Dolly Varden Stock Status and Habitat Preferences in the Lower Campbell Lake Watershed, Vancouver Island, British Columbia

By

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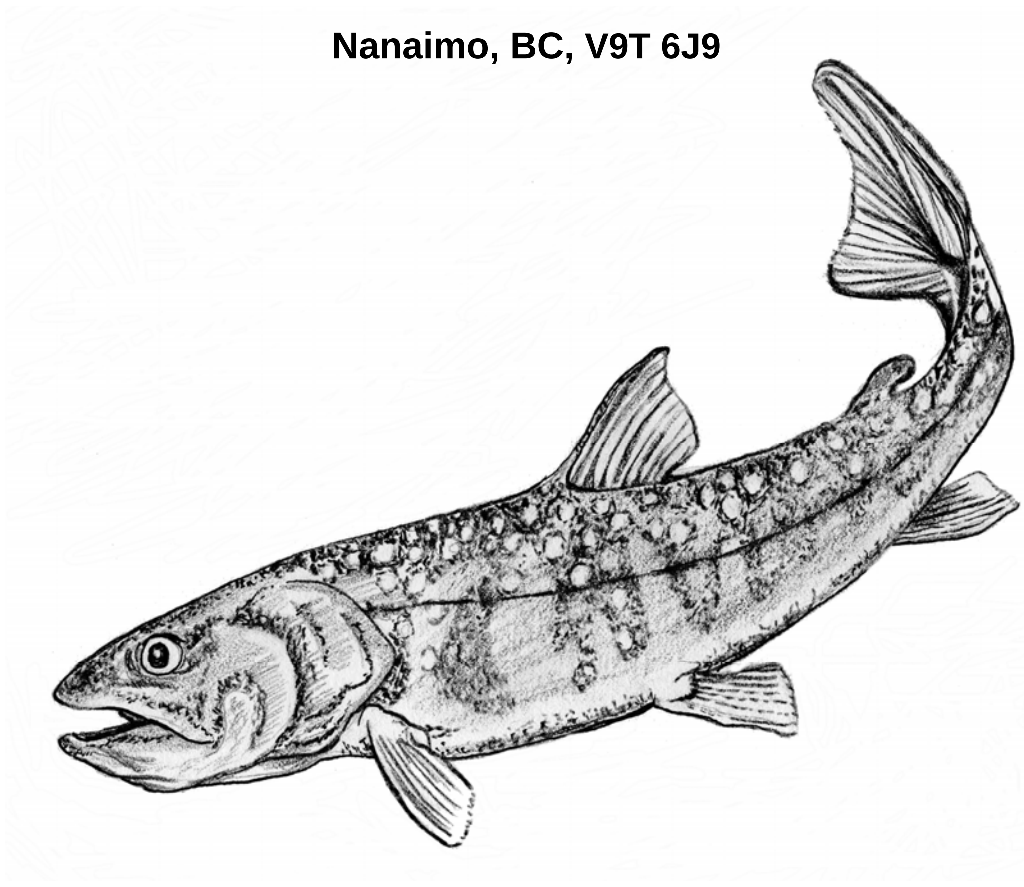

For the
British Columbia Conservation Foundation

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1.0 Introduction

Dolly Varden (Salvelinus malma) was originally described as a distinct species, but over the last century it has been known as a species and subspecies of the arctic char (S. alpinus) or a synonym of S. alpinus (Cavender, 1980). It is generally considered an anadromous species that moved inland into the western United States, western Canada, the interior of Alaska, Korea, Hokkaido, Northern Honshu, Kamchatka, and the maritime provinces of Siberia (Cavender, 1980). On the west coast of the continent, a northern form of the species occurs from the Alaska Peninsula east to the Beaufort Sea and the Mackenzie River (Wooding, 1994). A southern form occurs from northern California into western Montana, and in isolated streams in Nevada and Idaho (Scott and Crossman, 1973). In Canada, Dolly Varden occur from the headwaters of the South Saskatchewan River in Alberta, northwest through to all-but-extreme northeastern British Columbia.

Dolly Varden have adapted to a variety of habitats, and in some areas can be found in almost all type of fresh and saltwater capable of supporting fish (Armstrong and Morrow, 1980). They are found in all sizes of lakes, including those with and without access to the sea, and in extremely small isolated ponds. The species is found in large rivers and streams, both above and below blocks to anadromous fish, and even in intermittent rivulets. In saltwater, they are present almost every month of the year, although their abundance is seasonal (Armstrong and Morrow, 1980). They inhabit both offshore and inshore saltwater areas with a preference for the latter, and it is believed that anadromous fish do not move out into the open ocean but remain close to shore near river mouths (Scott and Crossman, 1973). Throughout their range, anadromous Dolly Varden occur often sympatrically with resident non-migratory stocks.

The southern form of the anadromous Dolly Varden has a habit of wintering in lakes and large rivers, which probably contributed substantially to its success in adapting to small and medium sized non-lake streams for spawning and rearing (Armstrong and Morrow, 1980). In areas where non-lake streams are incapable of supporting large numbers of over-wintering adult anadromous stocks, or where conditions such as winter droughts or icing limit their use of these streams, Dolly Varden often leave after spawning to reside in larger freshwater systems. It is thought that this adaptability is one reason why Dolly Varden have extended their distribution (Armstrong and Morrow, 1980).

In British Columbia, Dolly Varden occur throughout the province in all-but-extreme northeastern areas (Scott and Crossman, 1973). In all-but-the Okanagan, Queen Charlotte Islands and Vancouver Island, the species co-exists with bull trout (Salvelinus confluentus). On Vancouver Island, Dolly Varden populations are found mainly in drainages north of Campbell River and the outer west coast (Reid and Michalski, 2006).

1.1 Status and Classification

While many populations of char in BC are considered healthy, bull trout and Dolly Varden were provincially Blue-Listed in 1994 by the BC Conservation Data Centre to comply with the global listing by the Nature Conservancy (Pollard and Down, 2001). The classification as a Blue-Listed species means that although it is not immediately threatened, its status is of concern because of characteristics that make it particularly sensitive to human activities or natural events. In addition to listing these species of char, in 1995, the Ministry of Water, Land and Air Protection drafted The BC Fisheries Program Strategic Plan for the Conservation and Management of Char in BC. The goal of the plan was to conserve and restore wild char populations and wild char habitat through effective management strategies, including developing a thorough understanding of char biology, protecting and managing char habitat, informing and educating the public, and developing management strategies to conserve native stocks (Pollard and Down, 2001).

1.2 Dolly Varden on Vancouver Island

In general, Dolly Varden is not a target fishery on Vancouver Island; in 1995, the catch accounted for less than 2% of the total recreational fishery, with most of those adfluvial forms caught by lake anglers (Ministry of Water, Land and Air Protection, 1995). During our surveys, we contacted a number of anglers who told us they do not target the species because they believe it does not taste good. Many others said they still consider Dolly Varden a predator on salmon and trout and not worthy of their efforts. The attitude of Island anglers toward Dolly Varden follows a remarkably similar pattern to that of other anglers throughout western North America. In Alberta, California, Wyoming, Montana, Oregon and Alaska, the false reputation of Dolly Varden as a predator led to extensive eradication programs that reduced char to fractions of their former range. In Alaska, a bounty of $0.05 for each caudal fin resulted in the destruction of over 6 million sea-run Dolly Varden at the beginning of the century (Wooding, 1994). In Alberta in the 1920s, fisheries managers attempted to weed out char in many areas and although some stocks withstood these attempts at eradication, many others were extirpated entirely (Colpitts, 1993).

In recent times, incidental data collected by fisheries agencies has resulted in information about the species including the fact that they probably consume no more salmon eggs and young than do steelhead or cutthroat trout (Wooding, 1994). Additional studies, many incidental to studies focused on salmon and trout, also revealed how low Dolly Varden stocks had become in many areas. In response to this information, some fisheries managers implemented protective regulations, but management efforts in some areas were too late to stop the downward trend. In a few regions like Oregon and Alberta however, targeted management, including angler awareness programs, resulted in an increase in stock status and angler interest. Today, Dolly Varden stocks in these jurisdictions are growing and many fisheries managers point to this as evidence that once anglers become familiar with and begin to appreciate and target a species; they also begin to conserve it. (Stuart et. al., 1997).

Despite the fact that it comprised a relatively small fishery, fisheries managers on Vancouver Island varied the catch of Dolly Varden to 0 in the mid-1990s in response to incidental studies showing declines in both anadromous and freshwater stocks since at least the 1980s (Levey and Williams, 2003; Ward, 2001). Recognizing that very little fishery information on regional Dolly Varden stocks existed, Region 1 biologists identified the need for a comprehensive assessment of the stock status of Dolly Varden in one high use watershed on the Island. This study was identified as a priority during the 2002 Regional Fisheries Business Planning Session and was later provided with funding from the Minister through a special one-time Fish and Wildlife Inventory Program. This report is the result of that study, and its objectives are to:

1) assess Dolly Varden stock status and habitat preferences; and,

2) provide general guidance regarding the management and protection of Dolly Varden.

2.0 Study Area

The Lower Campbell Lake watershed is located in the Sayward Forest on eastern Vancouver Island approximately 30 km northwest of Campbell River (125^0 30' longitude and 50^0 02' latitude) (**Figure1**). In general, the area has moist, mild winters and cool, relatively dry summers. I focused this study in the Lower Campbell Lake watershed because it contains a complex of lakes that contain Dolly Varden, and is one of the major fisheries within the Region (**Figure 2**) (Reid and Michalski, 2006). In addition, the region had historical netting data for this area that I used for comparative purposes.

Figure 1. General location of the Campbell River Watershed on Vancouver Island.

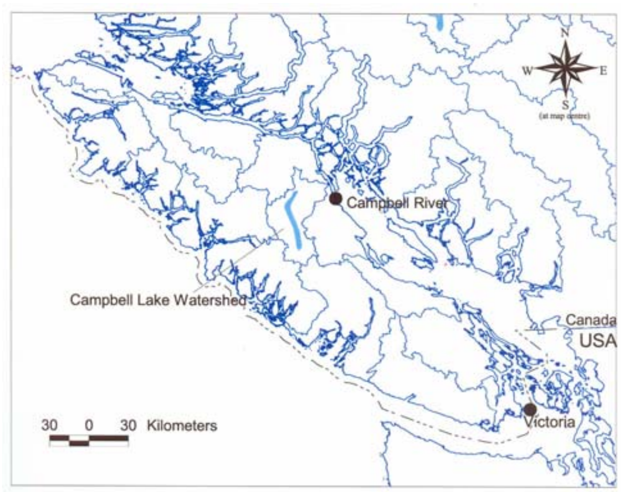
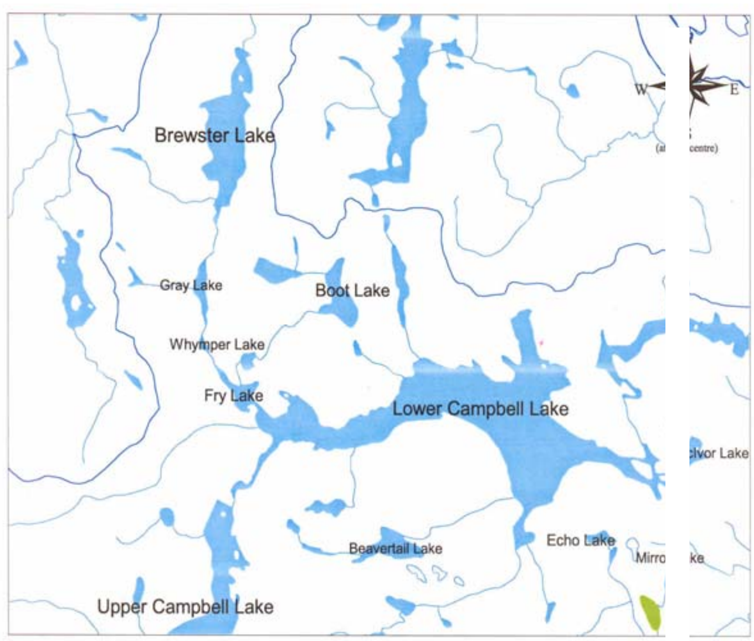


Figure 2. Study area showing Lower Campbell, Beavertail, Brewster, Boot, Fry, Gray, Little Echo, Lower Campbell, McIvor, Mirror, and Whymper lakes.



3.0 Methods

3.1 Lake Netting

We set Ministry-standard six-panel gillnets perpendicular from the shoreline in Beavertail, Brewster, Boot Fry, Little Echo and Mirror lakes in August and September between 2003 – 2004 **(Appendix 1**). We set our nets at the same time and in the same locations as historical sampling done by the Ministry to ensure results were comparable. We set nets at dusk, and retrieved them the next morning.

We weighed, measured the fork-length, sexed, and determined the maturity of each fish captured. We classified fish with fully developed gonads as mature. We also conducted a gross analysis of stomach contents where possible, and took scale samples from between the posterior edge of the dorsal fin and the lateral line. Scales were mounted on glass microscope slides and read by Lew Carswell, who has broad scale reading experience with Vancouver Island freshwater fish.

We entered our lake netting data and data from historic netting studies into Excel spreadsheets, then summarized the number of Dolly Varden caught, and the length, weight, sex and age of each fish. I analyzed data sets, first together to get general stock status and trend information for the watershed, then by lake to determine lake-specific population status.

I plotted length vs. weight for all Dolly Varden captured in gillnets between 1987–2004, then performed a regression analysis using JMP software to determine if there was a significant difference between fish captured early in the study, compared to our sampling.

I calculated condition factor (K) to determine if there had been a change between years or decades as:

$$K = \text{weight}/(\text{length})^3$$

I also summarized the results of the stomach content analysis to determine if fish were feeding on general prey types. I grouped all fish according to whether they were immature or mature, then summarized and compared fish lengths and maturity through time. I also analyzed the data to determine if there had been a shift in the age, length and maturity of Dolly Varden through time at each lake.

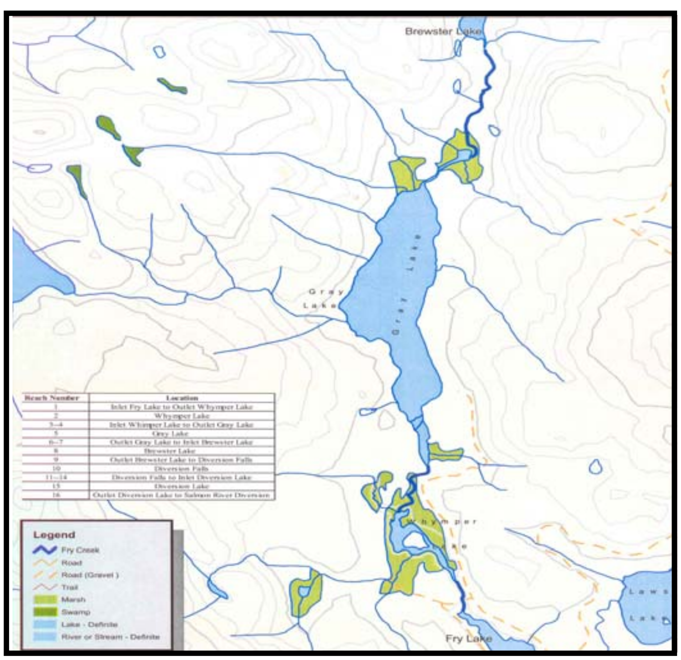
3.2 Snorkel Surveys

We conducted snorkel surveys below Strathcona dam, in the lotic section of water, weekly between August 15, 2002 and November 2004. We divided the tail-race into two sections, and snorkeled the length of the center and both sides of each section during each survey (**Figure 3**). We counted the number, species and size of each species of fish by section, and noted redd locations where possible. We took air and water temperatures during each survey, and photographed the site to document flow conditions during most swims.

Figure 3. Photograph of Strathcona Dam showing snorkel survey locations.

We used Resource Inventory Committee (RIC) standards to divide the creek into reaches, then conducted snorkel surveys by swimming each reach an average of twice per month during the study (**Figure 4**) (Resource Inventory Committee, 2001). We also conducted snorkel surveys at Fry Creek. We counted the number and estimated the size of each species of fish observed, and noted redd locations and numbers at each site. We recorded air and water temperatures at each site and, in Reach 1 and Reach 7, noted the height of staff gauges installed by the Ministry.

Figure 4. Details of the Fry Creek watershed showing Brewster, Gray, Whymper and Fry lakes.



We analyzed Strathcona snorkel data separately from that at Fry Creek and, for each site, we summarized the number of fish by species, length and, in the case of the dam, general locations of fish.

3.3 Microhabitat Surveys

We conducted a microhabitat survey in 2003 and 2004 at two reaches of Fry Creek to determine habitat preferences of Dolly Varden fry. At each site, we recorded general parameters including the GPS location, gradient, oxygen concentration, temperature, and bankfull and wetted width. We determined fry preferences by placing numbered stainless steel washers at each location where we observed fish, then noted for each washer number, the number of fish, fish focal depth, stream depth, focal velocity, substrate type and quantity, dominant and subdominant cover, and distance of fish to cover and to the bank. We also measured a cross-section transect at each site to determine fish distribution across the channel. In 2003 and 2004, we captured a maximum of 30 fry from each site using dipnets. We measured and weighed each fish and returned it to the stream.

