ARROW LAKES RESERVOIR CREEL SURVEY

2000 - 2002

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April 2004

Cover Photo: Glen Olson with large rainbow trout caught in the upper basin of Arrow Lakes Reservoir.

Executive Summary

Creel survey data were collected at three access points (Shelter Bay, Nakusp, Castlegar) to Arrow Lakes Reservoir for five days per month from 2000 to 2002 as part of an ongoing evaluation of the Hill Creek Hatchery and Spawning Channel and a lake fertilization program started in 1999. Data were extrapolated in accordance with methods used in previous years except that the analysis included calculation of the precision of the estimates.

Total estimated effort increased more than 50% from 7,940 angler-days in 2000 to over 12,000 angler-days in 2001 and 2002. This increase was caused by a doubling of effort in the upper basin (Nakusp, Shelter Bay). Residents of British Columbia comprised about 95% of the anglers in all years. Angler expenditures wholly attributable to the fishery are approximately $1,000,000 annually. The fishery for large rainbow trout has been featured in a provincial angling magazine and local radio station newscasts.

Kokanee harvest was highest in 2001 (9,979 fish; 2,165 kg) due to a large increase in angling effort in the upper basin when kokanee size was unusually large. In 2002, the kokanee harvest was similar to long term trends (6,156 fish; 843 kg), and upper basin kokanee effort returned to low levels.

Catch and harvest of bull trout, rainbow trout, and burbot all showed substantial increases from 2000 to 2002 to approximately double the long term averages. For bull trout, harvest increased from 970 fish (1,853 kg) in 2000 to over 1,700 fish (3,700 kg) in 2002. These increases were a function of both higher catch per unit effort (CPUE; from 0.05 to 0.075 fish/hr) and higher angler effort in the upper basin. The percentage of angled bull trout that were kept dropped slightly to 60% while the average size of retained fish increased slightly to 2.1 kg.

Rainbow trout harvest estimates of 3,700 to 4,800 fish (2,600 - 3,200 kg) in 2001 and 2002 were about twice as high as long term trends. The increase was due largely to increased effort in the upper basin, although CPUE in the upper basin also increased relative to the late 1990s. Average size of retained fish (1.2 kg) was greater than previous years while the percentage of fish kept decreased slightly to 75%.

Burbot harvest in 2001 and 2002 increased to 338 and 553 fish (855 kg) respectively compared to less than 200 fish/year from 1998-2000. This harvest level is still very low on a per hectare basis compared to some other North American lakes. However, almost all of the measured harvest occurs from the Nakusp area. Few anglers target burbot, but the CPUE is high for those who do (0.47 – 0.80 fish/hr)

Increases in harvests, catch rates, and size suggest that piscivorous fish populations may have responded rapidly (i.e., within three years of the beginning of fertilization) to higher productivity and kokanee abundance at least in the upper basin of the reservoir. This response at the upper trophic levels could be a function of both increases in survival and increases in growth, of bull trout and rainbow trout in the reservoir phase of their life

history. Since these results include only the first four years since the beginning of fertilization they could also be influenced by other factors such as weather patterns. Future creel surveys are necessary to document long term trends as the ecosystem adjusts to increased nutrient levels provided by fertilization.

Percentages of clipped bull trout and rainbow trout from Hill Creek Hatchery were less than 2% of the total harvest, indicating low survival to catchable size and contributions well below target levels. Bull trout populations appear to be maintaining themselves based on natural recruitment from remaining accessible tributaries. Although the dams have reduced spawning and juvenile rearing area, lake fertilization may result in higher survival of juveniles once they reach the reservoir. Natural recruitment of rainbow trout may also be improving, but this is less certain because some stocking of unclipped Gerrard strain fish occurred in the lower basin from 1995 to 2002. These trends should be monitored closely in future assessments.

Acknowledgements

I would like to thank the anglers who took time to contribute information to the surveys, and creel technicians Glen Olson, Myles Crowley (Diversified Ova Tech Ltd.), and Allison Alder (Hailstorm Ridge Environmental Services) for their efforts in collecting field data. Dr. Carl Schwarz (Simon Fraser University) generously provided assistance with statistical analyses. Beth Woodbridge assisted with data entry and report production, and Les Fleck provided scale ages for clipped fish. The report was improved by review comments from Harald Manson, Colin Spence and Jeff Burrows.

The Columbia Basin Fish and Wildlife Compensation Program is a joint initiative of BC Hydro and the British Columbia Ministry of Water, Land, and Air Protection to conserve and enhance fish and wildlife populations affected by BC Hydro dams in the Canadian portion of the Columbia River basin.

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1.0 INTRODUCTION

Arrow Lakes Reservoir is located between Castlegar and Revelstoke in the West Kootenay Region of British Columbia. It has a total surface area (upper and lower basins) of about 46,450 ha at full pool (Pieters et al. 2003), and is affected by dams at the reservoir outlet (Hugh L. Keenleyside Dam) and upstream (Mica and Revelstoke dams). Prior to completion of the dams, it was recognized that they would result in permanent losses of fish and wildlife habitat; in relation to Arrow Lakes reservoir, stream fisheries and spawning areas would be lost due to inundation and blocked migration (Anon. 1976). It was also realized later that the upstream reservoirs would act as nutrient traps, reducing the already low level of nutrients in the reservoir (Pieters et al. 2003).

Hill Creek Hatchery and Spawning Channel were constructed in the early 1980s with the goal of compensating for lost spawning and rearing habitat. The hatchery was designed for production of bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncorhynchus mykiss*), while the spawning channel was designed primarily for production of kokanee (*O. nerka*). Stocking of bull trout was continued up to the year 2000. Rainbow trout stocking from Hill Creek was ended after 1999, but smaller releases have continued in the lower basin through Selkirk College. Since bull trout typically enter the fishery starting at age 5 and can live for more than 10 years (Sebastian et al. 2000), stocked fish of both species could be at large in the lake until 2010 or later. The kokanee spawning channel operation is ongoing.

Lake fertilization, a second large-scale compensation initiative, began in 1999 (Pieters et al. 2003). This addresses the issue of nutrient loss due to upstream reservoirs. The goal is to increase reservoir productivity, which may increase growth and survival of fish in the lake phase of their life history. Funding for the spawning channel and the fertilization is provided by BC Hydro through the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP), a joint initiative of BC Hydro and the provincial government (Ministry of Water, Lands, and Air Protection).

Creel surveys have been conducted annually at selected access points on the reservoir since the 1970s to monitor the effects of the dams and the success of compensation efforts. The surveys also provide a useful index of effort and harvest, particularly with respect to the larger piscivorous species, bull trout and rainbow trout. Sebastian et al. (2000) summarized creel trends to 1997, and Arndt (2002a) reported results for 1998 and 1999. This report documents results from 2000 to 2002, and discusses them in relation to previous estimates and the hatchery and fertilization programs.

2.0 METHODS

2.1 Field Sampling

Creel technicians interviewed anglers at three access points for five days per month from January to December (Table 1; Figure 1). This provides coverage of approximately a sixth of the total days in each month, and one quarter of weekend days. An exception for 2001 is the Castlegar access point, where no data were available for January to March. Sampling was randomized within the day types shown in Table 1, except that days of fishing derbies were excluded. In keeping with past surveys, one Monday and two other weekdays were sampled each month, although for analysis purposes all weekdays were combined as recommended by Arndt (2002). Data from derbies held at Shelter Bay and Nakusp are summarized in a separate report for 1997 to 2001(Bray 2002).

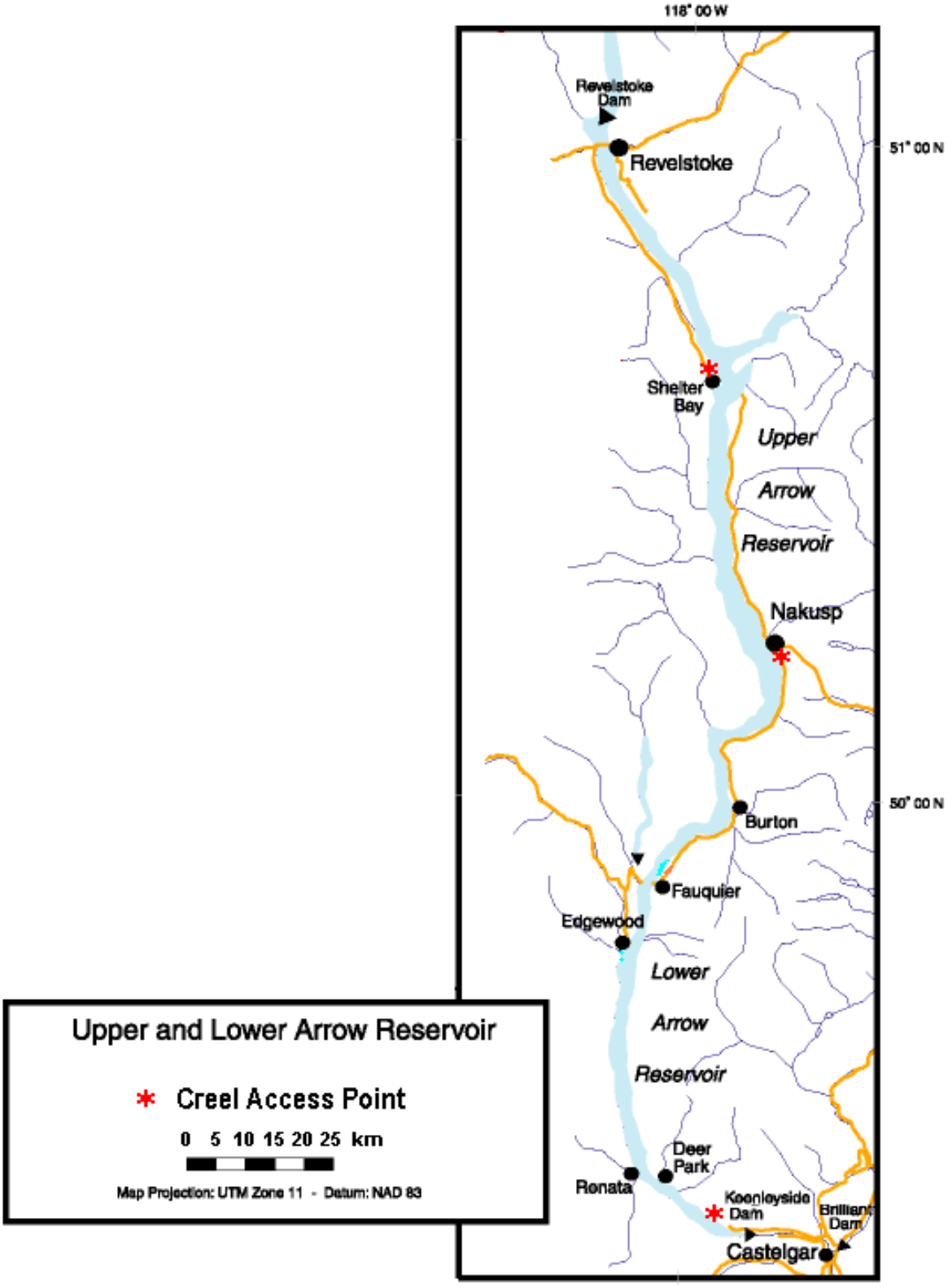

Figure 1. Map of Arrow Lakes Reservoir showing three access points used for the creel surveys from 2000 to 2002.

