and Fisheries Monitoring for Cowichan Lake

The following table lists projects focused on assessing the state of stocks and fisheries and implementing work to enhance the production of Cutthroat in Cowichan Lake and tributaries.

Activity	Objective	Tentative Schedule
Fish Stock Monitoring	Conduct gillnetting assessment and compare stock status and catch data to previous assessments	2015 and every 3 years
	Conduct snorkel surveys at index reaches and compare to previous counts and angler catch data	2016 and every 3 years
	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.	2016
Juvenile Assessments and Carrying Capacity of Stream Habitat	Determine juvenile abundance and carrying capacity of Cowichan Lake tributaries important to Cutthroat Trout (i.e. south-side tributaries). Use data to evaluate the need for Coho stocking and salvage (if occurring).	2016+
Fisheries Monitoring	Conduct angler counts and creel surveys; conduct angler preference survey during angler interviews. Monitor angler success rate to ensure fisheries management objectives are being met	2015 and every 3 years
	Monitor catch and fish length and weight at derby weigh ins	Every 2 years starting 2015
VILQ	Evaluate changes in fisheries statistics every three years.	2016 and every 3 years