I grouped and analyzed length data by year to determine length frequency differences between sites and changes in fish length between sampling dates. I plotted the distribution of Dolly Varden fry across the channel, as well as the frequency of fish at different stream and focal depths, and focal velocities. I also plotted the percent of each substrate and cover type, as well as the distance of fish to cover. I conducted a multiple regression analysis using JMP software to determine which, if any, of the microhabitat parameters could be used to predict locations of Dolly Varden fry within the stream channel.

4.0 Results

4.1 Stock Status

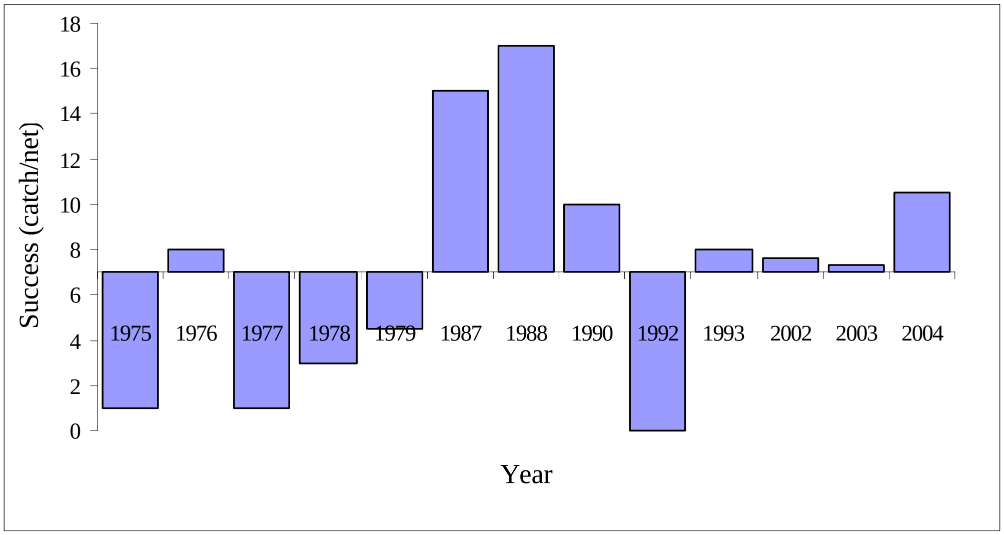
4.1.1 Gillnet Catches

Over the past three decades the ministry captured, on average, 22 Dolly Varden per sinking gillnet with catch/net highest at Beavertail Lake (**Table 1**). I plotted catch/net by year against the average catch/net and found that success began dropping in the 1990s, but increased again during our study (**Figure 5**).

Table 1. Total catch and catch/net for Dolly Varden using gillnets at Beavertail, Boot, Brewster, Fry, Gray and Mirror lakes, 1975 – 2004.

	Year													**Total**	**Average**
Beavertail	1975	1976	1978	1977	1979	1987	1988	1990	1992	1993	2002	2003	2004		
Catch	2	-----	-----	1	9	-----	17	-----	-----	-----	48	39	11	127	18
Catch/net	1	-----	-----	1	5	-----	17	-----	-----	-----	24	13	11	-----	10
Boot															
Catch	-----	-----	6	-----	-----	-----	-----	-----	-----	-----	0	0	0	6	2
Catch/net	-----	-----	2	-----	-----	-----	-----	-----	-----	-----	0	0	0	-----	1
Brewster															
Catch	-----	8	2	-----	-----	-----	-----	-----	-----	-----	4	5	12	31	6
Catch/net	-----	8	2	-----	-----	-----	-----	-----	-----	-----	2	5	12	-----	6
Fry															
Catch	-----	-----	8	-----	-----	-----	-----	-----	-----	-----	-----	-----	13	21	11
Catch/net	-----	-----	8	-----	-----	-----	-----	-----	-----	-----	-----	-----	13	-----	11
Gray															
Catch	-----	-----	2	-----	-----	-----	-----	-----	-----	-----	7	4	25	38	10
Catch/net	-----	-----	2	-----	-----	-----	-----	-----	-----	-----	4	4	25	-----	9
Little Echo															
Catch	-----	-----	-----	-----	12	-----	5	-----	-----	-----	0	0	-----	17	4
Catch/net	-----	-----	-----	-----	12	-----	5	-----	-----	-----	0	0	-----	-----	4
Mirror															
Catch	-----	-----	-----	-----	-----	15		10	0	8	2	4	2	41	6
Catch/net	-----	-----	-----	-----	-----	15		10	0	8	2	4	2	-----	6
Total Catch	2	8	18	1	21	15	22	10	0	8	61	52	63	281	22

Figure 5. Total success (catch/net) compared to average success for Dolly Varden at Beavertail, Boot, Brewster, Fry, Gray and Mirror lakes, 1975–2004.



4.1.2 Fish Size – Lower Campbell Lake Watershed

Dolly Varden captured in gillnets between 1975-2004, ranged from 13–50 cm in size (**Table 2**). The minimum, maximum, median and modal lengths all declined in 2000s. The minimum size ranged from 20.3 cm in 1975, to 27 cm in 1987 and 17.5 cm in 2004. The maximum size also varied, ranging from 30 cm in 1975 to 50 cm in 1978. Thereafter, the maximum size decreased to as low as 35.8 cm in 2002. Median size declined from 28.5 cm in 1978 to 21.8 cm in 2004.

Table 2. Total number, median and minimum and maximum lengths of Dolly Varden sampled using sinking gillnets at Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 1975 - 2004 (N=263).

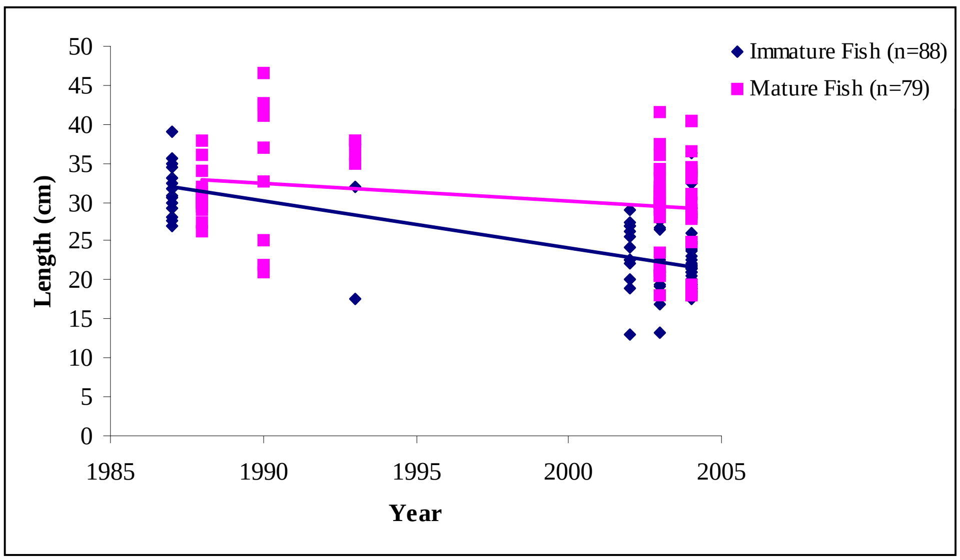
	1975	1977	1978	1979	1987	1988	1990	1993	2002	2003	2004	Totals
Number	2	1	18	12	15	22	10	8	61	51	63	263
Minimum	20.3	28.0	17.0	26.9	27.0	16.0	21.0	17.5	13.0	13.2	17.5	13.0
Maximum	30.0	28.0	50.0	40.4	39.1	47.0	46.5	38.0	35.8	41.5	40.5	50.0
Median	25.15	28.0	28.5	33.6	30.9	29.8	34.8	36.8	27.5	28.0	21.8	28.5
Mode	---	28.0	32.0	---	---	30.0	22.0	37.5	27.0	20.5	19.5	---
Average length	25.2	28.0	28.5	34.1	31.6	30.2	33.3	34.0	27.3	26.4	24.3	29.3
Average length/decade	29.0				30.9		33.7		26			

The average length of Dolly Varden captured between 1975 – 2004 in small lakes was 29.3 cm, although the average length of fish captured in the late 1970s – 1993 was above that, varying between approximately 30 cm – 34 cm (**Table 2**). Between 2002 – 2004, average lengths decreased from 27 cm to approximately 24 cm.

I found a shift in the modal length of Dolly Varden between the 28 cm – 32 cm range for 1975 – 1999 and the 19.5 cm – 27 cm range for 2002 – 2004 (**Table 2**). The mode shifted from 30 cm in 1988, to 22 cm in 1990 and 38 cm in 1993. In 1990 and 1993, however, only 10 and 8 Dolly Varden were captured respectively. Between 2002 – 2004, the mode shifted from 27 cm to 19 cm.

I grouped the data from all small lakes to determine differences in the change in lengths for immature vs. mature Dolly Varden. I found a decrease in the length of both immature and mature Dolly Varden between 1987 – 2004 (**Figure 6**). The average size of immature fish decreased from 31.2 cm to 21.8 cm between 1987 - 2004, while the average size of mature fish declined from 31.1 cm to 29.4 cm.

Figure 6. Length of immature and mature Dolly Varden captured in Brewster, Beavertail, Fry, Gray, Mirror lakes, 1987 - 2004 (N=167).



I also found that sizes of both male and female Dolly Varden decreased over the past 30 years (**Figure 7**; **Figure 8**). Immature fish of both sexes decreased from approximately 32 cm in the late 1980s, to 21 cm in 2004. Mature males and females decreased from approximately 35 cm to 30 cm during the same period.

Figure 7. Length of immature and mature male Dolly Varden captured in Brewster, Beavertail, Fry, Gray, Mirror lakes, 1985 - 2004 (N=85)

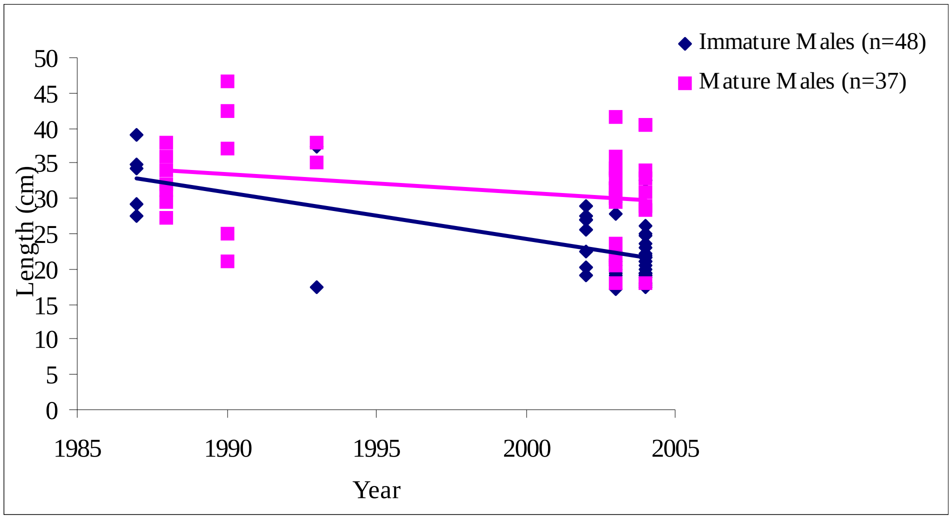
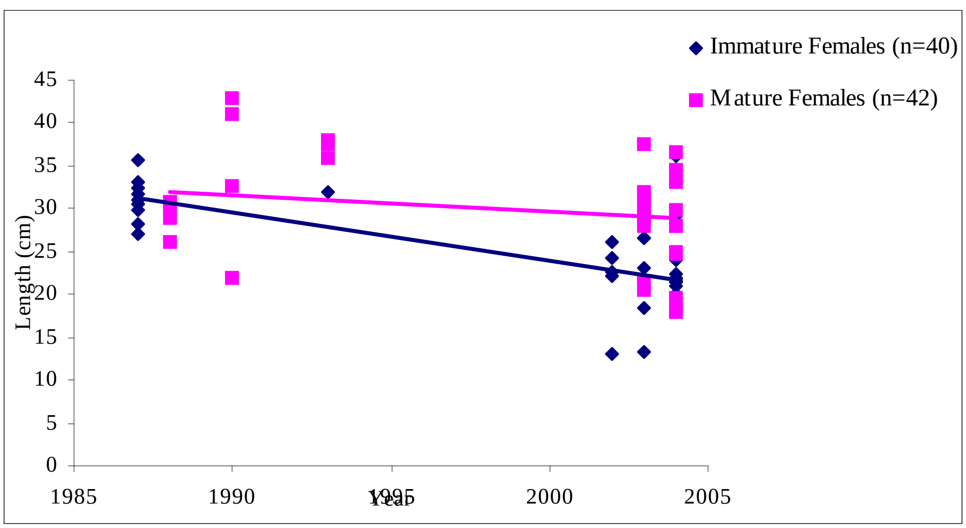


Figure 8. Length of immature and mature female Dolly Varden captured in Brewster, Beavertail, Fry, Gray, Mirror lakes, 1985 - 2004 (N=82)



4.1.3 Fish Size - Individual Lakes

In general, I found an overall decrease in maximum, average and modal lengths of Dolly Varden in small lakes in the watershed (**Table 3**). I classified the overall change in the minimum size as stable because the change in length was < 2.5 cm. At individual lakes, however, I found differences. At Beavertail Lake, for example, maximum size decreased by over 17 cm, while at Brewster Lake, maximum size increased by almost 14 cm. I also found a slight decrease in the catch/net for Dolly Varden during the study period. Of note, however, is the decrease in catch/net of 24 Dolly Varden at Mirror Lake.

Table 3. Comparison of the change in average size, modal length and catch per net of Dolly Varden captured in sinking gillnets in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 1978 - 2004. An arbitrary limit of +/- 2.5 cm was set as the boundary for the change categories for size; no boundaries were set for catch/lake. The overall trend was calculated by averaging the change for all lakes.

	Beavertail	Boot*	Brewster	Fry	Gray	Little Echo	Mirror	Overall Trend
Minimum Size (cm)								
Change	-2.6	-----	-1.9	0.5	-1.5	-2.4	-2.2	-1.6
Trend	Decrease	-----	Stable	Stable	Stable	Stable	Stable	Stable
Maximum Size (cm)								
Change	-17.1	-----	+13.7	+2.0	+11.5	-11.8	-14.2	-2.7
Trend	Decrease	-----	Increase	Stable	Increase	Decrease	Decrease	Decrease
Average Size (cm)								
Change	-9.7	-----	+2.9	1.0	1.1	-6.6	-6.7	-3.0
Trend	Decrease	-----	Increase	Stable	Stable	Decrease	Decrease	Decrease
Modal Length (cm)								
Change	-8.0	-----	-8.0	-10.0	-7.0	-7.0	-4.0	-7.3
Trend	Decrease	-----	Decrease	Decrease	Decrease	Decrease	Decrease	Decrease
Catch/Net								
Change	+10	-2	+4	+5	+7	-12	-24	-1.7
Trend	Increase	Decrease	Increase	Increase	Increase	Decrease	Decrease	Decrease

* Dolly Varden found in only one of three gillnet sets during survey period, therefore, no comparison between sizes was possible.

4.1.4 Age of Dolly Varden in Small Lakes

We aged a total of 125 Dolly Varden captured between 2002 – 2004 (**Figures 9 - 11**). In 2002, Dolly Varden age ranged from 2 - 5 years, with the greatest percentage of fish 3+ years old (**Figure 9**). In 2003, ages ranged from 3 – 7 years, with the greatest percentage of fish aged 5+ (**Figure 10**). In 2004, the greatest percentage of fish was again 3+ years, with fish between 2 – 6 years captured (**Figure 11**).

Figure 9. Percent of Dolly Varden of different ages captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2002 (N=34).

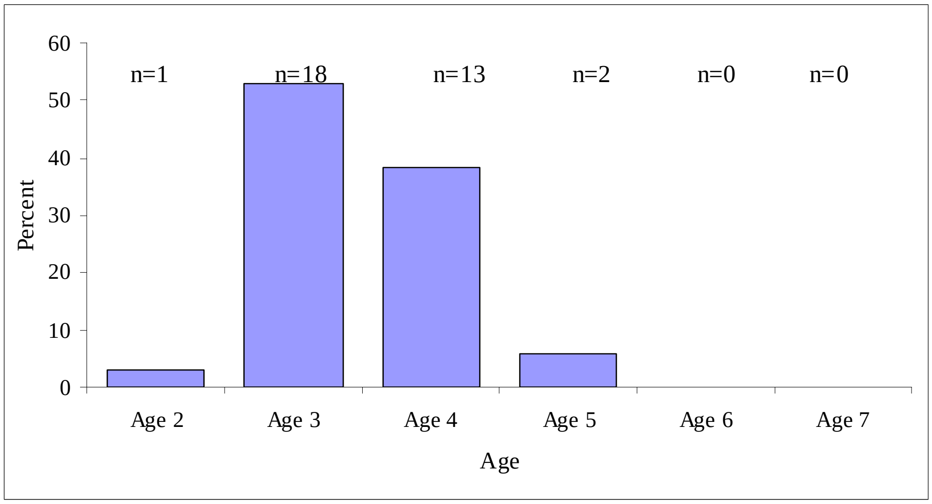


Figure 10. Percent of Dolly Varden of different ages captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2003 (N=29).