Table 1. Time and access strata for the Arrow Lakes Reservoir creel surveys from 2000 - 2002.

Day Type	Weekend	2 days per month
	Weekdays (including one Monday)	3 days per month
Access Locations	**Upper Arrow**	
	Shelter Bay boat ramp	5 days per month
	Nakusp government wharf	5 days per month
	Lower Arrow	
	Castlegar (Scotties and Syringa marinas, Syringa Park public boat launch)	5 days per month

Technicians were expected to stay at the access point for the duration of the fishing day, and the number of interviews is assumed to be the total effort for a given access point and day. Anglers were interviewed at the end of their trip. Information recorded included length of fishing trip, target species, species harvested and released, and angler residence. All harvested bull trout and rainbow trout were examined for the presence of hatchery clips and tags (contingent on angler permission). Length and weight measurements were recorded for a subsample of harvested fish with the stipulation that all fish from a given boat be measured if measurements were taken.

At the Shelter Bay and Nakusp access locations, there is only one boat ramp, and all angling parties can be contacted. For the Castlegar location, there are three ramps; the creel technician alternated between these sites during the summer high activity periods. In the winter months when angling effort is lower, coverage of all three ramps was sometimes possible by checking for parked vehicles and waiting at the appropriate ramp.

2.2 Analysis

Field data were entered into an Access database and then transferred to SAS for estimates of effort and harvest, or Systat for analysis of fish size data. SAS programming and analyses were generously provided by Dr. Carl Schwartz (Department of Statistics and Actuarial Science, Simon Fraser University). Systat analyses were completed using SYSTAT Version 10 at the Nelson CBFWCP office.

Effort and harvest estimates were calculated for each access point and month by expanding the average for a daytype (i.e. weekday vs. weekend) within a month by the number of days of that daytype in the month. Further description, including the method used to determine the precision, is provided in Appendix I. The 95% confidence limits were estimated as ± 2 standard errors.

The three sampled access locations are those with the highest use by boat anglers, however, other less-used locations were not sampled. In previous surveys five access points were sampled, but two (Fauquier and Edgewood) were discontinued in 2000 due to funding restrictions. Creel reports for previous years have expanded estimates from five access locations by 1.25 when projecting a total effort and harvest, to compensate for assumed missed boat access and shore-based anglers (Thorp 1995). This expansion factor was based on a professional judgement of the proportion of total effort included in the sampled access points (i.e., it was assumed that the sampled access points represented 4/5 of the total effort, but to my knowledge there were no data to base this upon). To

make 2000 – 2002 comparable, harvest estimates from the three remaining access points were expanded by a factor of 1.30, because Fauquier and Edgewood accounted for about 5% of the total harvest of most species[1] in the last year surveyed.

For angling effort, Castlegar effort was multiplied by 1.15 first, based on the approximate proportion of the lower basin effort that Edgewood and Fauquier comprised in 1998, and then expanded by the 1.25 factor for each basin. These expansions were used to allow comparisons to previous estimates. In the 2003/04 fiscal year, aerial boat counts will be conducted on the access point sampling days to provide appropriate expansion factors for the upper and lower basins.

In order to compare angler success rates over different years, the catch-per-unit-effort (CPUE) was determined for each access point/species combination by dividing the total fish caught by the total hours of targeted effort for that species. When a party of anglers targeted more than one species the total hours were allocated to both species. For example, if a party reported 5 hours angling effort seeking bull trout and rainbow trout, the 5 hours were included for both species totals. For the years prior to 1998, no data were collected on the number of released fish, therefore the CPUE includes kept fish only. From 1998 on, I have included released fish in the CPUE. Although this means that values before and after 1998 are not exactly comparable, the general trends should be valid because until relatively recently, very few fish were released (Grant Thorp, Glen Olson, pers. comm.). Fish clips were summed for bull trout and rainbow trout, and upper 95% confidence limits for the proportions of clipped fish in the harvest were calculated according to Sokal and Rohlf (1973).

[1] Although burbot were not recorded in the Fauquier and Edgewood creel surveys in 1998 and 1999, some burbot harvest has occurred near Fauquier in recent years (G. Olsen, pers. comm.)

3.0 RESULTS AND DISCUSSION

3.1 Angler Origin

The total number of anglers interviewed (including repeat contacts) was 1,071, 1,847, and 1,694 for 2000 to 2002, respectively. About 95% of the anglers were BC residents, with non-resident Canadians making up most of the remainder (Table 2). Nakusp has the highest percentage of non-resident anglers, perhaps because of the presence of charter fishing operations and a hot springs resort nearby. These results are consistent with long term trends except that the percentage of non-resident Canadians was about 10% in the 1980s and early 1990s (Appendix II).

Table 2. Number (N) and percent (%) of anglers interviewed by residence category for the 2000 to 2002 Arrow Lakes Reservoir creel surveys by access point.

	Shelter Bay		**Nakusp**		**Castlegar**		**Total**	
	2000							
Access Point	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
BC Resident	226	95.8	372	89.6	412	98.1	1010	94.3
Non-resident Canadian	10	4.2	31	7.5	4	0.9	45	4.2
Non-resident outside Canada	0	0.0	12	2.9	4	0.9	16	1.5
	2001*							
BC Resident	391	97.8	980	90.2	358	99.2	1729	93.6
Non-resident Canadian	9	2.2	81	7.5	3	0.8	93	5.0
Non-resident outside Canada	0	0.0	25	2.3	0	0.0	25	1.4
	2002							
BC Resident	284	94.0	833	92.4	489	99.8	1606	94.8
Non-resident Canadian	18	6.0	53	5.9	0	0.2	71	4.2
Non-resident outside Canada	0	0.0	16	1.8	1	0.0	17	1.0

* for the year 2001, data were not available for January to March at Castlegar.

3.2 Angling Effort

Estimated angling effort ranged from 7,940 to 13,923 angler-days, and from 36,325 to 65,540 rod-hours, over the three surveyed years (Table 3). There was a significant increase in 2001-2002 compared to previous years (Figure 2; note non-overlapping confidence limits). This increase was due to higher angling effort in the upper basin, especially from Nakusp. "Economic value" of the fishery, assuming an average expenditure[2] of $76 per angling day for BC residents and $131 for non-residents (Anon. 2002) was as high as $1,096,500.

Rainbow trout and bull trout were the two most important species in terms of directed effort; these species were targeted mainly in the upper basin (Shelter Bay, Nakusp) as has been the case in previous years (Figure 3). The majority of kokanee angling usually occurs in the lower basin

[2] These average expenditures per day were calculated from the "total expenditures wholly attributable to angling" and total number of fishing days reported for British Columbia non-resident and resident anglers in the *Survey of Recreational Fishing in Canada in 2000* (Anon. 2000). The expenditures do not include major purchases or investments wholly or partially attributable to angling.

(Castlegar area). However, there was a large increase in kokanee angling in the upper basin when the kokanee season was re-opened there in 2001 (Figure 2), such that half of the measured kokanee effort was from Nakusp (Figures 2, 3). In that year, kokanee in the upper basin were a larger size than they are in most years (see Section *3.3.3*). Burbot angling has been recorded only in the upper basin, and usually only at the Nakusp access (Figure 3), although there are anecdotal reports of burbot angling at the north end of the lower basin.

Table 3. Three measures of estimated angling effort (± 95% confidence limits) for the Arrow Lakes Reservoir creel survey from 2000 to 2002. Rod-hours are higher than angler-hours because a single angler in a boat is permitted to use two rods.

Variable	Location	2000	2001	2002
Angler-days	Shelter Bay	1,326 ± 340	2,192 ± 412	1,678 ± 292
	Nakusp	2,366 ± 504	6,118 ± 758	5,114 ± 522
	Castlegar	2,401 ± 388	*2,400 ± 416	2,683 ± 372
	Annual Total	**6,108 ± 846**	***10,710 ± 1,154**	**9,475 ± 840**
	X 1.3	**7,940 ± 846**	**13,923 ± 1,154**	**12,317 ± 840**
Angler-hours	Shelter Bay	6,518 ± 1,828	9,985 ± 1,914	7,578 ± 1,486
	Nakusp	10,566 ± 2,678	26,557 ± 3,946	22,324 ± 2,794
	Castlegar	9,237 ± 1,664	*10,500 ± 1,846	12,693 ± 2,190
	Annual Total	**26,334 ± 4,196**	***47,042 ± 5,452**	**42,594 ± 4,524**
	X 1.3	**34,234 ± 4,196**	**61,155 ± 5,452**	**55,372 ± 4,524**
Rod-hours	Shelter Bay	6,884 ± 1,882	10,771 ± 2,040	8,441 ± 1,628
	Nakusp	11,114 ± 1,384	28,144 ± 3,944	24,427 ± 2,946
	Castlegar	9,941 ± 1,808	*11,500 ± 2,036	13,693 ± 2,202
	Annual Total	**27,942 ± 4,326**	***50,415 ± 5,404**	**46,561 ± 4,700**
	X 1.3	**36,325 ± 4,326**	**65,540 ± 5,404**	**60,529 ± 4,700**

***** Castlegar data were not available for January to March 2001. In 2000 and 2002, these months comprised about 15% of the annual Castlegar effort. The 2001 estimates have been increased by this amount. Castlegar estimates for April to December were: 2,062 angler-days, 8,932 angler-hours, and 9,839 rod-hours.