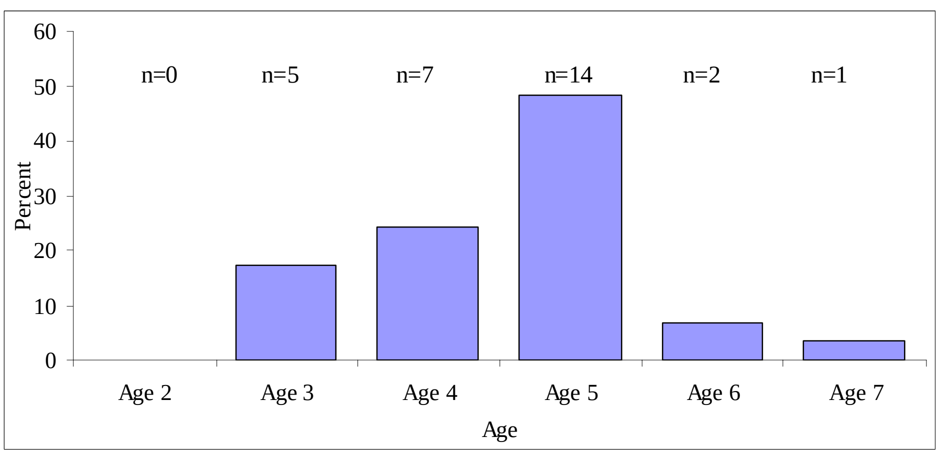
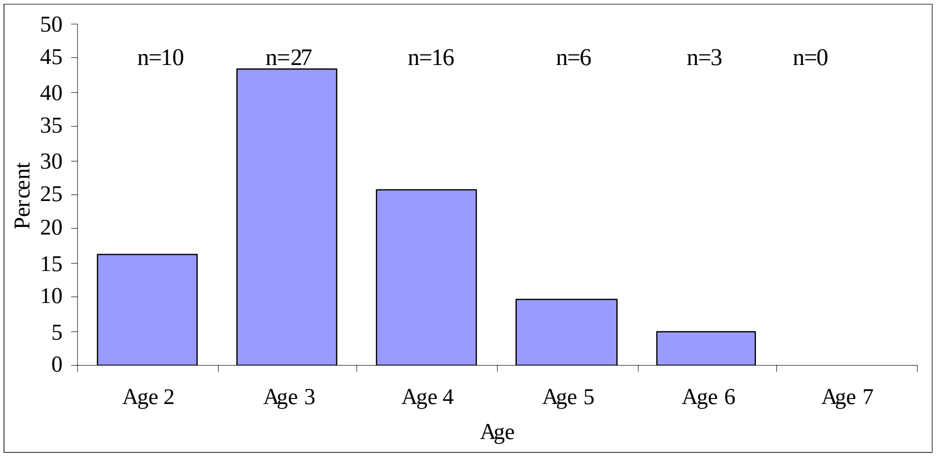


Figure 11. Percent of Dolly Varden of different ages captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2004 (N=62).



I present the average and range of fork lengths of each age category of Dolly Varden captured between 2002 – 2004 in **Figures 12 - 14**. In general, the average size of 2+ and 3+ fish ranged from 13 cm – 26 cm, while the average size of 5+ and 6+ fish ranged from 27 cm – 33 cm. In 2002, the maximum size of 3+ fish was 33 cm and in 2004, the maximum was 25 cm. In 2002, the maximum size of a 5+ fish was 38 cm, and in 2004 it was 36 cm.

Figure 12. Age-length relationship of Dolly Varden captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2002 (N=34).

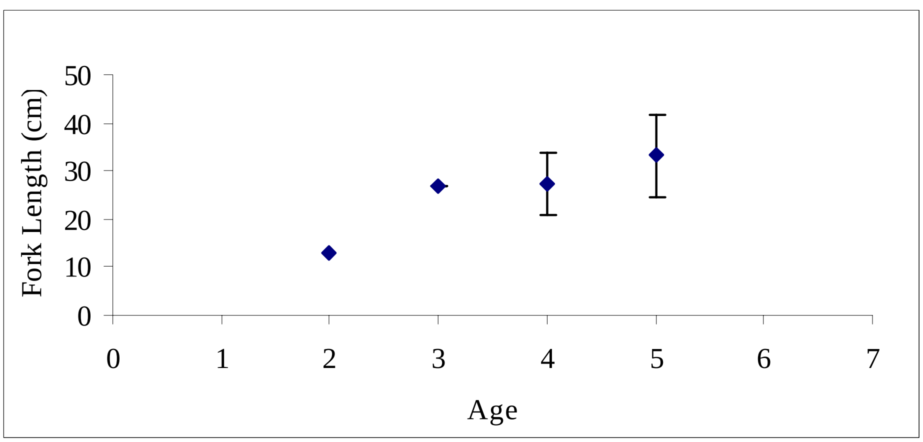


Figure 13. Age-length relationship of Dolly Varden captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2003 (N=29).

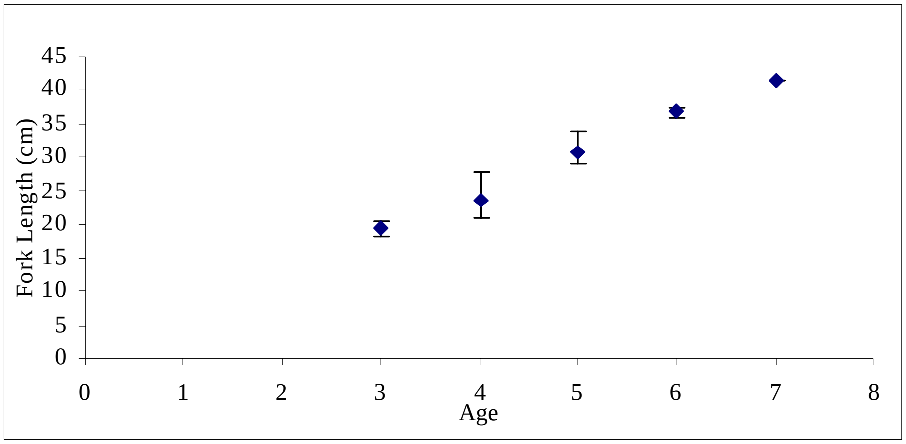
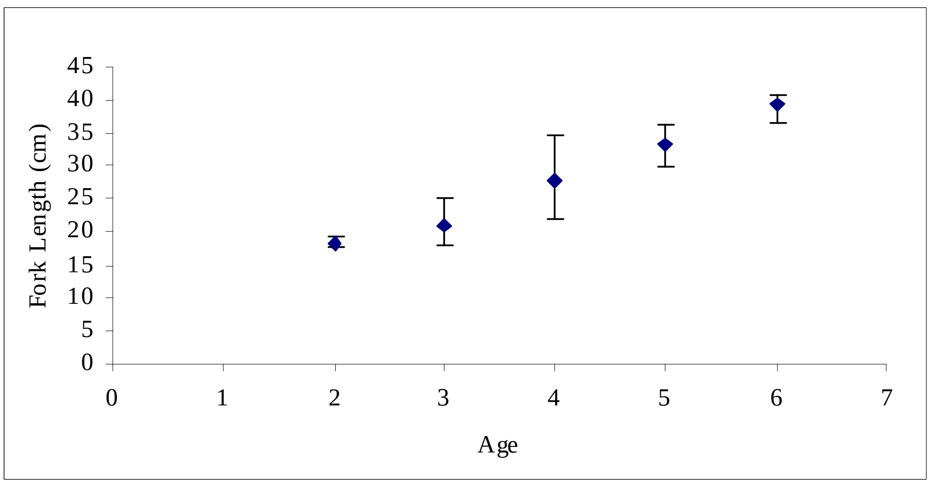


Figure 14. Age-length relationship of Dolly Varden captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2004 (N=62).



4.1.5 Maturation of Dolly Varden

We aged 39 Dolly Varden in 2002 and found 52% mature at age 3 while in 2004, only 17% were mature at that age (**Figure 15**). In 2002, over 50% of our catch were age 2 and almost 40% were age 3, while in 2003, almost 50% of our catch was age 5 (**Table 4**). In 2004, the greatest abundances of fish were age 2 and 3. We captured no age 7 fish in 2002 or 2004.

Figure 15. Length and age of mature Dolly Varden captured in Beavertail, Brewster, Fry, Gray and Mirror lakes, 2002 - 2004 (N=71).

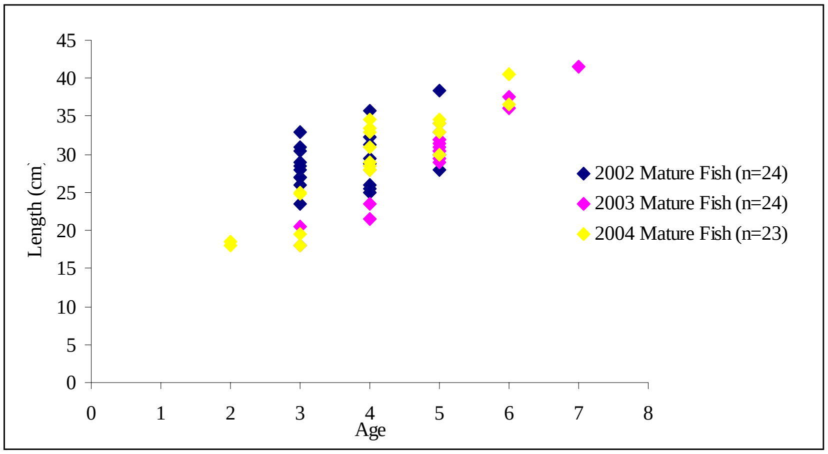


Table 4. Percent of each age class of Dolly Varden captured in sinking gillnets in Beavertail, Brewster, Fry, Gray and Mirror lakes, 2002 – 2004 (N=125).

	Percent		
	2002	**2003**	**2004**
Age 2	3	0	16
Age 3	53	17	44
Age 4	38	24	26
Age 5	6	48	10
Age 6	0	7	5
Age 7	0	3	0

We sexed 20 fish in 2002 and 2003, and found approximately equal proportions of males to females (**Figure 16**; **Figure 17**). In 2002, mature females ranged from 20 cm – 38 cm, and males from 24 cm – 34 cm (**Figure 16**). In 2004, over 60% of the fish captured were females ranging between 18 cm – 37 cm, while males ranged between 18 cm – 44 cm (**Figure 18**).

Figure 16. Length frequency distribution of sexually mature Dolly Varden captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2002 (N=20).

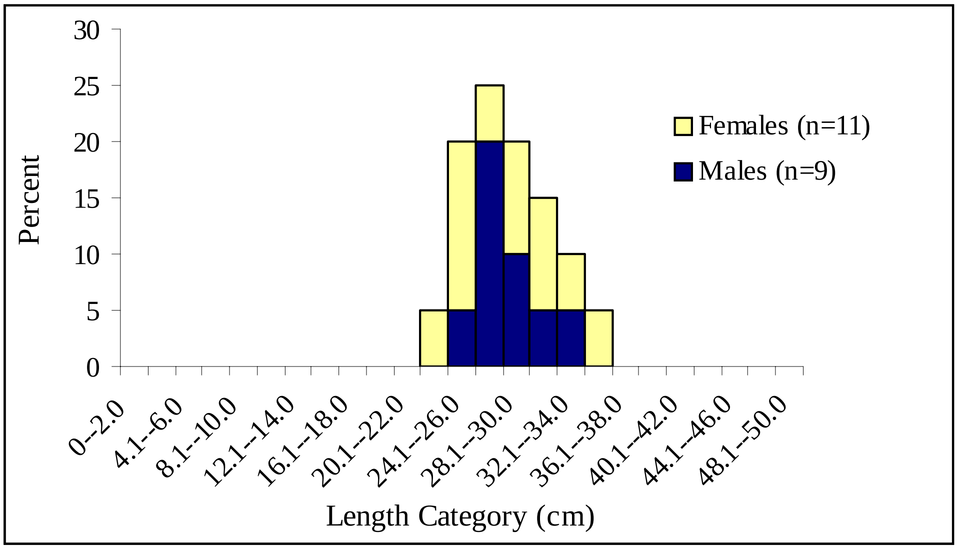


Figure 17. Length frequency distribution of sexually mature Dolly Varden captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2003 (N=30).

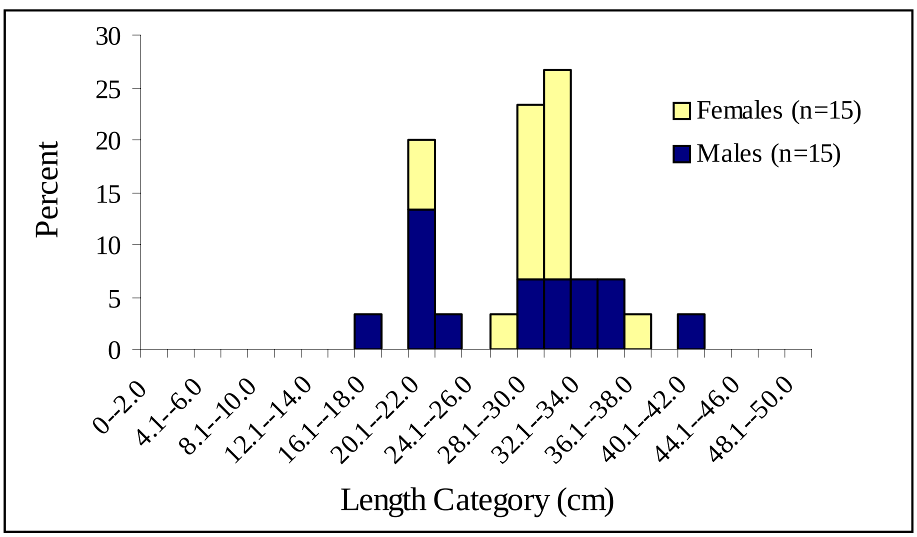
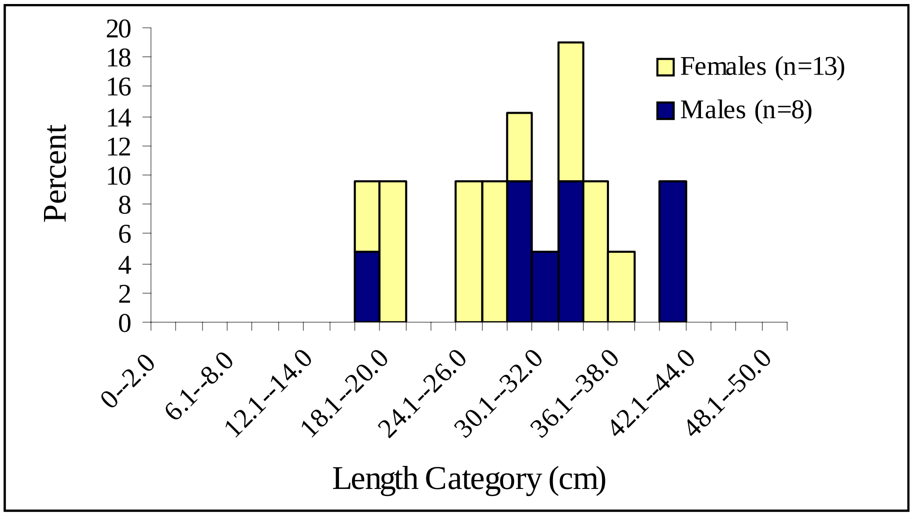


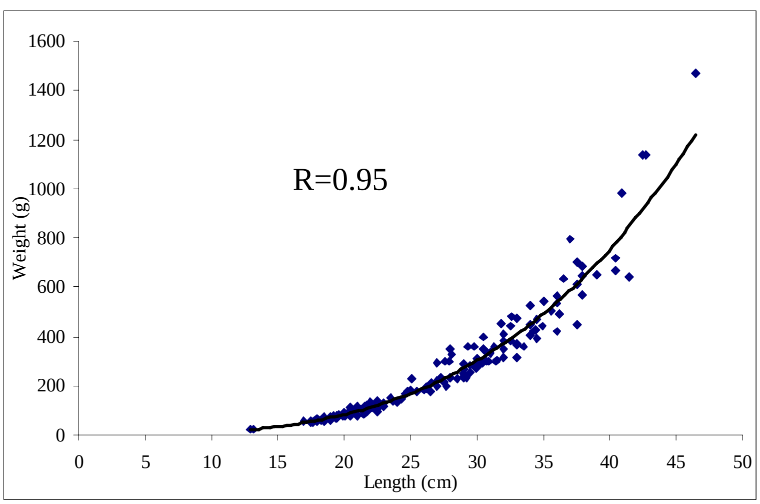
Figure 18. Length frequency distribution of sexually mature Dolly Varden captured in Beavertail, Boot, Brewster, Fry, Gray, Little Echo and Mirror lakes, 2004 (N=21).



4.1.6 Dolly Varden Growth in Small Lakes

I calculated the length:weight relationship for 167 Dolly Varden captured in gillnets between 1987 and 2004 (**Figure 19**). We sampled fish between age 2 - 7, ranging from approximately 13 cm and 20 grams to 45 cm and 1500 grams. Most fish captured were age 4 - 5, and ranged from 20 cm and 85 grams to 40 cm and 650 grams.

Figure 19. Length-weight relationship of Dolly Varden captured in sinking gillnets in Brewster, Beavertail, Fry, Gray and Mirror lakes, 1987 - 2004 (N=167).

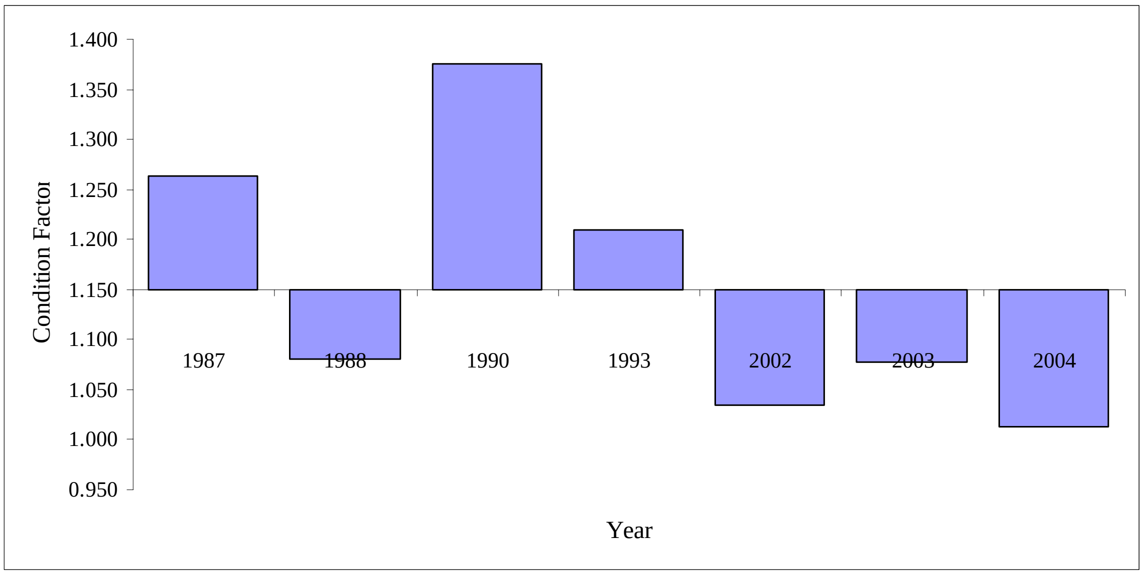


The condition factor (K) for Dolly Varden sampled 1987 - 2004 ranged from 0.8 – 1.58 (**Table 5**). Since 2002, the condition of Dolly Varden has declined below the grand average of 1.1 for the 30-year sampling period (**Figure 20**).

Table 5. Average, median, minimum, maximum and range of K averages for Dolly Varden captured in sinking gillnets in Brewster, Beavertail, Fry, Gray and Mirror lakes, 1987 - 2004 (N=167).

	1987	1988	1990	1993	2002	2003	2004	Total
Number of Fish	14	13	10	8	13	46	63	167
Average	1.263	1.080	1.376	1.209	1.035	1.077	1.013	1.150
Median	1.341	1.056	1.428	1.225	1.012	1.065	1.002	1.054444
Minimum	1.017	1.007	1.072	1.050	0.940	0.848	0.828	0.828
Maximum	1.473	1.178	1.570	1.329	1.210	1.578	1.375	1.578
Range	0.457	0.171	0.498	0.279	0.270	0.729	0.547	0.74943

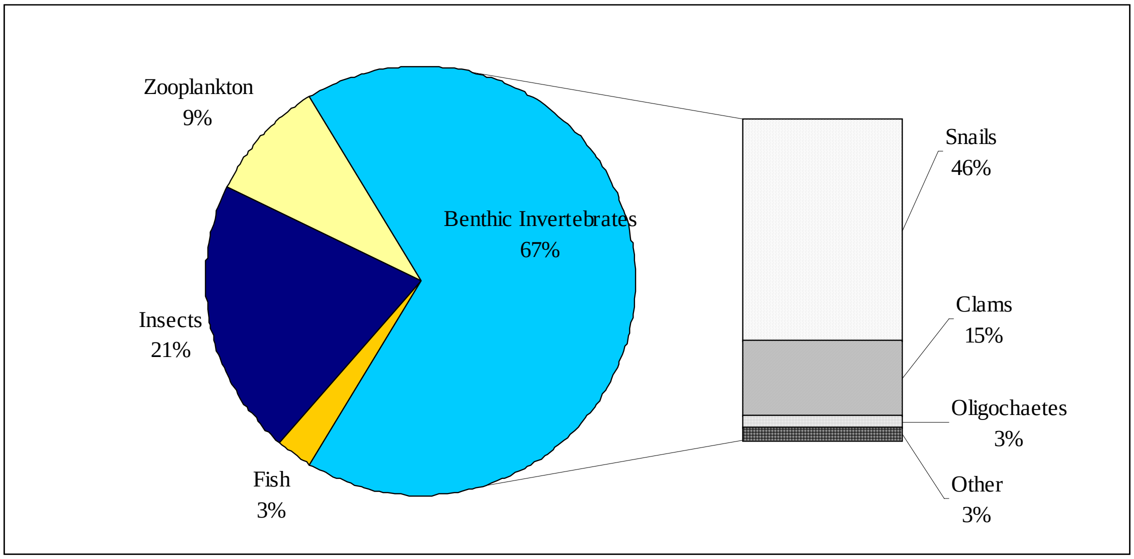
Figure 20. K averages by year compared to overall average for Dolly Varden captured in gillnets in Brewster, Beavertail, Fry, Gray and Mirror lakes, 1987 - 2004 (N=167).



4.1.7 Prey of Dolly Varden in Small Lakes

We analyzed the stomach contents of Dolly Varden captured in gillnets between 2002 - 2004 and found that almost 70% contained benthic invertebrates (**Figure 21**). Of that total, snails comprised almost 50% of the contents, while clams accounted for a further 15%.

Figure 21. Stomach contents of Dolly Varden captured in sinking gillnets in Brewster, Beavertail, Fry, Gray and Mirror lakes, 1978 - 2004 (N=110).



4.1.8 Dolly Varden Spawning Timing and Temperatures

We observed over 80% of adult Dolly Varden at Strathcona dam when the water temperature dropped from 16^{0}C – 8^{0}C (**Figure 22**). We also observed approximately 90% of the total number of redds at this location between September – November when the temperature was between 11^{0}C – 8^{0}C (**Figure 23**).

Figure 22. Cumulative percent of adult Dolly Varden and average monthly water temperature observed in monthly snorkel surveys May – December below Strathcona Dam, 1998 – 2004 (N=392).

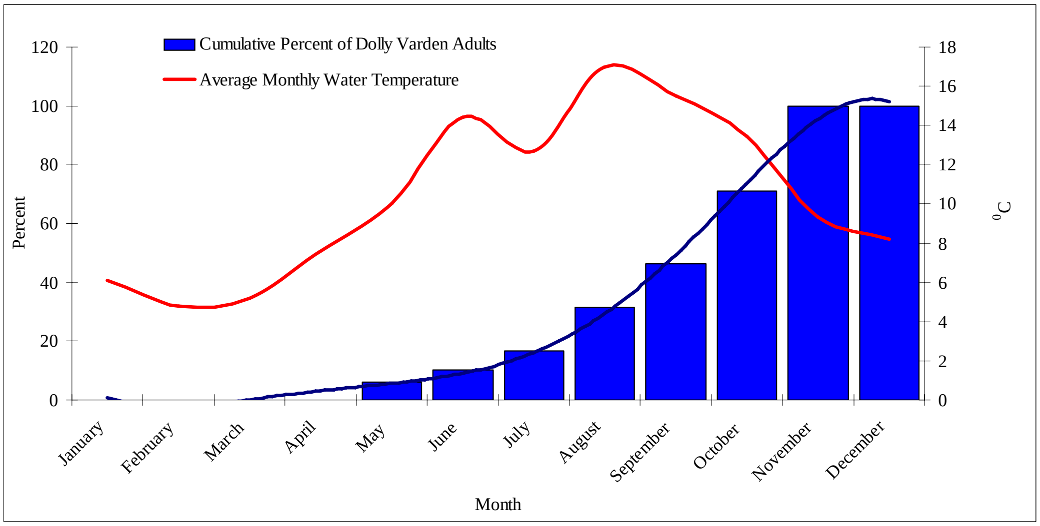
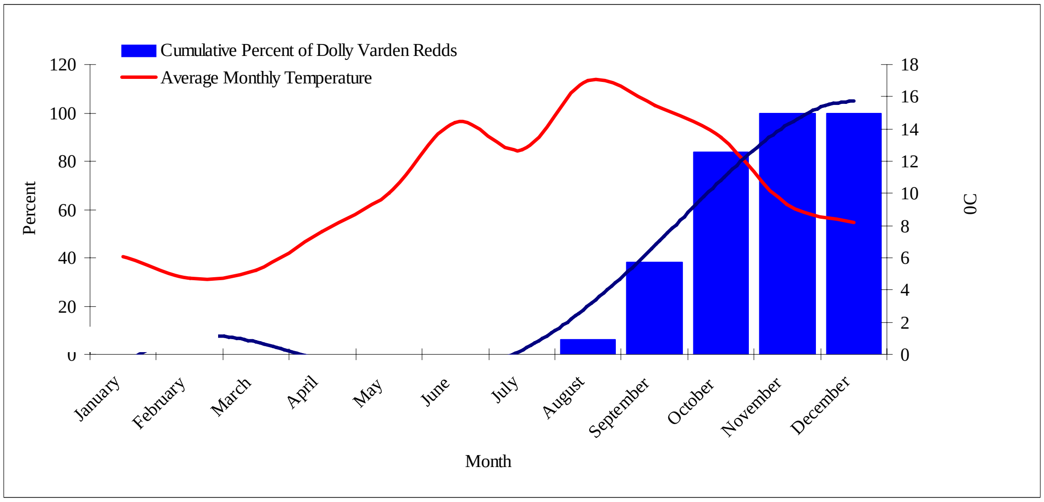


Figure 23. Average monthly water temperature versus cumulative percent of Dolly Varden redds observed in monthly snorkel surveys, August - December at Strathcona Dam, 1998 – 2004 (N=50).



We observed only two adult Dolly Varden in Fry Creek during the fall, however we did count redds during this period (**Figure 24**). We found over 90% of the redds between October – November when the temperature was approximately 13^{0}C. Because kokanee also use this reach, we excavated a small number of redds and examined the eggs to confirm they were from Dolly Varden. Reach 7, between Brewster and Gray lakes, contained 60% of the redds we observed (**Figure 25**).

Figure 24. Cumulative percent Dolly Varden redds (N=96) observed in Fry Creek by month versus average water temperature, 1998-2004.

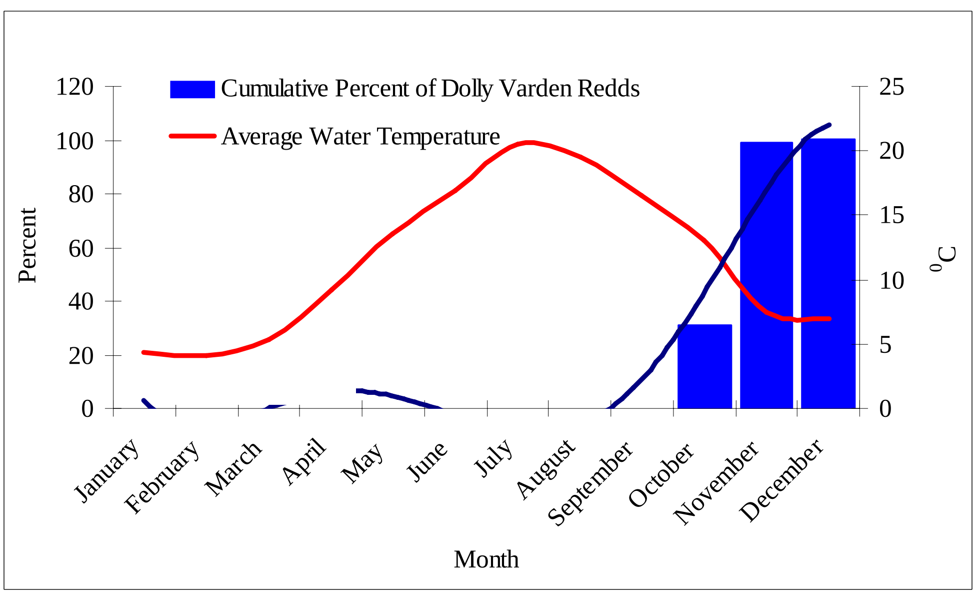
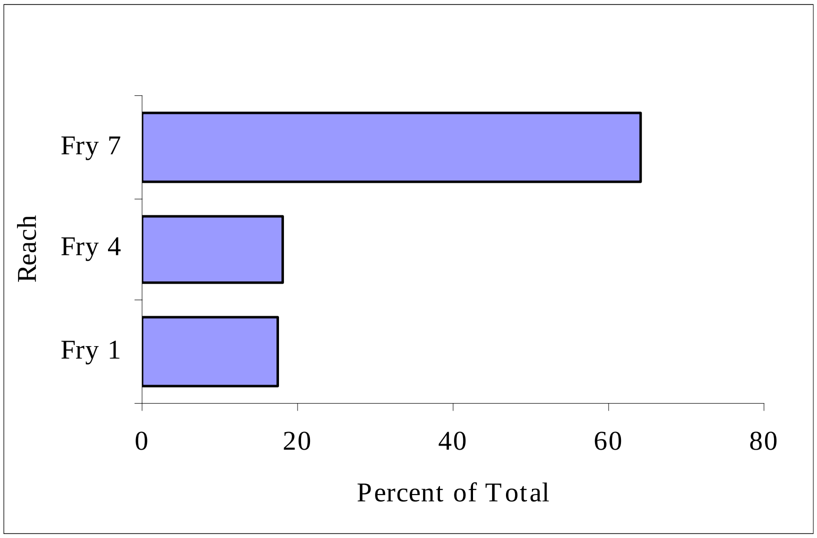


Figure 25. Percent of redds found in each reach of Fry Creek between October - December, 1998 - 2004 (N=193).

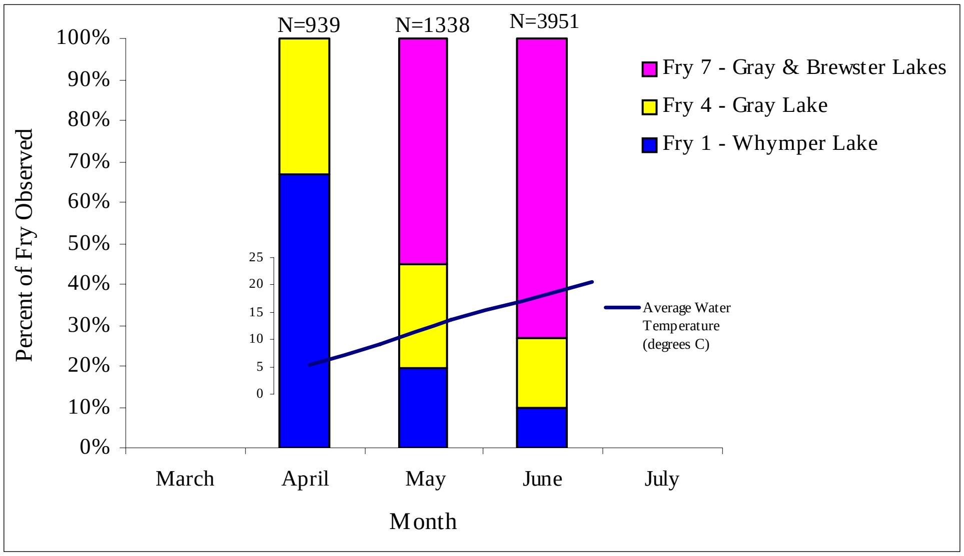


4.1.9 Dolly Varden Fry Emergence in Fry Creek

We began to find Dolly Varden fry in Fry Creek in the beginning of May in 2002 and 2003, approximately 200 days or 1,500 accumulated temperature units after we first observed Dolly Varden redds in the same locations. We confirmed these were char by capturing several fish and counting their fin rays. When the fry were large enough, we compared their morphological features to published descriptions to confirm they were Dolly Varden.

We observed Dolly Varden fry in Reaches 1 – 7 of Fry Creek between April - June when average stream temperatures were between 5^0C – 16^0C (**Figure 26**). We found fry in Reach 1, furthest downstream, early in the spring and in Reach7, the upstream reach, later in the spring.

Figure 26. Percent of Dolly Varden fry observed in each reach of Fry Creek, March - July, compared to average stream temperature, 2003 - 2004 (N = 6228).



We measured the length of Dolly Varden fry in both 2003 and 2004, and found the majority of fish between 24 mm - 30 mm both years (**Figure 27**; **Figure 28**). In 2003, all fish were buttoned-up at 27 mm, however in 2004, some fry still had yolk sacs at 30 mm.