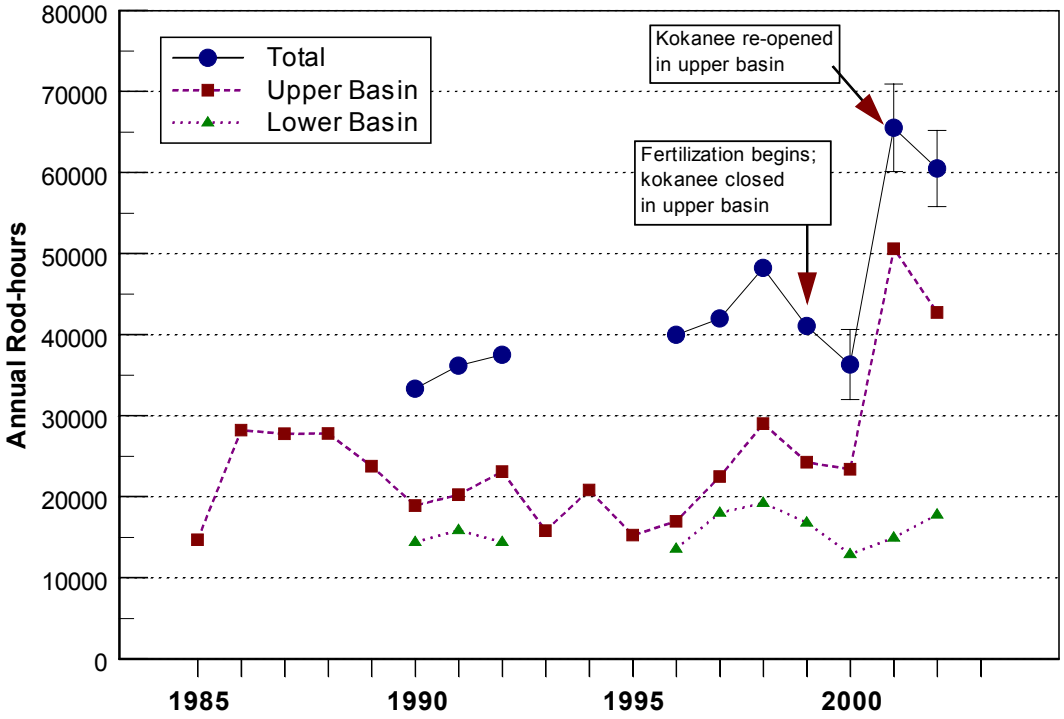

Figure 2. Trends in annual rod-hours for Arrow Lakes Reservoir from 1985 – 2002. Bars for the last three years indicate 95% confidence limits. Data prior to 1998 are from Sebastian et al. (2000), and for 1998-99 from Arndt (2002a).

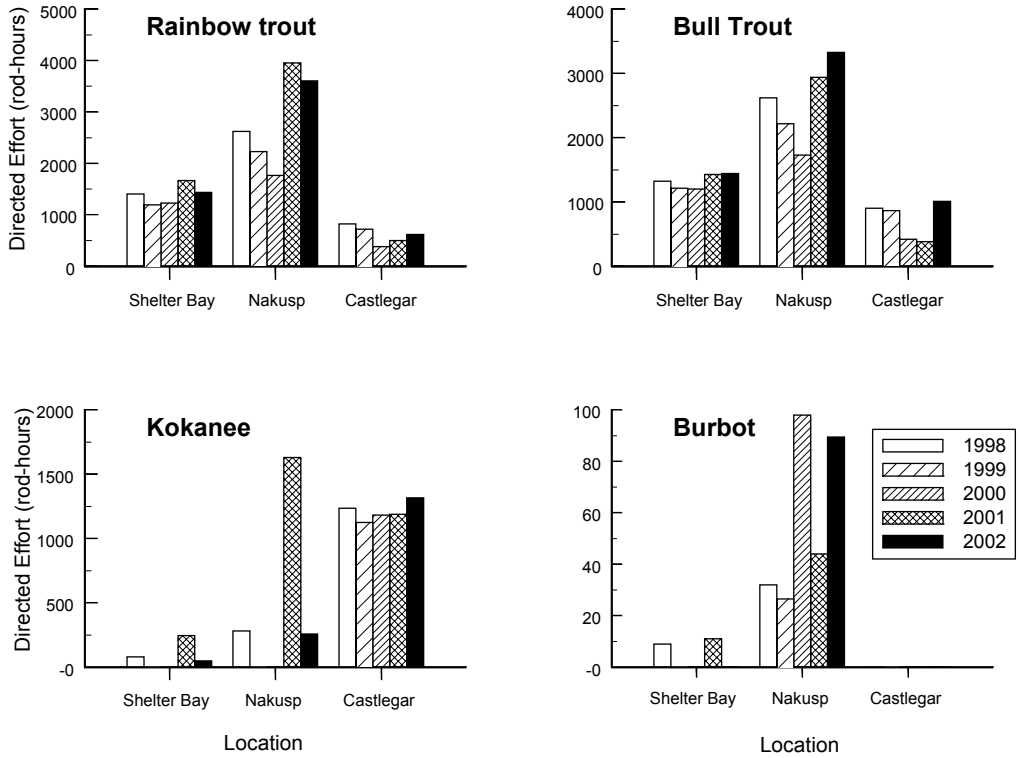

Figure 3. Directed angling effort (sum of sampled anglers) by species and access location from 1998 to 2002 in Arrow Lakes Reservoir. The kokanee season was closed in the upper basin (Shelter Bay, Nakusp) in 1999 and 2000.

3.3 Harvest, Size Distribution, and Catch-per-unit-effort

3.3.1 Bull Trout

Catch and harvest of bull trout increased substantially in 2001 and 2002 (Table 4). The estimate of 1,812 fish kept in 2002 is nearly double the long term annual average of approximately 1,000 fish (Figure 4a). This increase was a function of both increased effort and higher CPUE in the upper basin (Figure 4b,c); upper basin CPUE increased from approximately 0.05 fish/hr to 0.075 fish/hr, a reduction from an average of 20 to 13 hours to catch one bull trout. In the lower basin, catch, effort, and CPUE remained at or below historical levels (Figure 4). The CPUE for bull trout on Revelstoke Reservoir was 0.139 fish/hour in a May to September creel survey in 2000 (Bray and Campbell 2001)[3].

In addition to the increased catch, the mean weight of harvested bull trout increased slightly (Table 5), resulting in lake harvest levels of nearly 3,800 kg (0.08 kg/ha), compared to the 1998-99 average of ~2,000 kg (0.05 kg/ha). The percentage of fish kept appears to be dropping slightly (Table 4); this may be related to the presence of a greater number of smaller bull trout in the catch (Glen Olson, personal communication).

Length frequency distributions of bull trout (Figure 5) show a more sharply peaked distribution in the last two years, with high numbers of fish in the 50-60 cm range. This may be an indication of strong recruitment of younger age classes in recent years.

Table 4. Bull trout angler catch (± 95% confidence limits) and harvest statistics for Arrow Lakes Reservoir from 1998 to 2002. Data for 1998-1999 are from Arndt (2002a).

	Number Caught	Number Kept	% Kept	CPUE* (fish/hr)	Harvest (kg)
1998	1,808	1,338	74	0.051	2,606
1999	1,339	791	59	0.037	1,615
2000	1,490 ± 322	970 ± 230	65	0.054	1,853
2001	2,727 ± 390	1,694 ± 322	62	0.075	3,608
2002	3,009 ± 400	1,812 ± 246	60	0.071	3,762

* all access points combined; see Figure 4 for upper and lower basin CPUE

Table 5. Size statistics for bull trout in the Arrow Lakes Reservoir creel survey from 2000 to 2002. Data for 1998-1999 are from Arndt (2002a).

		Fork Length (cm)			Weight (g)	
Year	N	Mean ± 95% c.l.	Range		Mean ± 95% c.l.	Range
1998	169	56.9 ± 1.7	38 – 85		1,948 ± 160	500 – 5,450
1999	96	56.0 ± 1.9	35 – 81		2,042 ± 205	350 – 5,216
2000	105	53.3 ± 2.1	28 – 82		1,914 ± 223	425 – 6,000
2001	233	55.3 ± 1.2	31 – 89		2,128 ± 179	350 – 12,700
2002	231	55.0 ± 1.1	29 – 82		2,076 ± 149	123 – 8,325

[3] Calculated from Bray and Campbell (2001) data using only those anglers targeting 'bull trout' or 'any trout' and their catch (14 bull trout/100.5 hours).

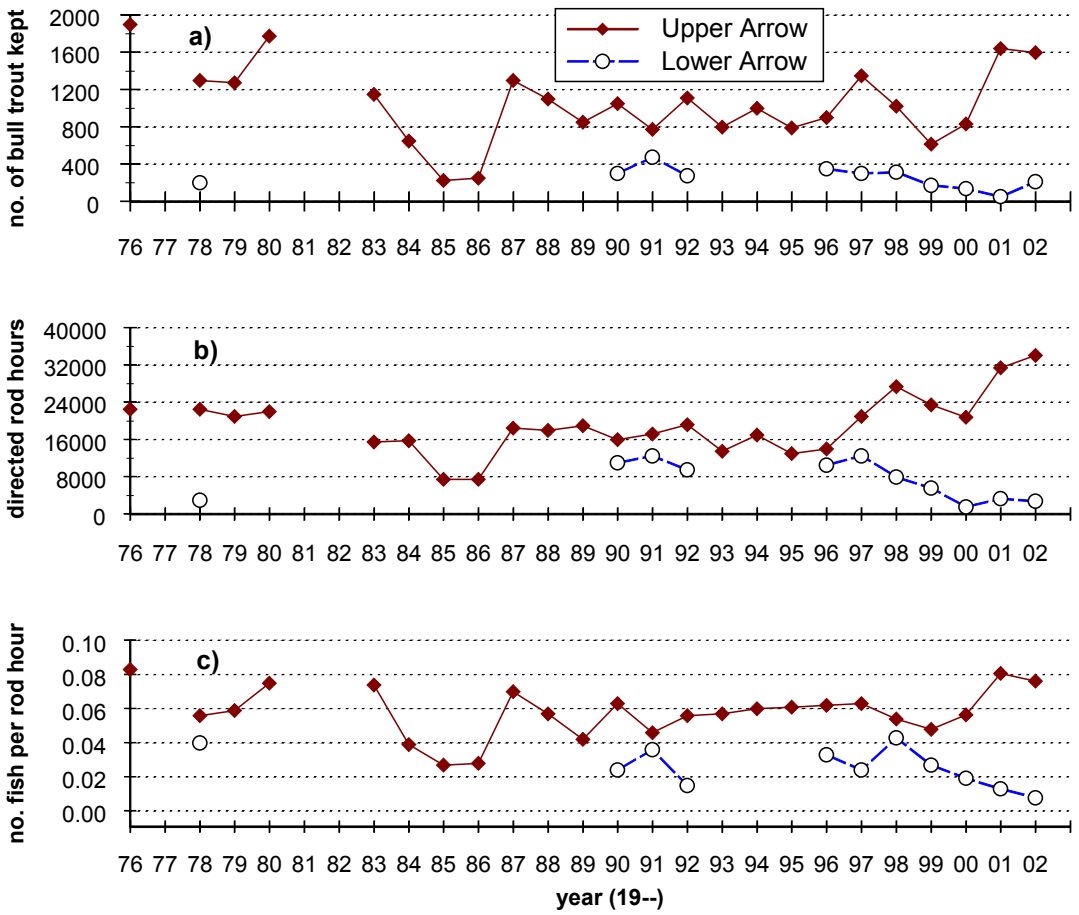

Figure 4. Trends in the (a) total number of fish kept, (b) directed rod-hours, and (c) CPUE for bull trout in Arrow Lakes Reservoir from 1976-2002. Data up to 1997 are from Sebastian et al. (2000) and for 1998-99 from Arndt (2002a).

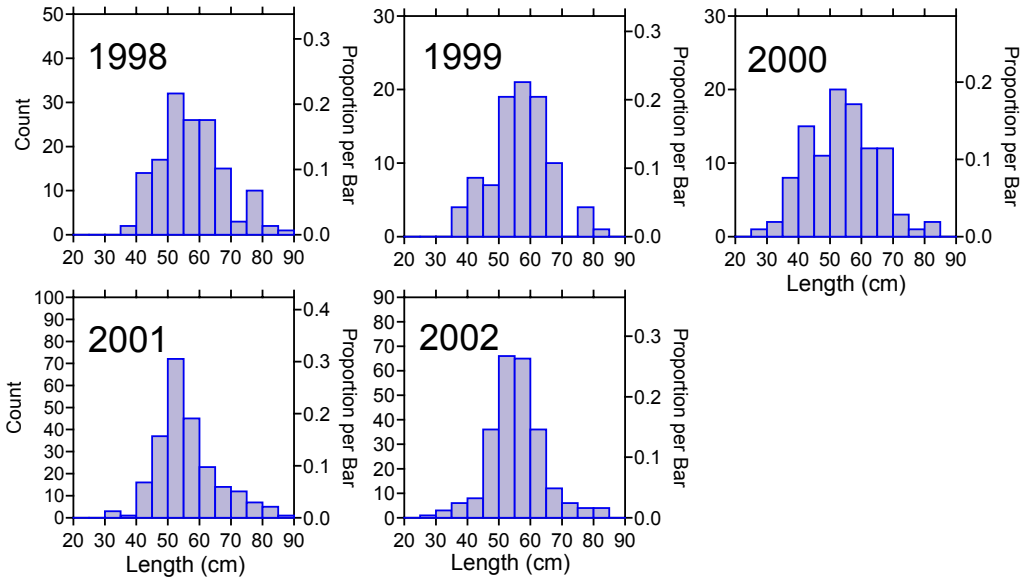

Figure 5. Fork length distributions of harvested bull trout from the Arrow Lakes Reservoir creel survey from 1998 to 2002.

3.3.2 Rainbow Trout

The catch and harvest trend for rainbow trout was similar to bull trout, with substantial increases from 2000 to 2002 (Table 6). Both effort and catch of rainbow trout in these years was approximately double the long-term average (Figure 6a,b) for the upper basin. In the upper basin, CPUE increased relative to the late 1990s but was similar to the early 1990s. In the lower basin, CPUE increased substantially between 1998 and 2002 to levels not previously documented (0.15 fish/rod-hour), but angler effort and catch did not increase in response (Figure 6). A creel survey on Revelstoke Reservoir in 2000 found a rainbow trout CPUE of 0.07 fish/hour for rainbow trout anglers (Bray and Campbell 2001).[4]

Average size of harvested rainbow trout also increased over the three year period (Table 7), resulting in a lake harvest of 3,232 kg (0.07 kg/ha) in 2002, more than double the 1998-1999 estimates. Length distributions show a stronger representation of fish over 40 cm in 2001 and 2002 (Figure 7) suggesting the possibility of stronger recruitment of piscivorous rainbows. As was the case with bull trout, there is some indication of a decrease in the percentage of fish kept (Table 6).

Table 6. Rainbow trout angler catch (± 95% confidence limits), catch per unit effort (CPUE) and harvest estimates for Arrow Lakes Reservoir from 1998 to 2002. Data for 1998-1999 are from Arndt (2002a).

	Number Caught	**Number Kept**	**% Kept**	**CPUE* (fish/hr)**	**Harvest (kg)**
1998	2,171	1,884	86.8	0.065	1,424
1999	2,130	1,766	82.9	0.070	1,148
2000	2,735 ± 518	2,256 ± 456	82.5	0.096	1,552
2001	4,819 ± 830	3,795 ± 578	78.8	0.095	2,619
2002	3,732 ± 606	2,796 ± 500	74.9	0.074	3,232

* all access points combined; see Figure 6 for upper and lower basin CPUE

Table 7. Size statistics for rainbow trout in the Arrow Lakes Reservoir creel survey from 1998 to 2002.

		Fork Length (cm)			**Weight (g)**	
Year	**N**	**Mean ± 95% c.l.**	**Range**		**Mean ± 95% c.l.**	**Range**
1998	168	36.4 ± 1.5	22 – 75		756 ± 150	200 - 5,670
1999	177	35.8 ± 1.3	23 - 84		650 ±	
2000	225	37.7 ± 0.9	24 – 75		688 ± 59	180 – 3,900
2001	400	37.7 ± 0.8	22 – 70		690 ± 60	85 – 4,762
2002	370	41.6 ± 1.2	18 – 92		1,156 ± 139	170 - 8,000

[4] Calculated from Bray and Campbell (2001) using only anglers targeting 'rainbow trout' or 'any trout' and their catch (5 fish/71.4 hours).

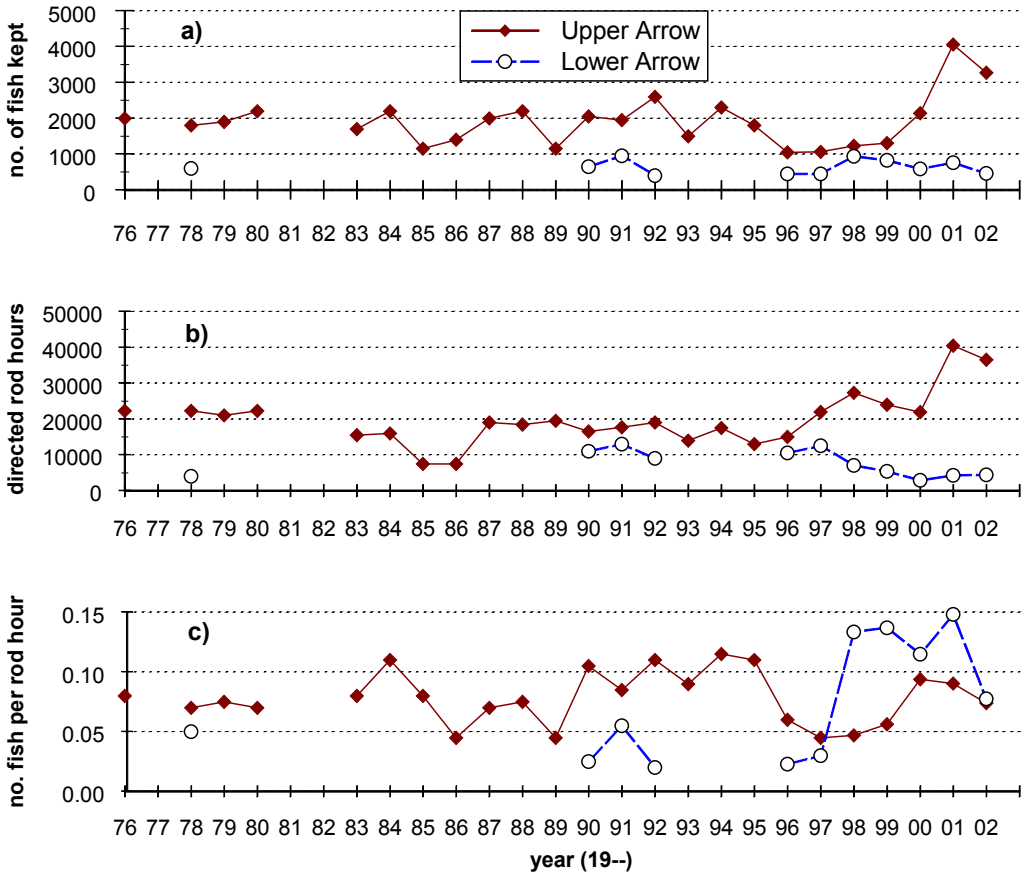

Figure 6. Trends in the (a) total number of fish kept, (b) directed rod-hours, and (c) CPUE for rainbow trout in Arrow Lakes Reservoir from 1976-2002. Data up to 1997 are from Sebastian et al. (2000) and for 1998-99 from Arndt (2002a).