Figure 27. Length frequency distribution of Dolly Varden fry captured in Fry Creek, May 2003, (N=124).

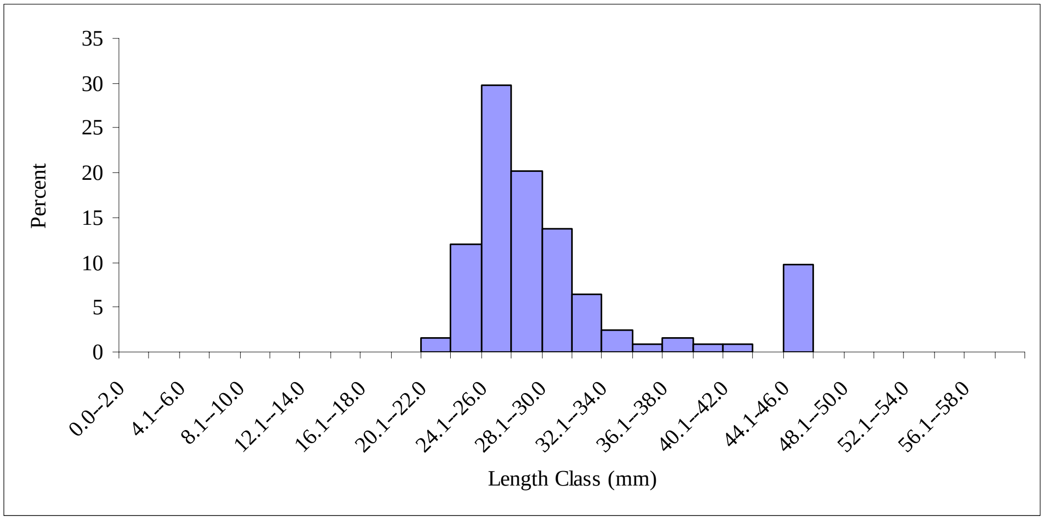
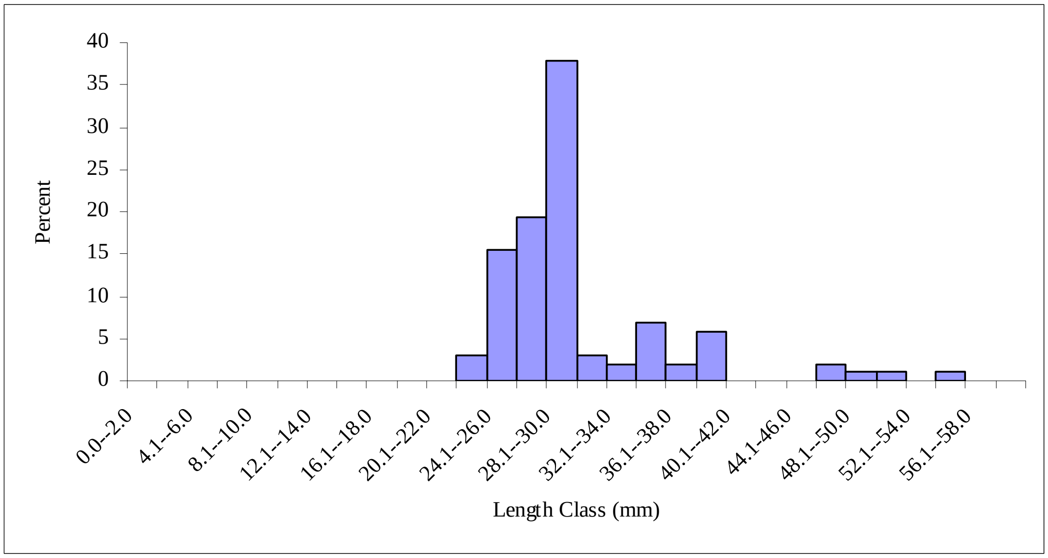


Figure 28. Length frequency of Dolly Varden fry captured in Fry Creek, May 2004, (N=103).



In 2003, fry ranged from 22 mm - 46 mm on May 12, and 44 mm – 46 mm on May 28 (**Figure 29**; **Figure 30**). In 2004, we began finding fry at 24 mm and, as the sampling period progressed, we found fry up to approximately 50 mm (**Figures 31 - 33**). In both 2003 and 2004, the temperature on sampling dates remained relatively constant at around 16^0C.

Figure 29. Length frequency distribution of Dolly Varden fry captured in Fry Creek, May 12, 2003 (N=114).

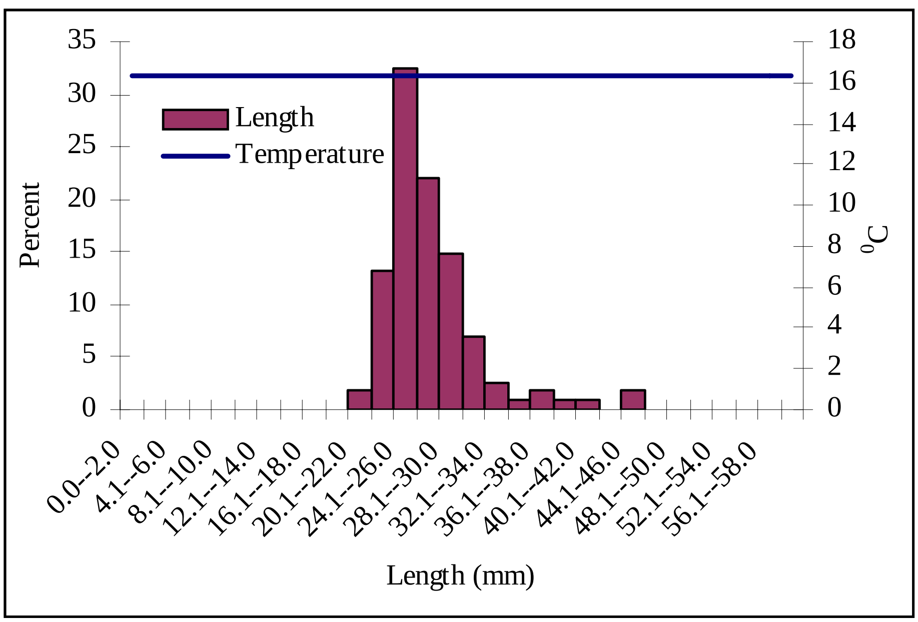


Figure 30. Length frequency distribution of Dolly Varden fry captured in Fry Creek, May 28, 2003 (N=10).

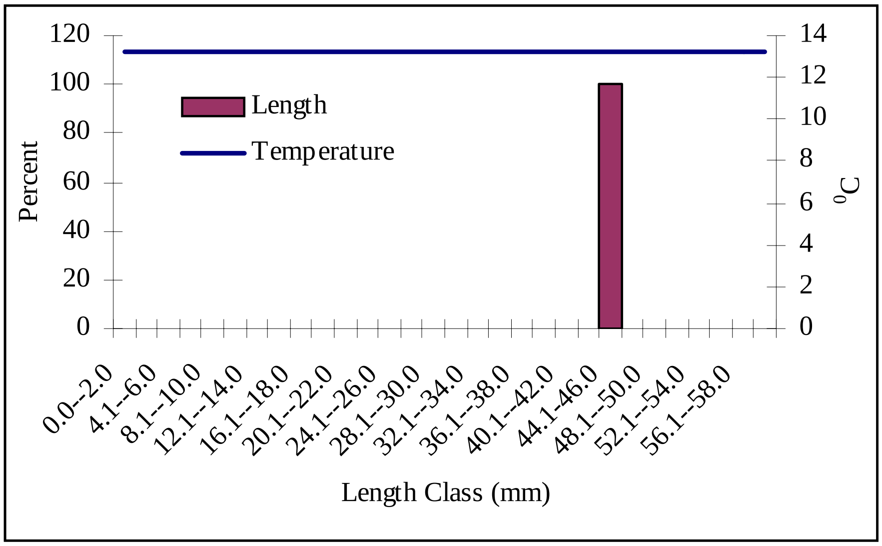


Figure 31. Length frequency of Dolly Varden fry captured in Fry Creek, May 15, 2004 (N=37).

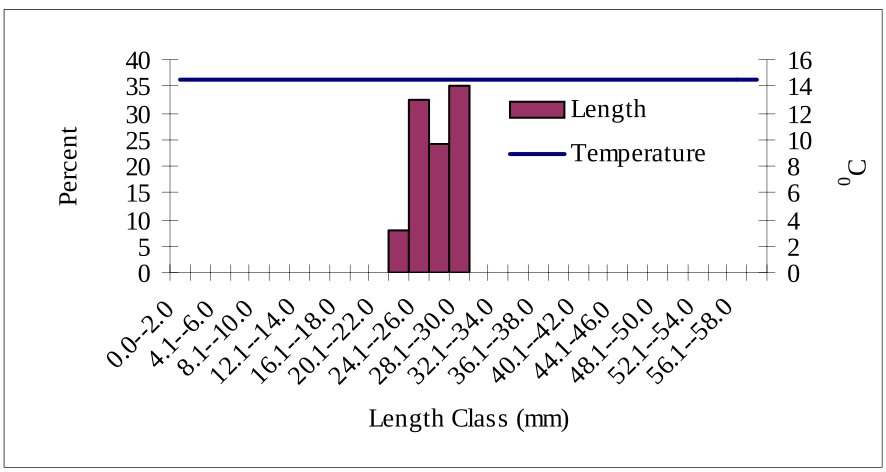


Figure 32. Length frequency of Dolly Varden fry captured in Fry Creek, May 22, 2004 (N=35).

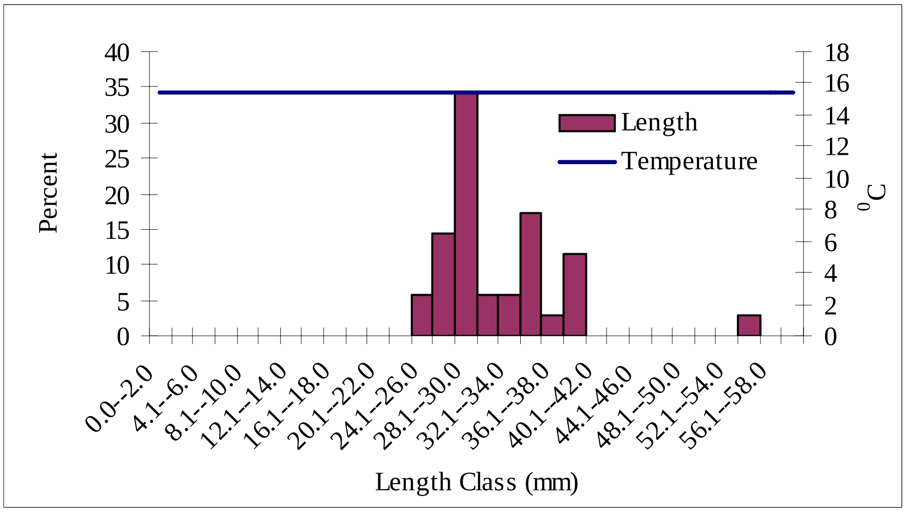
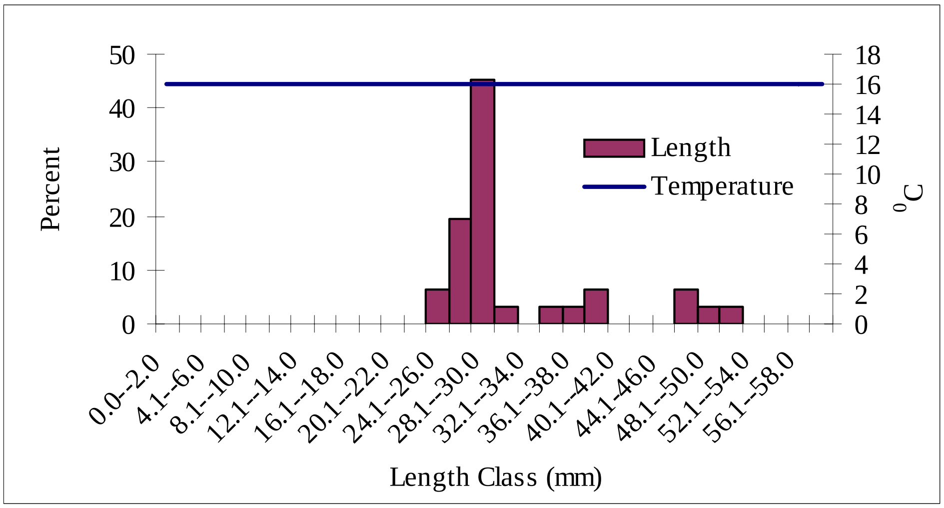


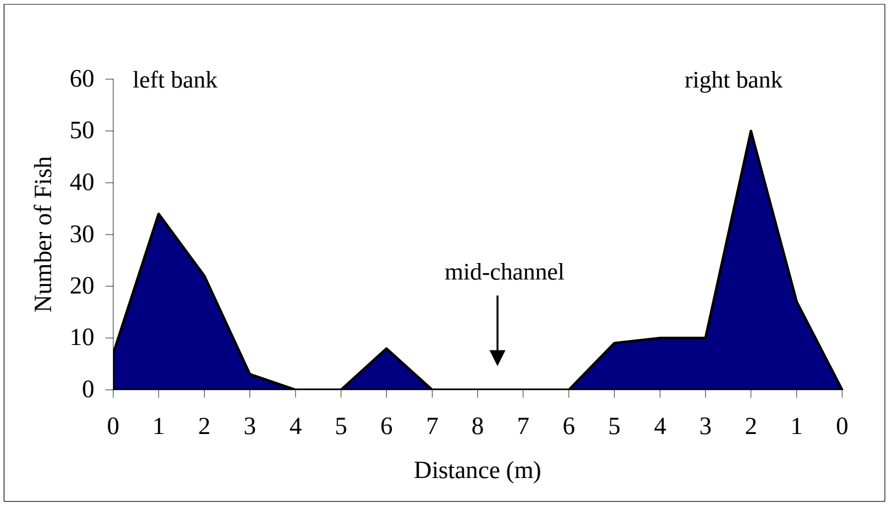
Figure 33. Length frequency of Dolly Varden fry captured in Fry Creek, May 26, 2004 (N=31).



4.1.10 Dolly Varden Fry Habitat Preferences in Fry Creek

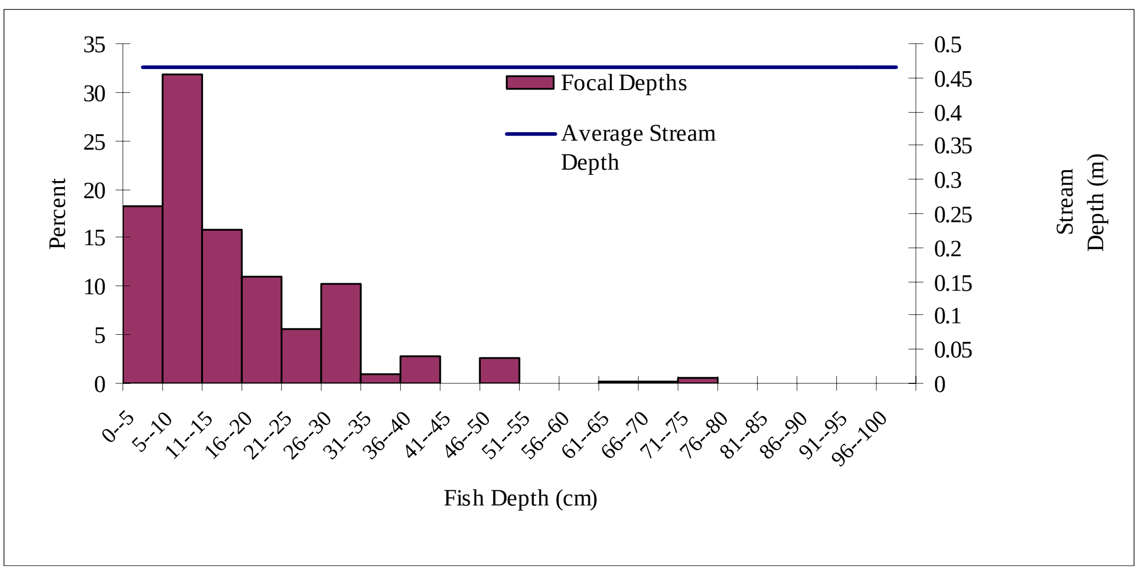
We examined the distribution of Dolly Varden fry across transects of Fry Creek and found that almost 85% were concentrated within 4 m – 6 m of the bank (**Figure 34**).

Figure 34. Distribution of Dolly Varden fry across Reaches 1 and 4 of Fry Creek, 2003 (N=170).