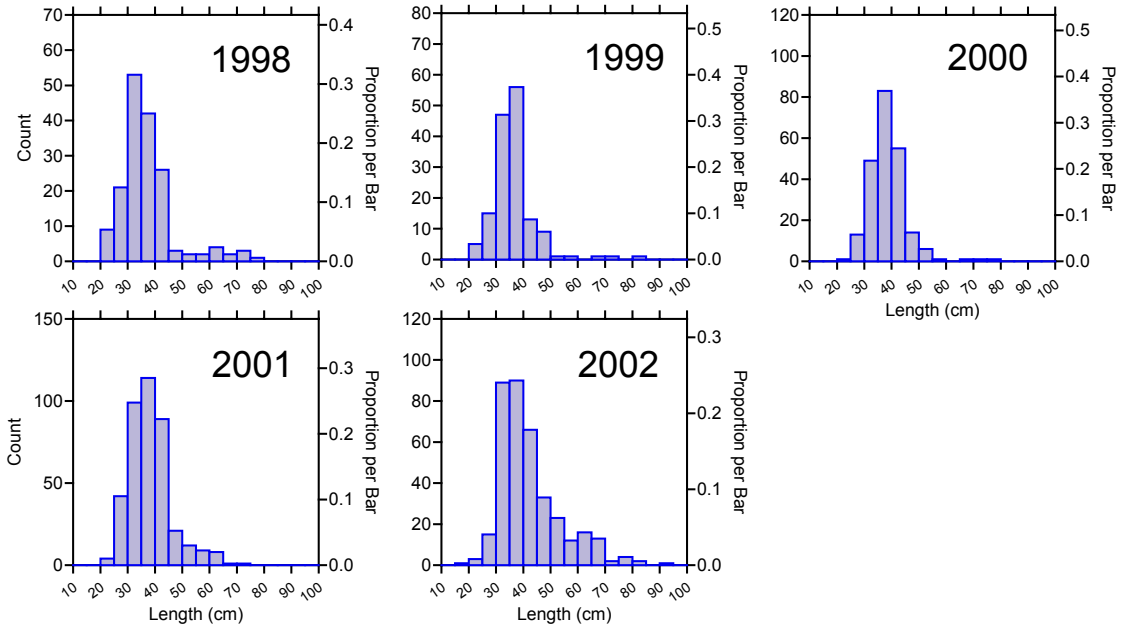

Figure 7. Fork length distributions of harvested rainbow trout from the Arrow Lakes Reservoir creel survey from 1998 to 2002.

3.3.3 Kokanee

Overall, kokanee catch from 2000-2002 was similar to the late 1990s and less than catches in the late 1980s and early 1990s (Table 8; Figure 8a). However, a large increase in kokanee-directed effort occurred out of Nakusp in 2001 resulting in the highest recorded levels of angling effort in the upper basin (Figures 2, 3). Although there is not usually a large amount of kokanee fishing in the upper basin, the average size of kokanee was substantially larger that year with some fish over 40 cm and nearly a kilogram in weight (Table 9, Appendix V). Size of kokanee and CPUE decreased in 2002 (0.43 to 0.23 fish/hr in the upper basin; Figure 8c), and the amount of kokanee angling decreased dramatically (Figure 8b). This indicates the potential importance of a kokanee fishery, and the effect of fish size on angler effort. A creel survey on Revelstoke Reservoir in 2000 found a CPUE of 0.30 fish/hour for kokanee anglers (Bray and Campbell 2001).[5]

Table 8. Kokanee angler catch (± 95% confidence limits), CPUE, and harvest estimates for Arrow Lakes Reservoir from 1998 – 2002. Data for 1998-1999 are from Arndt (2002a). Size measurements were not available for 1999 and 2000.

	Number Caught	**Number Kept**	**% Kept**	**CPUE* (fish/hr)**	**Harvest (kg)**
1998	10,161	10,115	99.5	0.756	1,487
1999	8,939	8,461	94.7	1.080	na
2000	8,056 ± 1,118	7,400 ± 1,036	91.9	0.829	na
2001	12,845 ± 2,336	9,979 ± 1,550	77.7	0.518	2,165
2002	9,853 ± 1,986	6,156 ± 1,092	62.5	0.765	843

***** all access points combined; see Figure 8 for upper and lower basin CPUE

Table 9. Size statistics for kokanee in the Arrow Lakes Reservoir creel survey for 1998, 2001 and 2002. No kokanee measurements are available for 1999 and 2000.

		Fork Length (cm)			**Weight (g)**	
Year	**N**	**Mean ± 95% c.l.**	**Range**		**Mean ± 95% c.l.**	**Range**
1998	104	25.3 ± 0.9	18 – 34		158 ± 14	50 - 450
2001	646	25.7 ± 0.3	17 - 42		217 ± 8	56 - 963
2002	123	22.5 ± 0.7	16 - 41		137 ± 19	28 – 708

[5] Calculated from Bray and Campbell data using anglers targeting kokanee (406 kokanee/1,354 hours).

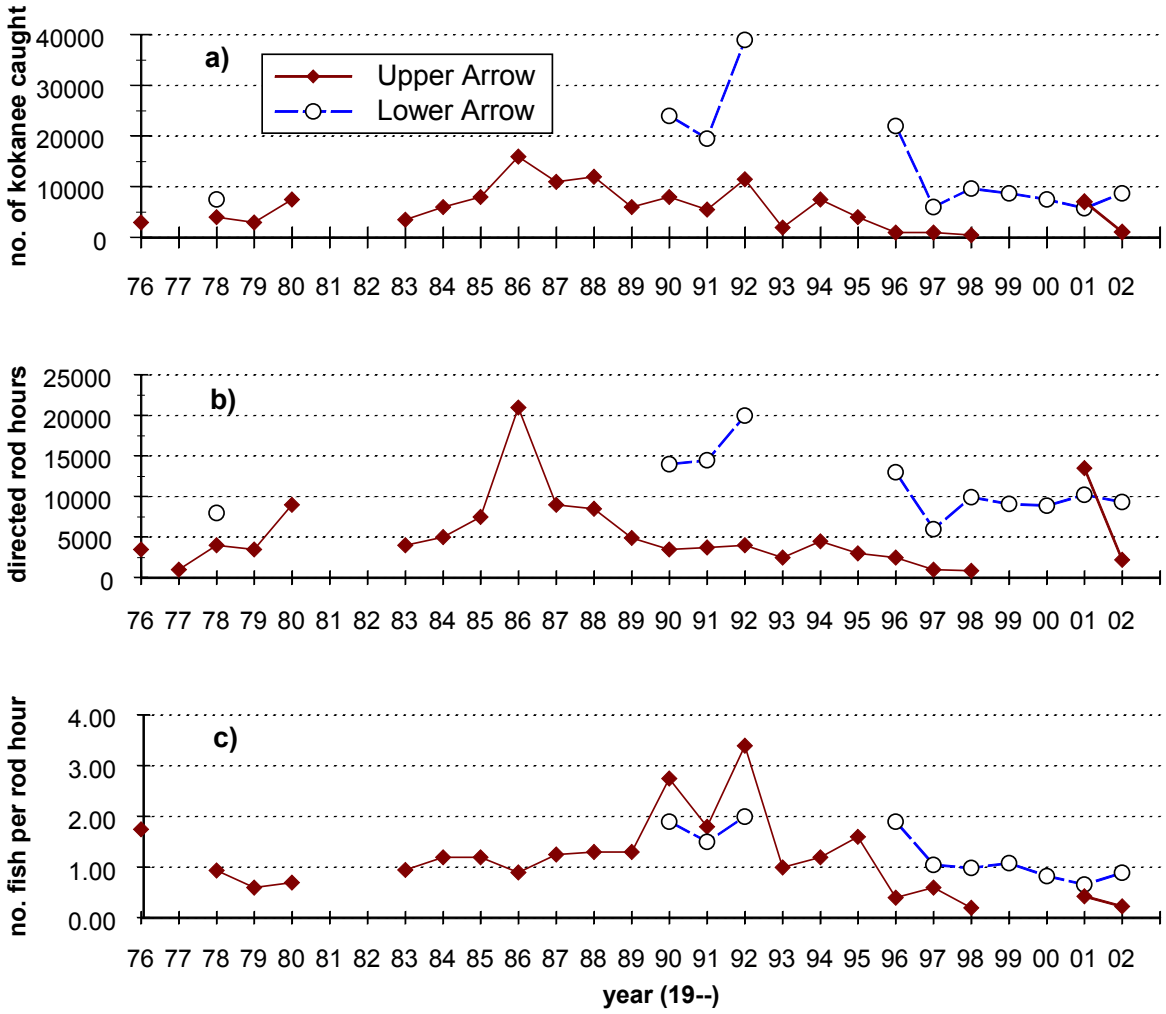

Figure 8. Trends in the (a) total number of fish kept, (b) directed rod-hours, and (c) CPUE for kokanee in Arrow Lakes Reservoir from 1976-2002. Data up to 1997 are from Sebastian et al. (2000) and for 1998-99 from Arndt (2002a).

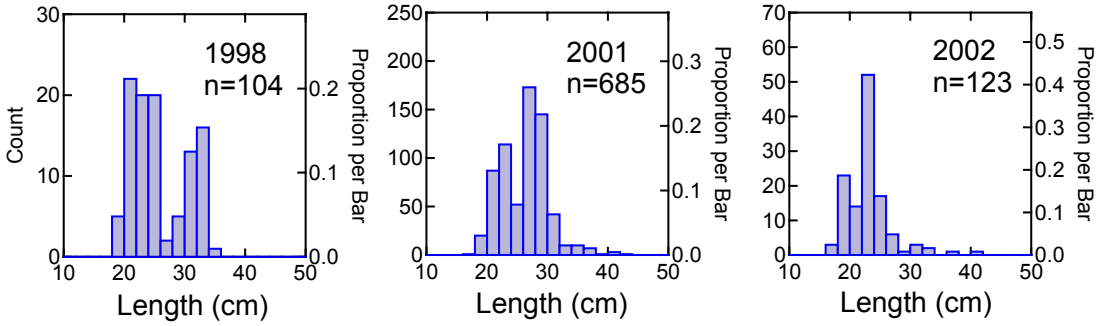

Figure 9. Length frequency distributions of kokanee from Arrow Lakes Reservoir in 1998, 2001, and 2002. Samples for the first two years are all from the upper basin; for 2002 about half were from the lower basin. No data were available for 1999 and 2000.

3.3.4 Burbot

Although burbot angling has been recorded throughout the year in the reservoir, the low number of sampled burbot anglers resulted in catch estimates with wide confidence limits. Nevertheless, trends suggest that angling effort and harvest of burbot increased substantially from 2000 to 2002. Levels were more than double those in 1998-99, although effort is still very low overall at less than 1000 rod-hours (Table 10). For those anglers who do fish for burbot, CPUE has been consistently high, exceeding other Kootenay Region lakes for which recent data are available (Table 11). These catch rates are somewhat to the range of CPUE values that occurred in the burbot fishery in the West Arm of Kootenay Lake between 1967 and 1976 (Table 11).

Table 10. Estimated burbot angler effort, catch and harvest (± 95% confidence limits), percentage of fish kept, and CPUE for Arrow Lakes Reservoir from 1998 to 2002. Data for 1998-1999 are from Arndt (2002a).

	Directed Rod-Hours	Number Caught	Number Kept	% Kept	CPUE (fish/hr)	Harvest (kg)
1998	287	175	175	100.0	0.488	226
1999	115	146	122	83.6	1.019	158
2000	689	335 ± 332	172 ± 224	51.5	0.469	199
2001	442	368 ± 176	338 ± 158	91.9	0.800	519
2002	700	553 ± 228	553 ± 228	100.0	0.760	855

Table 11. Burbot CPUE from creel surveys in four Kootenay Region Lakes.

Lake	Years	CPUE (fish/hr)	Season
Arrow Reservoir	1998 – 2002	0.47 – 1.02	All year
Columbia Lake[1]	1995 – 2001	0.08 – 0.44	Winter
Windermere Lake[1]	1996 – 1997	0.43 - 0.44	Winter
Moyie Lake[2]	2002	0.04	Winter
Kootenay Lake West Arm[3]	1967 - 1976	0.28 - 1.48	February to June

[1] Arndt (2002b)
[2] data from Kenton Andreashuk, Columbia-Kootenay Fisheries Renewal Partnership
[3] Martin (1976)

There is also some indication of an increase in size in 2001 and 2002 (Table 12; Figure 10) although the sample size is low in 1998 and 2000. The relative consistency in modal length suggests that recruitment in Arrow Lakes Reservoir is more consistent from year to year than in Columbia Lake in the East Kootenay. In Columbia Lake, there were marked changes in length frequency between 1996 and 2001 that were driven by periodic influxes of very abundant cohorts with poor recruitment in intervening years (Arndt 2002c; Taylor and Arndt, in review). Burbot harvested in Arrow Lakes Reservoir are large compared to other burbot lakes with creel data in the Kootenay Region (Figure 11). Future creel surveys should measure as many burbot as possible and collect otoliths, if possible, to monitor the age structure of the population. On a whole-reservoir basis, burbot harvest in the Arrow Lakes Reservoir is very low compared to other North American Lakes (Table 13), however, all of the measured harvest comes from the Nakusp access and it may represent a substantially larger removal per unit area if there is a sub-population residing in that area year

round. The site of the majority of harvest is in the narrows between the upper and lower basins. This location is similar to the entrance to the West Arm of Kootenay Lake, where there was a strong fishery in the late 1960s and 1970s (Martin 1976; Ahrens and Korman 2002).

Table 12. Size statistics for burbot measured in the Arrow Lakes Reservoir creel survey from 1998 to 2002.

		Total Length (cm)			**Weight (g)**	
Year	**N**	**Mean± 95% c.l.**	**Range**		**Mean± 95% c.l.**	**Range**
1998-99	23	60.6 ± 5.1	41 - 86		1,294 ± 241	454 – 2,268
2000	6	60.0 ± 4.8	52 – 65		1,196 ± 419	700 – 1,700
2001	39	63.1 ± 2.3	50 – 86		1,596 ± 191	737 – 3,345
2002	78	63.8 ± 1.8	45 - 84		1,608 ± 134	737 – 3,685

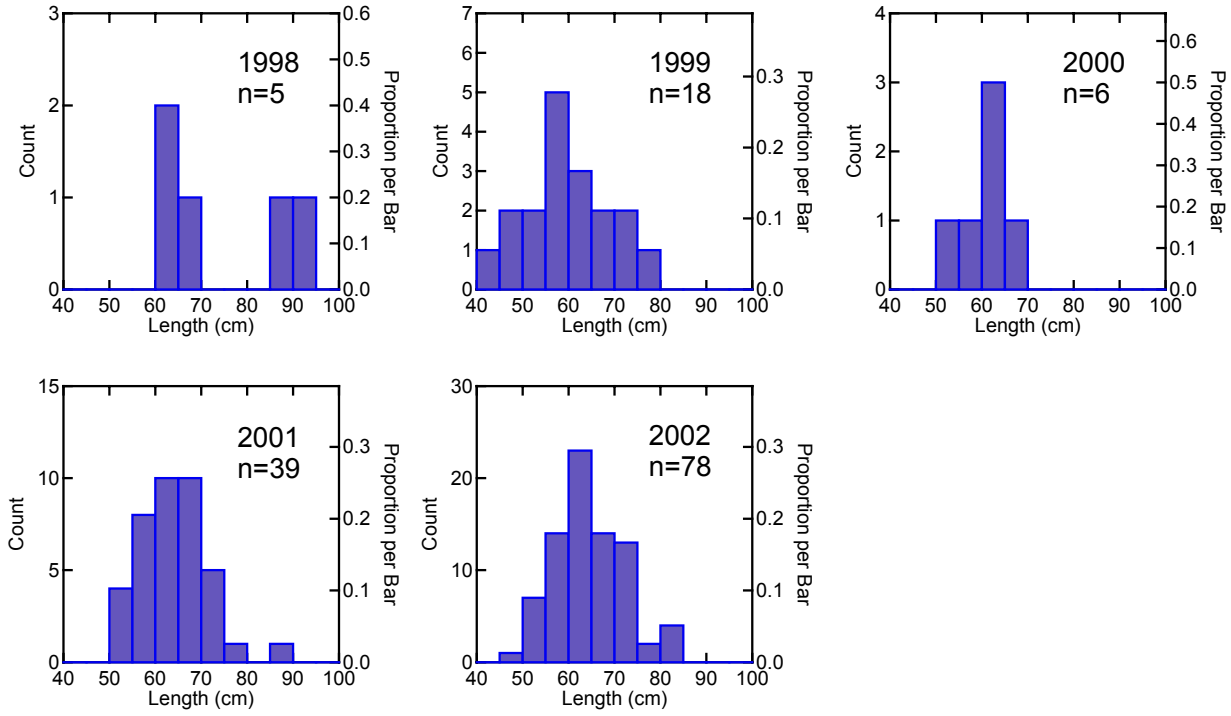

Figure 10. Length frequency distributions of burbot angled in Arrow Lakes Reservoir from 1998 to 2002.

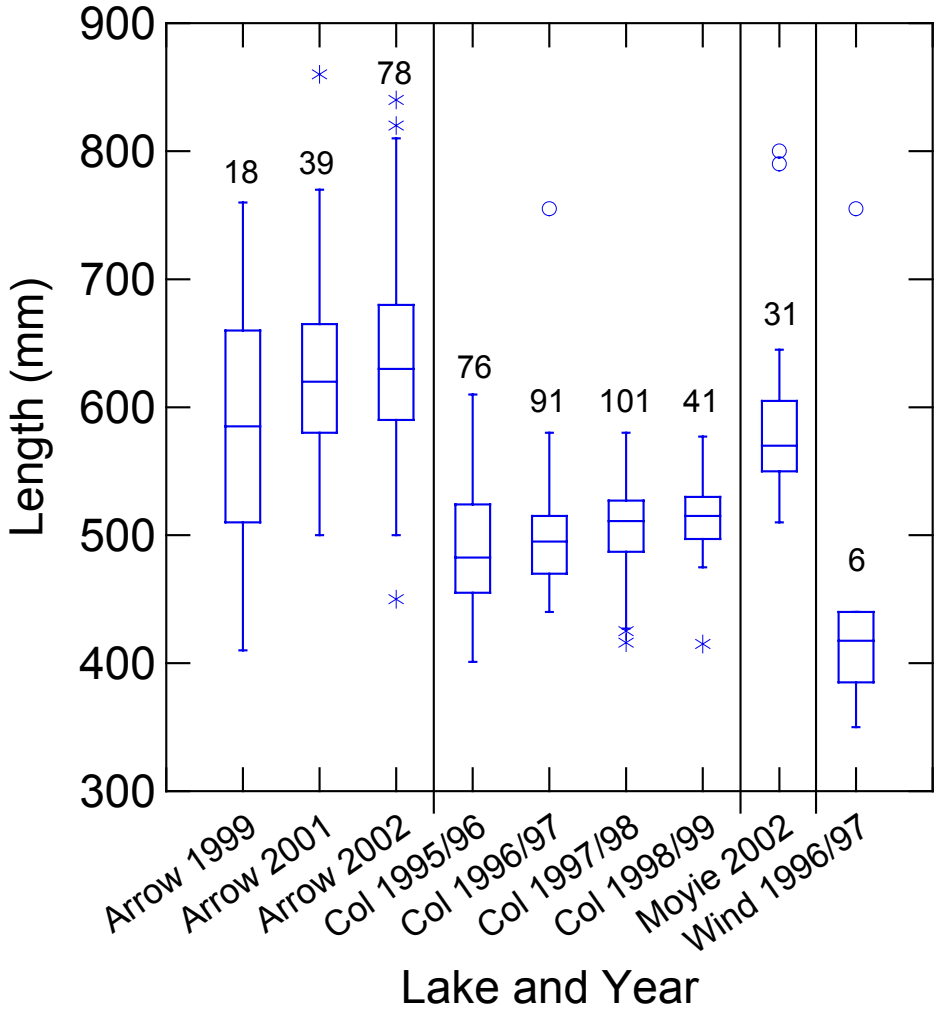

Figure 11. Box plots comparing total length of burbot harvested from Arrow, Columbia (Col), Moyie, and Windermere (Wind) Lakes in the Kootenay Region. Centre horizontal line indicates the median; box includes values between the 25th and 75th percentiles, and whiskers extend to 1.5 times the interquartile range. Outside values are shown by * or ○. Sample size is shown above each box plot.