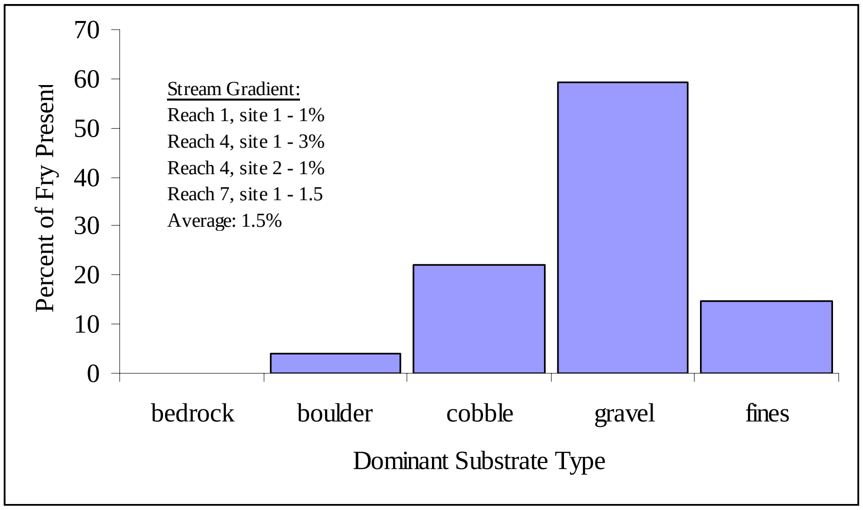
We also found almost 50% of Dolly Varden fry within 10 m of the stream bottom and over 60% concentrated within 15 cm of the bottom, even when the average stream depth was almost 0.5 m (**Figure 35**).

Figure 35. Frequency distributions of focal depths occupied by Dolly Varden fry compared to average stream depth in Fry Creek, May 12 and 13, 2003, and May 15, 22 and 26, 2004 (N=708).



We observed the highest percentage of Dolly Varden fry at sites where gravel was the dominant substrate, which was also in the area of redd concentration (**Figure 36**).

Figure 36. Percent of fry at sites with different dominant substrates in Reaches 1, 4 and 7 of Fry Creek, 2003 - 2004 (N=691).



We observed almost 70% of Dolly Varden fry within 0.5 m of cover, with most fish in close proximity to either bolder or cobble, or some form of vegetation (**Figure 37**; **Figure 38**).

Figure 37. Frequency distribution of the distance-to-cover of Dolly Varden fry observed in Reaches 1, 4 and 7 of Fry Creek, May 12 and 13, 2003 and May 15, 22 and 26, 2004 (N=689).

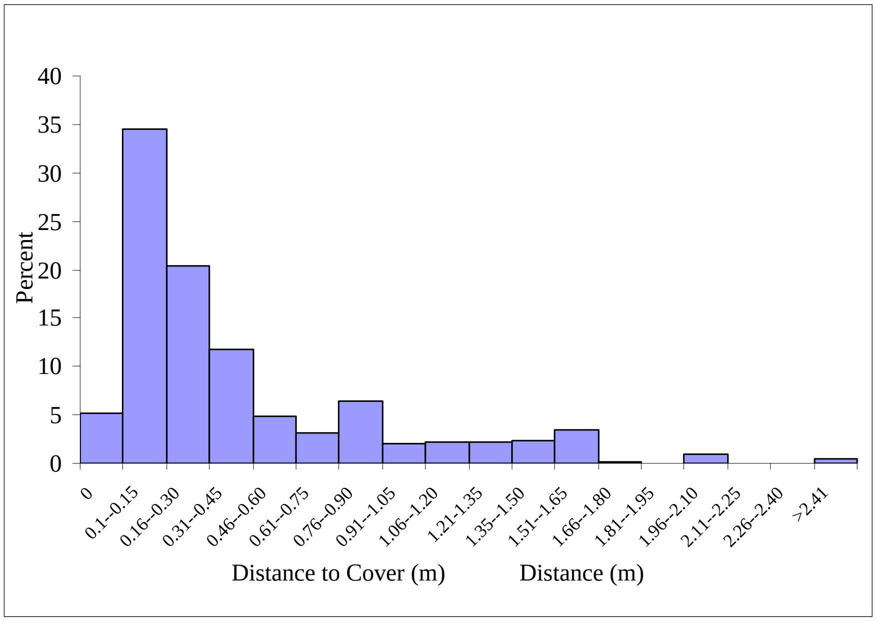
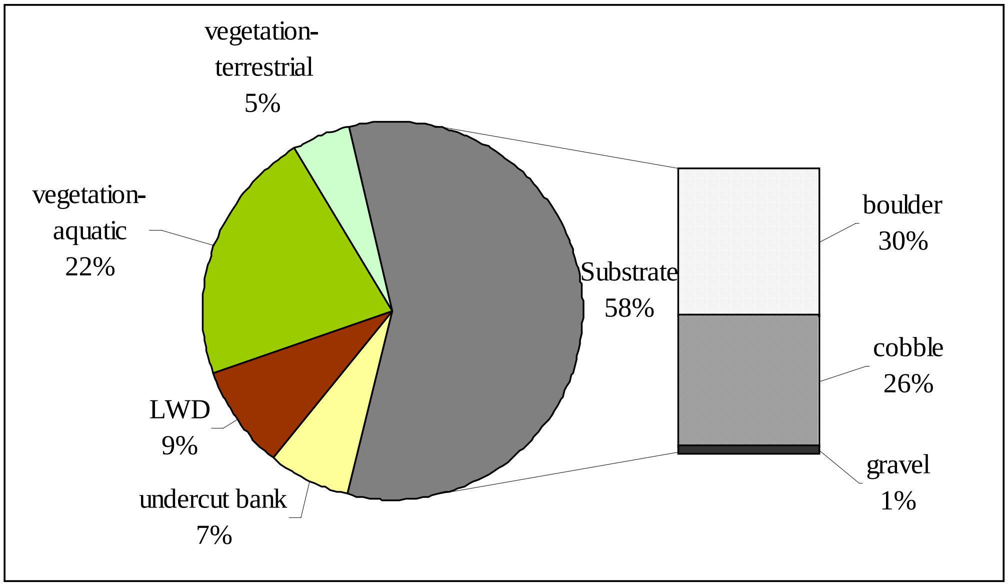
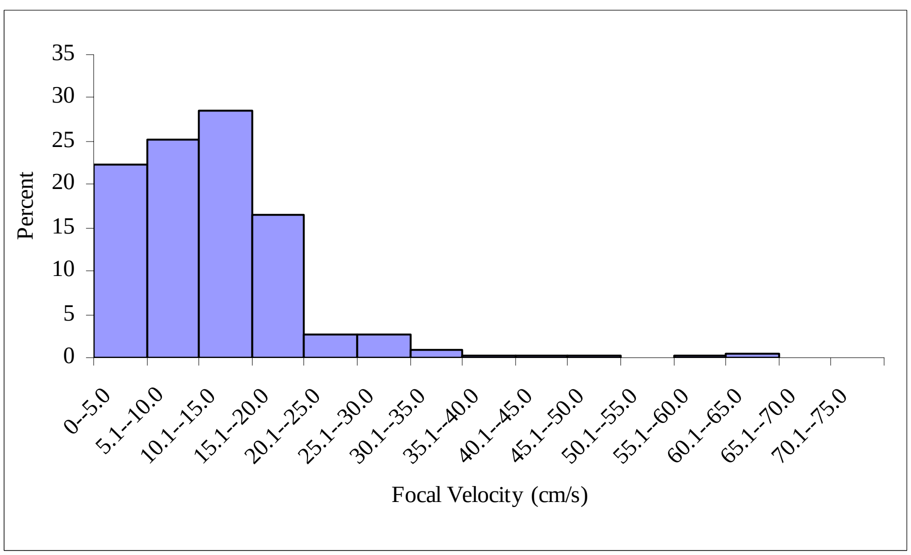


Figure 38. Percent of Dolly Varden fry observed at each cover type at Reaches 1, 4 and 7 of Fry Creek, May 12 and 13, 2003 and May 15, 22 and 26, 2004 (N=689).



We found over 75% of Dolly Varden fry at focal velocities <15 cm/s, and over 90% at focal velocities <20 cm/s (**Figure 39**).

Figure 39. Frequency distributions of Dolly Varden fry at various focal velocities in Reaches 1, 4 and 7 of Fry Creek on May 12 and 23, 2003 and May 15, 22 and 26 2004 (N=675).



I conducted a multiple regression analysis to determine which habitat parameter was the best predictor of Dolly Varden fry location, and found that distance-to-shore and distance-to-cover were strongly correlated. When I removed distance-to-shore from the model, I found that both focal velocity and focal depth had significant effects on the number of Dolly Varden found at specific locations (**Table 6**).

Table 6. Summary of fit, analysis of variance and effects of focal depth, distance-to-cover, and focal velocity on the number of Dolly Varden fry found at specific locations in Reaches 1, 4 and 7 of Fry Creek, May 12 and 23, 2003 and May 15, 22 and 26, 2004.

Summary of Fit - Whole Model				
R Square	0.066		Average of Responses	3.539
R Square - adjusted	0.0489		Observations	167
Analysis of Variance				
Source	DF	Sum of Squares	Average Square	F Ratio
Model	3	92.4843	30.828	3.8446
Error	163	1307.01	8.019	Prob>F 0.0108
C. Total	166	1399.5		
Effect Tests	DF	Sum of Squares	F Ratio	Prob>F
Focal Depth	1	39.007	4.865	0.029
Focal Velocity	1	69.566	8.68	0.0037
Distance-to-Cover	1	1.802	0.2247	0.636

5.0 Summary and Management Recommendations

5.1 Summary of Life History Characteristics of Dolly Varden in the Lower Campbell Lake Watershed

Dolly Varden in the Lower Campbell Lake watershed spawn from September to October on the descending thermocline when temperatures are between 8^0C - 16^0C (**Table 7**). Fry first begin to appear at 25 cm in length and maintain their yolk sac until they reach approximately 30 cm. They are distributed within 5 m of the stream bank and 15 cm above the stream bottom. The majority stay within 0.5 m of substrate and/or vegetative cover and where stream velocities are <20 cm/sec. When the fry reach 50 mm, they recruit to lakes where they live for up to 7 years. Dolly Varden begin to mature at age 3, but the majority mature at age 4. The minimum length the fish mature at is 20 cm and the maximum size reached is 45 cm - 50 cm.

Table 7. General life history characteristics and habitat preferences of Dolly Varden in the Lower Campbell Lake watershed.

Life History Stage	General Life History Characteristics and Preferences
Fry Incubation	September/October-April/May 550-877 ATUs
	Swim-up at 25 cm
	Button-up by 30 cm
Habitat Preferences	Within 5 m of stream bank
	Within 15 cm of stream bottom
	Close to redds in average 1.5% gradient and gravel substrate
	Within 0.5 m of substrate or vegetative cover
	Focal velocities 15 cm/sec - 20 cm/sec
Movement	Recruit to lakes at 50 mm
	Lake resident in bottom or low velocity areas
Adults Maturation	Between 3 - 4 years; minimum length 20 cm
Prey Preferences	Benthic Invertebrates
Life Span	6 - 7 years
Maximum Size	45 cm - 50 cm
Spawning	8^0 C - 16^0C; gravel substrate; 1 - 3% gradient

5.2 Stock Status and Management Recommendations

5.2.1 Regulations

Overall, Dolly Varden populations have declined in the last 25 - 30 years. Only in Brewster and Fry lakes do populations appear stable, although there is some concern here also. In these and all other lakes, the modal and mean lengths of Dolly Varden have declined, and there has been a decline in fish over 45 cm since 1990 (**Table 2**; **Table 3**).

While there is some indication this trend has started to reverse (**Table 2**; **Figure 17 - 19**) which may be the result of the catch-and-release regulation implemented in 2000, it does not appear this restriction has been in place long enough to allow stocks to stabilize and recover from declines suspected after 1980 (Michalski, 2006). As a result, **I recommend the Ministry:**

1. **Maintain the catch-and-release regulation.**

Lough's (2002) work on Dolly Varden in the Campbell Lake watershed suggests that, in contrast to the situation in large streams with year-round flow, Dolly Varden spawning in small and intermittent streams begins following the first major freshet that allows flow to resume and spawners to migrate. We found Dolly Varden redds as early as September, however we identified the majority of redds beginning in October when temperatures were below13^{0}C (**Figure 24**; **Figure 25**). We also observed adult Dolly Varden moving into Strathcona dam as early as August however, when the temperature was approximately 16^{0}C, and Lough made similar observations in mid-September 2002 (Lough, 2002). In addition to the availability of water, Dolly Varden may move into Strathcona early to avoid high water temperatures in Lower Campbell Lake and given the availability of larger streams such as the Greenstone River, I believe this may be a possibility in these and similar streams. Therefore, **I recommend the Ministry:**

2. **Close all streams flowing into Lower Campbell lake August 1 – December 31 to protect migrating and spawning Dolly Varden, and**

3. **Implement a creel survey to determine the effectiveness of all regulations.**

Because of their proximity and the availability of baseline data, I recommend creel surveys be conducted on Brewster and Gray lakes. I also suggest these surveys be incorporated into the Campbell River BC Hydro Water Use Planning (WUP) program to be implemented in 2006/07 (Wightman, 2006, pers. com). The goal of the WUP program is to find a better balance between competing uses of water, such as fish and electrical power needs that are environmentally, socially and economically acceptable to British Columbians (BC Hydro, 2006). One of the objectives of the Campbell River WUP is to maximize the abundance and diversity of indigenous fish populations and, during WUP development, the Campbell River WUP Consultative Committee made a number of recommendations including designing and implementing monitoring plans, and conducting technical reviews of monitoring results five years after plan implementation. Creel surveys could be implemented inexpensively through a partnership between the Ministry of Environment and BC Hydro, particularly if point creels are employed, and the 5-year time frame would provide enough data to determine if Dolly Varden are responding to the regulations.

5.2.2 Stock Monitoring

I found the condition factor of Dolly Varden in the Lower Campbell Lake watershed has declined which may be the result of a decline in lake productivity (**Table 4**; **Figure 20**). In the late 1950s, Northcote and Larkin (1956) examined the productivity of provincial lakes and found systems on Vancouver Island were characterized by low TDS (<100), low-to-moderate numbers of plankton and bottom fauna, and poor fish values.

In addition to the decline in condition factor, the age at maturity of Dolly Varden has declined for both males and females (**Figure 15**; **Figure 21**). Dolly Varden are now maturing at a younger age and smaller size, which may impact the total population because the overall fecundity may be reduced. Again, I recommend this situation be monitored, as the catch-and-release regulation should increase spawning escapements of larger Dolly Varden which in turn should result in higher egg deposition. Therefore, **I recommend the Ministry:**

4. **Implement a bi-annual lake netting program at Beavertail, Brewster and Gray lakes to monitor changes in Dolly Varden age and growth.**

5.2.3 Watershed Restoration

Fry Creek is part of the Salmon River diversion operated by BC Hydro, and as a result is subject to extreme fluctuations in flow (Cooper, 20056). McPhail and Murray (1979) and Lough (2002) noted the importance of small streams with relatively stable flows for Dolly Varden spawning. Diversions from the Salmon River make up a very high proportion of the total inflow to the Campbell River system and, in some years, three-quarters of the annual flow of this river is diverted for power generation (BC Hydro, 2002). These diversions can result in significant and sometimes erratic flow oscillations, which I believe altered natural baseline limnological conditions resulting in a flow regime that does not mimic natural conditions. According to Bell (1973), the average velocity at which adult Dolly Varden can maintain prolonged swimming is 0.9 m/sec. In October 2004, Cooper measured velocities ranging from approximately 0.7 m/sec - 2 m/sec in margin habitats of Fry Creek which roughly correspond to the areas we observed redds (**Figure 40**). Cooper also noted his measurements equate to approximately one-fifth of the maximum flow BC Hydro is licensed to discharge, and that later in the month he measured a diversion flow of 14.6 m^3/s which occurred in upper Fry Creek within 14 hours of release (Cooper, 2006, pers. com).

In addition to high flows impacting migrating and spawning adults, a lack of flow has impacted incubating and rearing Dolly Varden. We began observing Dolly Varden fry in Fry Creek in mid-April when they were approximately 25 mm. When working in the Campbell Lake watershed, Lough (2002) found Dolly Varden emergence extended from mid-March to early-May, however, in other streams he found emergence extended as late as June 30. On several occasions, we noted flows low enough to dewater redds and margin habitats in periods prior to 100% emergence as estimated by the above-referenced studies (**Figure 40**).

Figure 40. Photograph of exposed spawning beds on right bank of Reach 4 of Fry Creek, April 2003.

The mechanics of emergence are similar in most salmonids and are considered complete when fry become neutrally buoyant (McPhail and Murphy, 1979; Dill, 1968). According to McPhail and Murphy (1979) however, Dolly Varden are somewhat different than other salmonids because of the long delay between emergence and filling the swim bladder, and these researchers speculate this delay could be an adaptation to allow fry time to grow strong enough to maintain a position in the current. I found velocity was the best predictor of where Dolly Varden fry can be expected in the stream (**Table 6**). Clearly, stable and low velocity stream margins are of critical importance to adult Dolly Varden, and stable flow conditions must be maintained for longer periods for Dolly Varden fry (**Figure 34**). Because of the critical importance of flow on all life history stages of Dolly Varden, and the impacts that increased discharge, dewatering and the extreme oscillations in flow resulting from hydro operations have on all life history stages of Dolly Varden, **I recommend the Ministry:**

5. **Develop a flow agreement with BC Hydro to maintain stream velocities at <3 m/s September 1 - March 31; and <0.5 m/s and 60% - 80% bankfull width April 1 – June 30 in Fry Creek.**

I have suggested target flows based on the results in this study and a limited amount of information from other sources. The first step in developing a flow agreement is for the Ministry and BC Hydro to develop a stage-discharge curve for the Salmon River/Fry Creek system to verify my recommendations, or identify alternate appropriate target flows for Dolly Varden. The development of a stage-discharge curve was the original objective in Cooper's (2005) study, however his work was discontinued due to a lack of resources. All background information and the equipment required to continue Cooper's work is in place, as are partnerships with Environment Canada and several branches of the Ministry of Environment, consequently this study requires limited resources to complete.

The second part of my recommended agreement focuses on ensuring adequate flow in times when the Salmon River/Fry Creek watershed is suffering from low flow regardless of BC Hydro operations. As part of the present study, I asked Eakins Hydrological Consulting to determine if there were opportunities for enhancing and/or constructing water storage facilities to provide 100%, 80% and 60% bankfull discharge to Fry Creek between April 1 - June 30. Basing estimations on a series of field measurements throughout the system, Eakins concluded that 60% of bankfull discharge could be provided to all reaches of Fry Creek between April – June by increasing storage on Brewster, Gray and/or Whymper lakes (Eakins Hydrological Consulting, 2005). In 2004, I requested funds from BC Hydro's Bridge Coastal Program to pursue water storage projects, however my proposal was denied because it was felt it would better fit within the objectives of the Campbell River WUP Monitoring Program. As a result, **I recommend the Ministry:**

6. **Request funding from the Campbell River Water Use Plan program to:**
   a) **develop a stage-discharge curve;**
   b) **develop a detailed flow agreement; and,**
   c) **plan and implement water storage options for the Salmon River/Fry Creek system.**

In addition to developing a flow agreement to protect margin habitats in Fry Creek, **I also recommend:**

7. **Adding boulder and cobble substrate at the margins of Fry Creek for juvenile and adult Dolly Varden.**

During our snorkel surveys, we noted sections of Fry Creek where outside banks and the stream bottom were scoured to sharp drop-offs and hardpan, and I speculate this has resulted from intensified flows caused by the operation of the Salmon River Diversion, particularly during high diversion flows. I also believe the removal of substrate in areas suitable for spawning has exacerbated a situation which was already naturally limiting given there are four lakes within the Fry Creek system, but less than 1,000 linear meters of stream habitat, only about half of which has suitable substrate or the appropriate gradient. In addition to addressing the loss of already naturally-low amounts of spawning habitat, adding spawning substrate will help offset competition from an increasing number of kokanee spawning in Reach 7 which, given the overlap in timing and consequently the likelihood of redd superimposition, may be impacting incubating Dolly Varden.

In addition to benefiting adults and incubating eggs, adding boulder/cobble substrate at the margins of Fry Creek will benefit rearing Dolly Varden fry. While we found that aquatic vegetation was an important cover type for this life history stage, we also found most fry close to boulder and cobble (**Figure 37**; **Figure 38**) and speculate that substrate is the preferred cover type for the species. Our results are supported by Dolloff and Reeves (1989), who also found that age 0+ Dolly Varden were typically observed on or near the bottom and over gravel which, together with rock and fine debris, comprised their total substrate use. If substrate is added to Fry Creek, it will be necessary to ensure it is not flushed out of the system and as such **I also recommend:**

8. **Anchoring Large Woody Debris (LWD) at stream margins to protect spawning platforms and other substrate.**

Although there are a number of log jams at lake inlets within the Fry Creek system, we observed virtually no LWD in the creek. Although not preferred over other cover, a number of researchers found that LWD comprises an important component of Dolly Varden habitat, and numbers and production of this species are reduced by its removal (Dolloff, 1983; Elliot, 1986; Cardinal, 1980). Elliot (1986) found reduced numbers of Dolly Varden and fish with reduced mean lengths susceptible to displacement by high flows following the removal of logging debris. Addressing the lack of LWD in Fry Creek should be a priority, given Elliot's findings, our overall results regarding change in fish size and the intensified flows caused by the Salmon River diversion.

In addition to being a diversion channel, Fry Creek is also a portage route used by canoeists and consequently, LWD may have been removed to facilitate movement through the channel and re-introducing it may not be supported. To allow the restoration of Fry Creek, while also accommodating industrial and recreational requirements, **I recommend the Ministry:**

9. **Investigate the feasibility of constructing side channels in the Fry Creek watershed to accommodate diversion flows and recreational use.**

Recent work by Morley et al. (2005) suggests that while constructed side channels are used extensively by coho, these areas are not important habitats for other species such as trout. We found the greatest abundance of juvenile Dolly Varden in gradients >1.5%, and in boulder/cobble/gravel substrate close to original redds. As a result, side channels constructed in or adjacent to the Fry Creek wetlands would not likely be preferred by Dolly Varden or trout, and therefore these areas could accommodate recreational and hydro requirements, leaving Fry creek to be restored and protected for fish.

In addition to implementing stream restoration projects to improve Dolly Varden recruitment, **I also recommend:**

10. **Improving food availability through nutrient-enrichment to lakes in the Fry Creek watershed.**

We only found Dolly Varden up to 50 mm, but did not observe any above that length or numbers of juvenile Dolly Varden in Fry Creek even in months with sufficient flow (**Figures 27 - 32**). Lough and Hay (2001) found an absence of Dolly Varden fry when he electrofished tributaries in this area and speculated that young-of-the-year move quickly to the lake after emergence. We began to catch Dolly Varden in our lake-set gillnets when fish were in their second year and at least 15 cm in length. By this time, Dolly Varden had already been feeding on benthic invertebrates and, to a lesser extent, insects and zooplankton. Researchers, including Morton (1982), and Schutz and Northcote (1972), found that Dolly Varden feed more successfully on benthic prey than do cutthroat, and that Dolly Varden only switch from benthic to surface feeding when bottom food is absent or relatively scarce. Given that we found both benthic and pelagic prey in the stomach contents of Dolly Varden (**Figure 22**), it may be that some fish were utilizing food from the bottom, midwater and surface zones, which could indicate that limited benthic food required a change in diet, habits, or a decline in the numbers of cutthroat trout which may limit Dolly Varden to deeper zones (Northcote, 2005; pers. com.).

BC Hydro recognizes that decreased aquatic productivity due to water depth, temperature, or water quality changes is responsible for fewer plant, invertebrate and fish resources at Strathcona Dam (BC Hydro, 2000). This dam is responsible for decreased productivity upstream in Upper Campbell Lake, but also as far downstream as Reach 1 of Fry Creek, where backwatered conditions were noted in our study and several times over the past decade (S. Rimmer, pers. com., 2005). While this may be limiting productivity within the lower portion of Reach 1 of Fry Creek, I believe even more significant decreases to watershed productivity are caused by the ongoing operation of the Salmon River Diversion.

Diversion operations cause increased flushing, leading to declines in lake and stream productivity because nutrients are flushed through the system too quickly to be taken-up by biological means. High flows increase sedimentation rates and excessive water level fluctuations which creates turbidity and habitat limitations, again preventing nutrient uptake and cycling, and by destabilizing the littoral zone which creates phosphate-sinks and low production habitat (Stockner and Ashley, 2003). Ultimately, these factors combine and lead to declining fish stocks and individual fish size (Stockner and Ashley, 2003). A number of researchers, including Stockner et al. (2000), Ashley et al. (1999), Ashley and Slaney (1997) and Scrivener and Brown (1993), found the addition of inorganic nutrients to oligotrophic lakes and streams stimulates aquatic insect growth, improves invertebrate food supply, and increases the growth and abundance of salmonids. Stockner's studies are particularly relevant given his work was performed on hydro-impacted systems and on trout-char-kokanee complexes such as those within the Fry Creek watershed. Not only did Stockner demonstrate the collapse of the production of these species at nutrient deficient systems, his work resulted in significant increases in productivity at these same systems. As a result, I believe there is considerable likelihood of the success of this approach in the Fry Creek watershed. The ministry has already completed some nutrient-enrichment studies in the Lower Campbell watershed in the mid-1990s, however data from this study was never fully analyzed. As such, I suggest the steps in a future nutrient-enrichment study include:

a) reviewing the nutrient-enrichment work completed in the Lower Campbell Lake watershed;
b) using the information from (a) to develop a protocol for nutrient-enrichment at lakes of varying morphology, limnology and fish composition;

c) determining the potential for productivity response to nutrient enrichment at Brewster, Whymper, Gray and Fry lakes;
d) implementing projects at one or more of the above noted lakes;
e) monitoring the response of Dolly Varden to determine project success and modifications if required; and
f) continuing nutrient enrichment until there has been a shift in average length of Dolly Varden to approximately 30 cm, which was the average length for each decade between 1970-1990 and is close to the historical age at maturity for the Campbell Lake system (McMynn and Larkin, 1953).

5.2.4 Long Term Recovery

The suggested nutrient addition project, or any of the aforementioned management and restoration projects should not be considered or implemented in isolation and, for that reason, **I recommend the Ministry:**

11. Implement the Vancouver Island Blue-Listed Freshwater Sportfish Recovery Plan.

The Vancouver Island Blue-Listed Sportfish Recovery Plan provides long-term guidance to aid in the recovery of resident adfluvial freshwater stocks of Dolly Varden char and coastal cutthroat trout in the highest angler-use areas in the Vancouver Island Region (Reid and Michalski, 2006). It also outlines long-term strategies and projects to protect and restore both of these species at risk and their habitats. The plan was developed after a review of the preliminary results from Lower Campbell Lake studies showed that Dolly Varden stocks and fish size had declined and, as a result, the recommendations in the plan are based on current and historical stock status and fisheries data and information (Michalski, 2006).

The use of scientific and inventory information for developing standards and management, providing clear strategies and legislation to protect and restore species and their habitats, and the protection of species at risk have all been identified by the Ministry of Environment, the Environmental Stewardship Division, and the Fish and Wildlife Section as priorities (Benton, 2005; Wilkin, 2005; Hooton, 2005). Moreover, the protection and restoration of BC’s watersheds, species and ecosystem monitoring, and increased partnerships to conserve species and their habitats, have also been identified as Ministry, Division and Section priorities (Benton, 2005; Wilkin, 2005; Hooton, 2005). The recommendations in the Blue-Listed Plan include implementing conservative regulations, collecting habitat and fish stock data, developing habitat enhancement projects, monitoring stocks and habitats to determine project success, informing and educating the public about Blue-Listed species, and involving non-government groups in conservation and restoration efforts. Each of these recommendations are consistent with government priorities, and therefore implementation of the Blue-Listed Plan should be a regional, if not Ministry priority.

One of the recommendations in the Vancouver Island Blue-Listed Sportfish Recovery Plan is to implement public and angler awareness programs to increase the understanding and conservation of Dolly Varden. This recommendation was based on the experience of fisheries managers in a number of jurisdictions who implemented these projects and witnessed a turn-around in angler appreciation and conservation of the species. For example, in Alberta, after a long history of disregard and misunderstanding, there was a reverse in angler interest in char and increases in stock status following the implementation of public involvement projects, and some managers credit the stock increases to the combination of management actions and increased public awareness (Colpitts, 1993). Also in Alberta, angler-awareness projects implemented by non-government organizations such as Trout Unlimited Canada (TUC) were instrumental in raising awareness regarding char, and educating about all sport fishing resources and what anglers must do to conserve them (Blake, 1997). As a result, **I recommend the Ministry, in partnership with non-government organizations and angling clubs:**

12. **Implement angler and public awareness programs to build the appreciation and understanding of the stock status, biology, ecology and habitat requirements of Dolly Varden.**

Raising public awareness regarding specific fish species has been instrumental in those species receiving attention, not only with client groups, but also at the most senior levels of government and occasionally, as is the case with steelhead and sturgeon, across national boundaries. Bull trout is an example of a species that has captured the attention of the public and fisheries managers, but as Haas (2001) points out, while that species has become a very high profile species of concern, Dolly Varden receive little or no attention. Moreover, he notes that the long-standing confusion between bull trout and Dolly Varden due to their similarity should already indicate some equality in the potentially significant risks to Dolly Varden (Haas, 2001).

Dolly Varden have lower maximum water temperature preferences than bull trout and, given the appropriately critical importance attributed to the low temperature preferences of that species, Dolly Varden are at an even higher risk of temperature impacts (Haas, 2001). Haas points out that temperature increases are also one of the strongest and most regularly documented generalized watershed impacts of human land-use activities (Haas, 2001). Haas and McPhail (1991) note that in southwestern BC, Dolly Varden have a more restricted southerly distribution than bull trout, and many Dolly Varden populations are in strong decline, and largely from human impacts. Coincidentally the southwestern portion of the province, particularly the Georgia Basin which includes both the Lower Mainland and Vancouver Island, is one of the fastest growing regions in North America (Owen, 1994). With that growth will come increased land use and its associated impacts including temperature change.

In their paper outlining the provincial perspective on the status, management and protection of bull trout in BC, Pollard and Down (2001) note that while bull trout are considered to be a vulnerable species in BC, there has not been the need to create a provincial recovery team as has been the case in a variety of other jurisdictions where they are considered endangered. Given our findings regarding declines in numbers and size of Dolly Varden over the past three decades in the Lower Campbell Lake watershed, and Haas' (2001) findings and recommendation that Dolly Varden warrant considerably more and immediate attention than the minimal levels they have been receiving, I suggest that Dolly Varden is the provincial char of concern and, as such, **I recommend the Ministry:**

13. **Establish a provincial committee to determine the status and potential impacts to Dolly Varden in BC, and make recommendations regarding the need to develop a provincial Dolly Varden recovery and management plan.**

Summary of Management Recommendations for Dolly Varden

Management Category	Recommendation
Regulations	1. Maintain the catch-and-release regulation. 2. Close all streams flowing into Lower Campbell Lake August 1 – December 31 to protect migrating and spawning Dolly Varden.
Stock Monitoring	3. Implement a creel survey to determine the effectiveness of all regulations. 4. Implement a bi-annual lake netting program at Beavertail, Brewster and Gray lakes to monitor changes in Dolly Varden age and growth.
Watershed Restoration	5. Develop a flow agreement with BC Hydro to maintain stream velocities at <3 m/s September 1 - March 31; and <0.5 m/s and 60% - 80% bankfull width April 1 – June 30 in Fry Creek.
	6. Request funding from the Campbell River Water Use Plan program to: a. develop a stage-discharge curve; b. develop a detailed flow agreement; and, c. plan and implement water storage options for the Salmon River/Fry Creek system.
	7. Add boulder and cobble substrate at the margins of Fry Creek for juvenile and adult Dolly Varden.
	8. Anchor Large Woody Debris (LWD) at stream margins to protect spawning platforms and other substrate.
	9. Investigate the feasibility of constructing side channels in the Fry Creek watershed to accommodate diversion flows and recreational use. 10. Improve food availability through nutrient-enrichment to lakes in the Fry Creek watershed.

Management Category	Recommendation
Long Term Recovery	11. Implement the Vancouver Island Blue-Listed Freshwater Sportfish Recovery Plan. 12. Implement angler and public awareness programs to build the appreciation and understanding of the stock status, biology, ecology and habitat requirements of Dolly Varden. 13. Establish a provincial committee to determine the status and potential impacts to Dolly Varden in BC, and make recommendations regarding the need to develop a provincial Dolly Varden recovery and management plan.