Table 13. Comparison of Arrow Lakes Reservoir burbot harvest to other lakes in British Columbia, Maine, and Alaska. Arrow Lakes Reservoir is divided into pre and post-fertilization years.

Lake	Size (ha)	Harvest		Period Measured
		Fish/ha	Kg/ha	
Arrow Lakes Reservoir	**46,450**	**0.003 - 0.004**	**0.003-0.005**	**1998-1999**
Arrow Lakes Reservoir	**46,450**	**0.007- 0.012**	**0.009-0.019**	**2000-2002**
Columbia Lake, BC[1]	2,574	0.02 – 0.19	0.02 – 0.15	1995-2001
Windermere Lake, BC[1]	1,584	0.02	0.01	1996-1997
Moosehead Lake, Maine[2]	30,308	0.07 – 0.23	0.03 – 0.17	1985-1999
Moose/Tulsona Lakes, Alaska[3]	260	0.08 – 2.63	NA	1987-1997
Susitna/Tyone Lakes, Alaska[3]	4,205	0.01 – 0.18	NA	1987-1997
Lake Louise, Alaska[3]	6,519	0.04 – 0.15	NA	1987-1990
Harding Lake, Alaska[4]	1,000	0.00 – 0.42	NA	1983-1998

[1] Arndt (2002b); [2] Quinn (2000); [3] Taube (2000); [4] Doxey (2000)

3.4 Hatchery Contribution

The percentage of clipped fish in the creel was less than 2% for both bull trout and rainbow trout for the three surveyed years (Table 14). These low percentages are consistent with results from previous years, and suggest that survival of stocked fish from Hill Creek Hatchery was very low after release (Arndt 2002a).[6] Most clipped fish were caught at Shelter Bay or Nakusp. Clipped fish came from several brood years (Table 15). In some cases it was difficult to assign the brood year because of overlap in the size range at older ages. Also in some cases, scale age did not match the brood year of clips.

It has generally been assumed that rainbow trout over 5 pounds (2.25 kg) are the piscivorous Gerrard strain. By this criterion, only 6% (4/64) of the Gerrards measured between 2000 and 2002 were clipped. This compares to 18% (3/17) in the 1998-1999 surveys (Arndt 2002a), 29% in 1994 (Winsby and Stone 1996), and 37% in 1995 (Thorp 1995). Based on the relatively high percentage of clips prior to 2000, Arndt (2002a) suggested that it might be necessary to continue stocking Gerrard strain fish if maintaining a fishery for large-size rainbow trout was deemed to be a priority. The increased catch of larger rainbows without clips in recent years could be an indication that natural production of Gerrard rainbows will maintain a good fishery without stocking.

Table 14. Summary of the number and percent (upper 95% confidence limit) of hatchery-clipped bull trout and rainbow trout in Arrow Lakes Reservoir creel samples from 2000 to 2002.

Bull Trout	**2000**			**2001**			**2002**		
Location	**Number sampled**	**Number clipped**	**%**	**Number sampled**	**Number clipped**	**%**	**Number sampled**	**Number clipped**	**%**
Shelter Bay	40	2	5.3	71	0	0	64	0	0
Nakusp	61	0	0	142	1	0.7	153	0	0
Castlegar	18	0	0	7	0	0	36	0	0
Total	*119*	*2*	*1.7 (6.4)*	*220*	*1*	*0.5 (2.5)*	*253*	*0*	*0 (1.4)*
Rainbow Trout	**2000**			**2001**			**2002**		
Location	**Number sampled**	**Number clipped**	**%**	**Number sampled**	**Number clipped**	**%**	**Number sampled**	**Number clipped**	**%**
Shelter Bay	89	3	3.4	147	5	3.4	71	2	2.8
Nakusp	129	0	0	249	4	1.6	246	1	0.4
Castlegar	71	0	0	85	0	0	56	2	3.6
Total	*289*	*3*	*1.0 (2.9)*	*481*	*9*	*1.9 (3.6)*	*373*	*5*	*1.3 (3.1)*

Although all fish from Hill Creek Hatchery were clipped (G. Thorp, personal communication), conclusions about the lack of contribution from stocked fish are complicated by the fact that some unclipped Gerrard rainbows were released into the lower basin by other hatcheries (data from Provincial stocking records). In most cases, the number released was low (total of 8,700 unmarked yearlings from Selkirk College between 1997 and 2002), although 20,000 unclipped yearlings were released in 1995. It is unlikely that these fish would comprise a significant component of the 2000-

[6] In Hill Creek Spawning Channel in 2002, 34 bull trout were enumerated into the channel of which 17 (50%) were clipped (G. Thorp, pers. comm.). Hill Creek was stocked with bull trout up to 1998 and is thought to be poor quality habitat for natural bull trout reproduction.

2002 harvest, given the low survival of Hill Creek stockings and the age structure of the harvest (most rainbow trout < age 6; data not shown). Nevertheless, the possibility of a contribution from unmarked stocked fish cannot be ruled out. Trends in clipped fish should be monitored closely in future creel surveys, and all hatchery releases should be clipped.

Table 15. Location, clip, probable brood year and size for clipped fish in the 2000 to 2002 creel surveys. Brood year was estimated based on clip, length at capture, and scale age if available. Rainbow trout over 50 cm were assumed to be Gerrard stock and those under 50 cm Hill Creek stock. Clips are as follows: AD=adipose; ALM=adipose/left maxillary; ARM=adipose/right maxillary; RM=right maxillary; LM=left maxillary. Stocking records were obtained from Sebastian et al. (2000) and a spreadsheet from Hill Creek hatchery.

Bull Trout						
	Location	**Clip**	**Brood Year**	**Length (cm)**	**Weight (g)**	**Scale Age**
2000	Shelter Bay	AD	1993	61	1450	-
	Shelter Bay	AD	1993	65	2000	-
2001	Nakusp	AD	1996	50	1700	4 or 5
Rainbow Trout						
2000	Shelter Bay	ALM	1992 or 1996	37	600	-
	Shelter Bay	ALM	1992 or 1996	38	600	-
	Shelter Bay	AD	1994 or 1997	37.5	500	-
2001	Shelter Bay	ARM	1995?	29	400	3
	Shelter Bay	RM	1996 Gerrard?	37	600	4
	Shelter Bay	AD	1997	42.5	800	4 or 5
	Shelter Bay	ARM	1995?	42	750	4
	Shelter Bay	ALM	1996	40	620	5
	Nakusp	AD	1995? Gerrard	70	2875	-
	Nakusp	AD	1994 or 1997	43	567	-
	Nakusp	AD	1997	32	453	-
	Nakusp	RM	1995 Gerrard	64	3515	5 or 6
	Nakusp	ALM*	1996 Gerrard	72	4819	5
	Nakusp	AD*	1995 Gerrard	66	3742	5 or 6
	Nakusp	LM*	1996 Gerrard	66	3969	-
2002	Shelter Bay	ALM	1996? Gerrard	65	3750	4
	Shelter Bay	RM	1990?	38	800	3
	Nakusp	AD	1997	37	567	-
	Castlegar	RM	1990?	48.3	-	4
	Castlegar	LM	1996? Gerrard	81	8000	5

* fish returned from days not included in the creel survey

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Post-Fertilization Trends

Given that this report includes only the first four years post fertilization, and the likelihood that other factors such as weather patterns influence fish populations, it would be premature to assert that changes in the fishery and biological characteristics of the harvest are definitely due to fertilization. Nevertheless, some notable changes have occured in recent years that strongly suggest a positive response.

Overall, activity in the fishery has increased; angler days in 2001 and 2002 were 20-40% higher than 1998-99, and annual rod-hours doubled in the upper basin. Winter fishing for "trophy-trout" in Arrow Lakes was recently featured in a provincial angling magazine along with a report on the fertilization program[7]. A local radio station[8] and newspapers with regional[9] and provincial[10] circulation have also highlighted catches of large rainbow trout and the fertilization program. This activity translates into economic benefits of approximately $1 million annually to the province and local area (see section 3.2), and helps maintain the quality of environment and recreational opportunities that were enjoyed prior to the dams.

4.1.1 Kokanee

Fertilization of Arrow Lakes Reservoir began in the growing season of 1999 in the upper basin, with application occuring from the ferry between Shelter and Galena Bays (Pieters et al. 2000). Since then, in-lake kokanee abundance has increased substantially. Hydroacoustic estimates (all age groups combined) were approximately 20 million in 2001 and 2002, increased from less than 5 million in 1998 and 1999 (Pieters et. al. 2003; D. Sebastian, pers. comm.). In 2001, the kokanee season was re-opened in the upper basin, and in that year kokanee size was larger than usual (217 g; see section *3.3.3*), probably because densities were low in relation to the available food in the early years of fertilization. The sharp increase in angling effort in the upper basin in 2001 shows the potential for kokanee to create important fisheries when kokanee are a larger size and in reasonably good abundance.

In 2002, the average size of kokanee decreased (137 g) and angler effort for kokanee in the upper basin returned to low levels. Kokanee typically show a density-dependent growth response; higher survival and growth in the reservoir has resulted in returns of more spawners at higher fecundity as well as a greater proportion of age 2+ spawners since 1999 (Pieters et al. 2003). Consequently, the size of kokanee under fertilized conditions may not be as large as 2001 over the long term if survival is high. Increased numbers of small kokanee provide abundant forage for piscivores, but may not be of interest to many anglers under current regulations (5 fish/day). If numbers of kokanee stabilize at these higher levels, consideration could be given to a return to a 10 fish daily limit. This might provide more incentive for anglers to make use of this resource (Glen Olsen, charter fishing operator and creel technician, pers. comm.).