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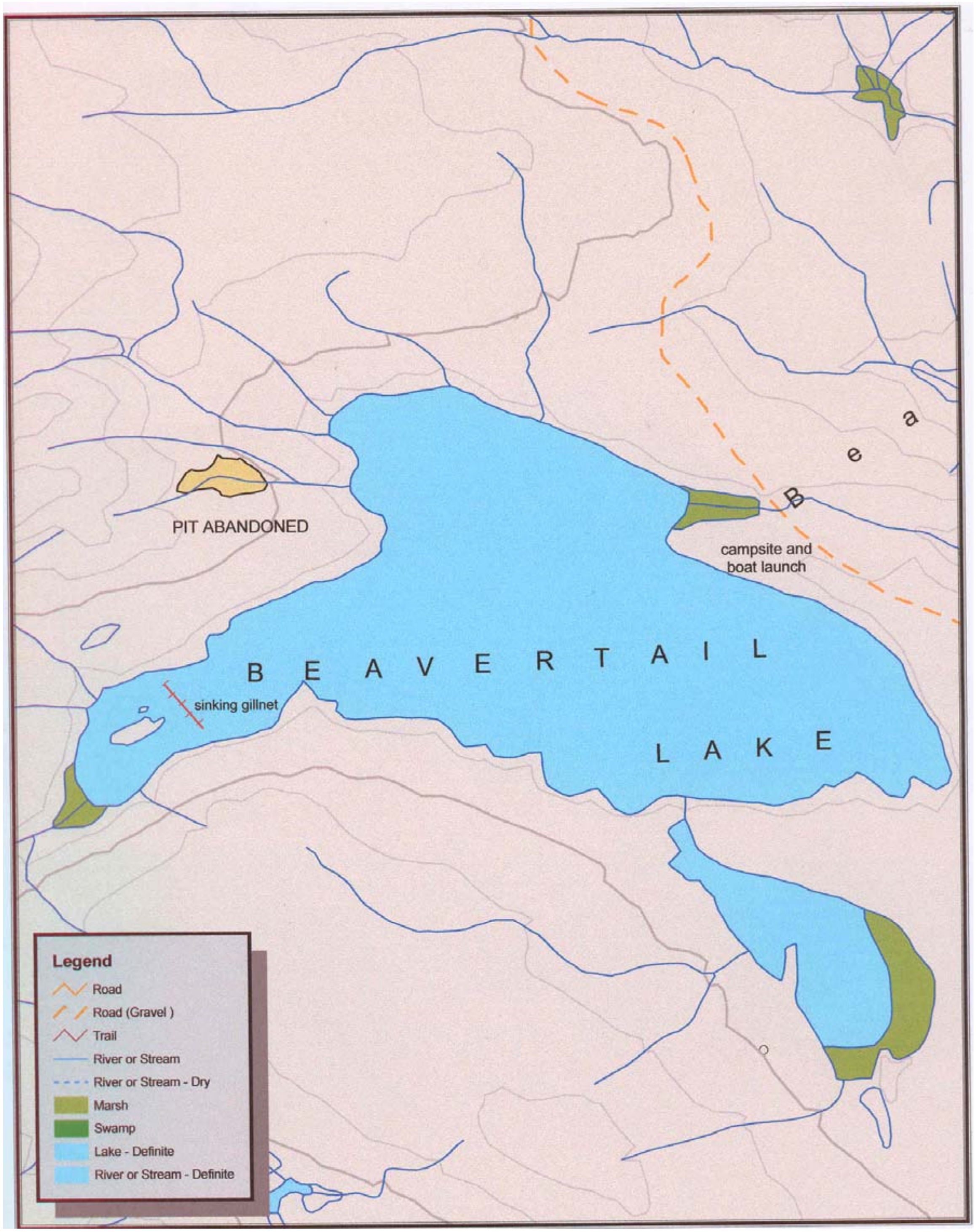
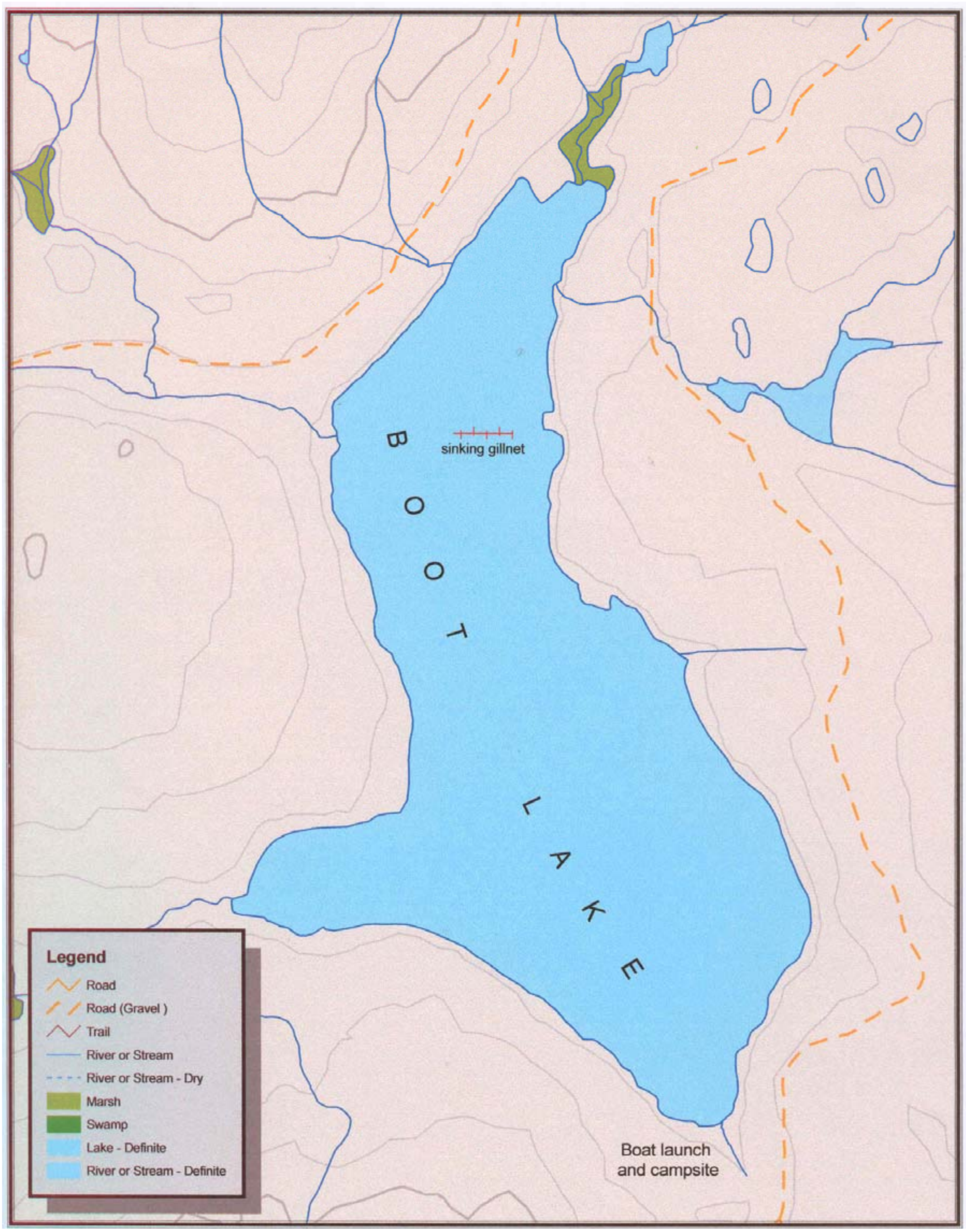
7.0 Appendices

Appendix 1. Beavertail Lake Gillnet Location

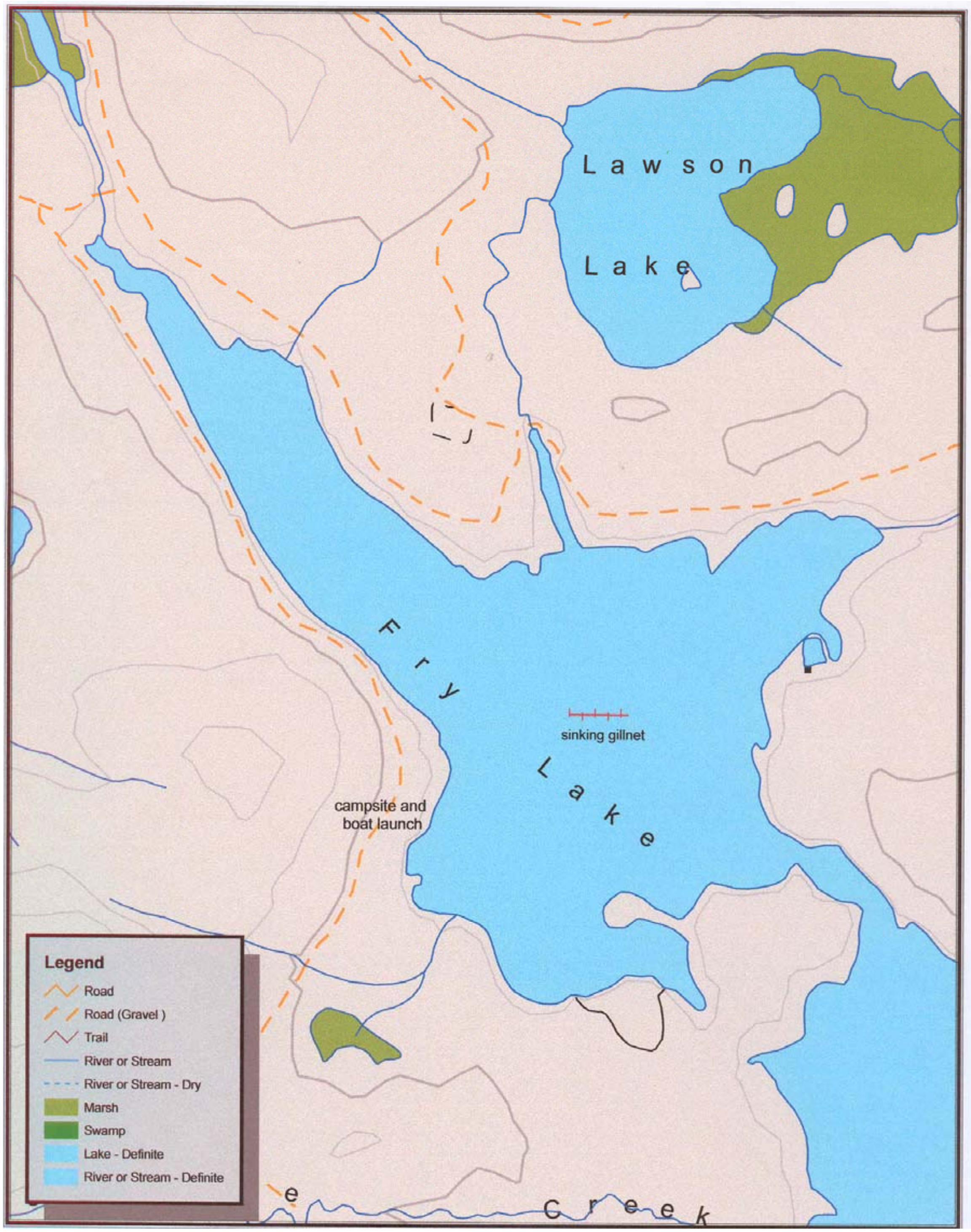


Appendix 1. Brewster Lake Gillnet Location

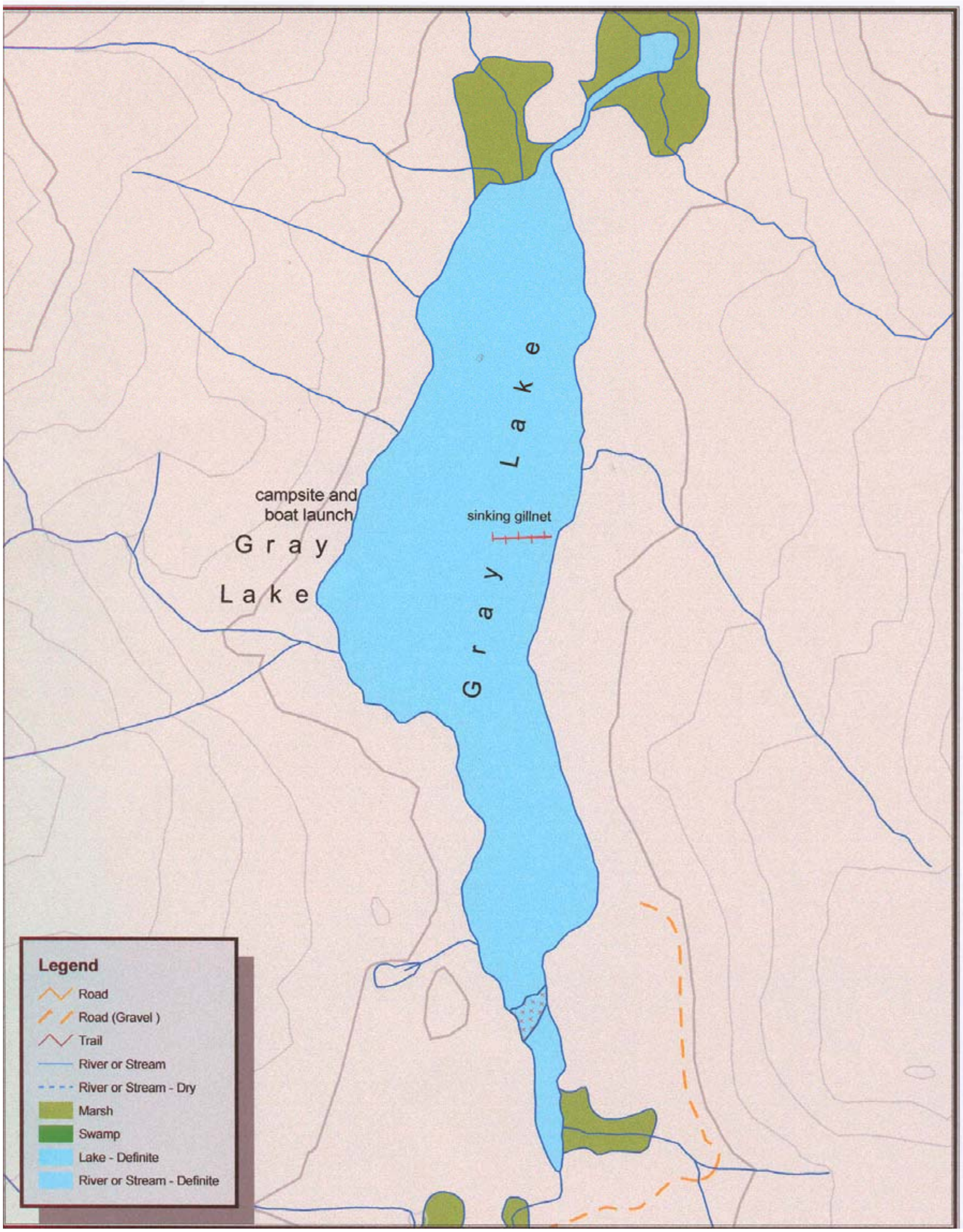
Appendix 1. Boot Lake Gillnet Location



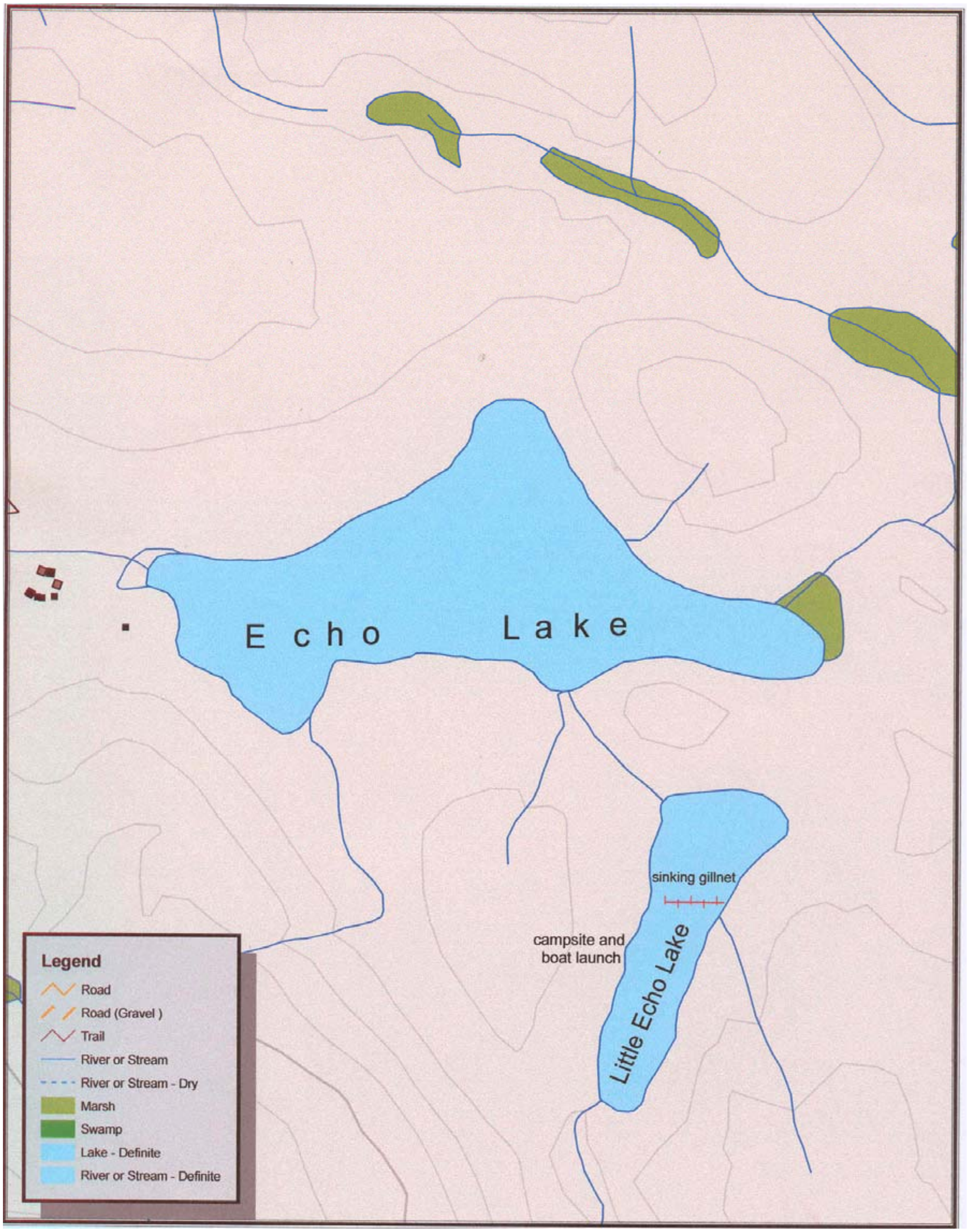
Appendix 1. Fry Lake Gillnet Location



Appendix 1. Gray Lake Gillnet Location



Appendix 1. Little Echo Lake Gillnet Location



Appendix 1. Mirror Lake Gillnet Location