[7] D.C. Kimble. Kootenay Kings. BC Outdoors Sport Fishing magazine, November/December 2002, p.52.
[8] KBS Radio (Castlegar) broadcast interviews on February 25, 26 with a local angler/tackle storeowner (regarding the catch of a 27 lb. rainbow trout) and CBFWCP public communications coordinator Barry Bartlett (regarding the fertilization program). Newscasts on the following weekend used excerpts of the interviews to highlight the fishing and fertilization program.
[9] Ethan Baron. Fish project makes world-wide waves. Venture, Business in the Kootenay and Boundary, February 2000
[10] Steven Hume. A comeback for the kokanee. Vancouver Sun, Saturday Edition, March 9, 2002. (circulation 700,000)

4.1.2 Other Fish

Bull trout and larger rainbow trout represent the higher trophic levels in the reservoir since their diet as they near maturity is almost exclusively smaller fish (Bray 2002). Smaller rainbow trout may represent a more intermediate level since they consume zooplankton and some fish, although they are probably less affected by fertilization because a large component of their spring-summer diet is terrestrial insects (Bray 2002). Burbot consume large amounts of *Mysis* shrimp (G. Olsen, pers. comm.) and also likely feed on kokanee.

Catch estimates for bull trout, rainbow trout, and burbot all increased to approximately double pre-fertilization levels. Bull trout CPUE for the upper basin in 2001 was the highest since the early 1980s, and rainbow trout CPUE in the upper basin was about twice as high as the late 1990s. Lower basin rainbow trout CPUE was the highest recorded to date, although this increase started in 1998, in advance of the first year of fertilization. Size of harvested fish also increased for these species. In addition, bull trout condition factors have shown an increasing trend since the beginning of fertilization, and were significantly higher in post-fertilization (1999-2001) than pre-fertilization (1997-1998) years for fish sampled at fishing derbies in Nakusp and Shelter Bay (Bray 2002). These results suggest an increase in both growth and abundance of these species.

Length-frequency distributions further suggest strong recruitment of bull trout and rainbow trout in recent years. This is supported by an increase in the percentage of released fish, which tend to be the smaller fish (Glen Olsen, pers. comm.). A possible mechanism for increased production of piscivores is increased survival and growth of juveniles once they enter the reservoir, due to the increased abundance of kokanee and other foods. In McKenzie Creek north of Nakusp, McPhail and Murray (1979) found evidence of a spring emigration of newly emerged bull trout fry as well as autumn migrations of larger juveniles. Otolith growth patterns suggested that the survival of emigrating fry was relatively low at that time (comprised 15% of lake-caught adults). However, if reservoir survival for fry and older juveniles increases under fertilized conditions, natural recruitment rates should be higher even though the quantity of stream spawning and rearing habitat has not increased. A similar process might benefit piscivorous and smaller stocks of rainbow trout.

Further study of bull trout and rainbow trout life history in the reservoir would aid in understanding how fertilization influences the productivity of these species. Bull trout spawning tributaries are currently being identified by telemetry (Bray and Mylechreest 1999) and tributary temperature data were collected in 2003 as an additional means of screening for suitable habitats. Hill Creek Hatchery production of bull trout was discontinued due to low survival after release, therefore it is essential to identify, protect, and optimize remaining spawning and rearing areas. Spawning areas for piscivorous rainbow trout in the reservoir are not currently known and should also be determined for protection and restoration if necessary.

4.2 Recommendations

1. Continue an annual creel survey on Arrow Lakes Reservoir to monitor harvest trends for kokanee, bull trout, rainbow trout and other species. Changes in catch and size data can be used to infer post-fertilization recruitment. This information also provides evidence of the benefits to anglers and local communities, and helps determine what percentage of the increased production from fertilization is harvested.

Alternate year creel surveys could be considered when the intial experimental fertilization period is completed and reservoir conditions appear to be stabilized, although this would provide less resolution of trends.

2. Undertake aerial boat counts in 2003 and revise analysis methods appropriately. This will allow a data-based extrapolation of the access point harvest and effort. Once these estimates are available, the Arrow fishery should be compared to creel surveys of other large lakes in the province to put the value of the fishery into a larger context.

3. Continue boat and shore angler counts from air on an annual basis as funding permits. The proportion of anglers coming from sampled access points is unlikely to remain constant over the long term.

4. Consider expanding sampled access locations to include the upper Revelstoke Reach and Beaton Arm if aerial boat surveys in 2003 indicate that a substantial amount of angling occurs there.

5. Determine the sources and monitor natural bull trout and rainbow trout recruitment in Arrow Lakes Reservoir. This will help protect and perhaps enhance the remaining critical spawning and rearing habitats. Hatchery stocking of these species has been discontinued due to low survival and return to the creel, but the sources of natural recruits are not known. A negative impact on the sources could result in population reductions that are unrelated to the fertilization, but with the current state of knowledge this could not be detected.

6. Determine whether fertilization has affected growth rates, condition, and age-at-maturity of piscivores. Changes in these aspects of life history may interact with kokanee populations and the trophic dynamics of the lake ecosystem as a whole.

7. If funding can be obtained, consider implementing a similar creel survey on Kootenay Lake to document and compare the benefits of fertilization in that system.

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6.0 APPENDICES

APPENDIX I.

Estimating the Precision of the Creel Surveys on Arrow Lake

Prepared for BC Hydro

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1. Introduction

Creel surveys are conducted each year at Arrow Lake, British Columbia. The sampling protocol is explained in detail in Arndt (2002) and the methods section of this report. Briefly, the lake is sampled at 3 access points for 5 days per month from January to December. This provides coverage of approximately a sixth of the total days in each month, and a quarter of weekend days. Sampling was randomized within the day types shown in Table 1, except that days of fishing derbies were excluded. In keeping with past surveys, one Monday and two other weekdays were sampled each month, although for analysis purposes all weekdays were combined as recommended by Arndt (2002).

Technicians were expected to stay at the access point for the duration of the fishing day, and the number of interviews is assumed to be the total effort for a given access point and day. There were no boat counts on the lake. Anglers were interviewed at the end of their trip. Information recorded included length of fishing trip, target species, species harvested and released, and angler residence. All harvested fish were examined for the presence of hatchery clips and tags (contingent on angler permission). Length and weight measurements were recorded for a subsample of harvested fish with the stipulation that all fish from a given boat be measured if measurements were taken.

Table 1. Time and access strata for the Arrow Lakes Reservoir creel surveys from 2000 - 2002.

Day type	Weekend	2 days per month
	Weekdays (including one Monday)	3 days per month
Access Locations	**Upper Arrow**	
	Shelter Bay boat ramp	5 days per month
	Nakusp government wharf	5 days per month
	Lower Arrow	
	Castlegar (Scotties and Syringa marinas, Syringa Park)	5 days per month

2. Analysis of Design and Assumptions

Each year's study appears to be a stratified design (strata defined by site and month and daytype) where days are selected randomly in each site-month-daytype combination. On these selected days, clerks visited the site and recorded information from all returning parties of angler to this access point. Pollock et al (1994) discuss this design extensively.

The following assumptions will be made:

(a) creel clerks selected weekdays/weekends independently at random in each month. As noted above, at least one Monday was chosen in each month, and the remaining weekdays were selected from the other days of the week. One could define three strata within each month, weekends, weekdays, and Monday, but with only one Monday selected in each month, the variance over Mondays cannot be computed without further assumptions. Consequently, despite this restricted randomization, the sample of weekdays will be assumed to be a random sample of all weekdays in the month. The effect of this upon the estimates and estimated precision is unknown as the pattern on effort on Mondays relative to the other days of the week is presently unknown. However, Arndt (personal communications) examined the pattern of effort on Mondays and found that it was similar to other weekdays.[11]

(b) At least 2 days of each type are measured in each month. This allows an estimate of the precision for that daytype to be computed for that month-site combination. If only one day-type was visited in a particular month, some guess will have to be used for the standard deviation for that month-daytype combination (e.g. an average?)

(c) Fishing derbies are treated separately and estimated separated and simply added to the estimated totals. Did a fishing derby affect when the survey was run, i.e. if the derby was on Tuesday, then the creel clerks did extra effort on Monday and Wednesday?

(d) Reported numbers are the TOTALS at that access point for those days. No parties are missed from that site-month-daytype combination. Arndt (person communication) indicated that this should be true for Nakusp and Shelter Bay sites, but may at the Castlegar access point it is difficult (impossible) to contact everyone in the summer months (too many people/more than one boat ramp). For now the missed effort is considered as part of the effort from unsampled access points and corrected using an adjustment factor (see below). I recommend that for future surveys, it may be beneficial for clerks to simply try and sub-sample the returning anglers, e.g. sample every 3rd party. This sampling fraction can then be used in the computations without having to do ad hoc adjustments afterwards.

(e) No missing data from parties. For example, were there any parties that refused to be interviewed or did not provide any information?

(f) The *ad hoc* adjustment for access points not surveyed will be done as in past years.

(g) All landing sites were surveyed on the same days in the month, i.e. if the 3rd of the month was a selected day, then all sites were surveyed on the 3rd.

[11] Apparently, when this survey was started (late 1970s) most of the stores in the area were closed on Mondays. So the Monday was treated as its own daytype because there tended to be more fishing effort then.

3. Estimates and estimated standard errors.

The following steps are taken to find the standard error of estimate for the yearly total for a particular site. This is demonstrated in the attached spreadsheet for finding the estimates for the total number of angler-trips taken at Castlegar. The estimates are formed as simple expansion of the average for a daytype within a month by the number of daytypes within that month. The standard error at this first step is based on that for estimating a total from a simple random sample as outlined in many books on sampling and demonstrated by Pollock et al (1994). It is not necessary to use the method of successive differences because each daytype has at least 2 replicates.

The subscripts used are:

m=month,
t=type of day (weekend, weekday),
d=date within that day-type.

Notation:

A_{mtd}	Total number of anglers for that month, day-type, date combination.,
$\overline{A}_{mt} = \sum_{d} A_{mtd}$	Average number of angler per day for month, day-type combination
$s(A_{mt}.)$	Standard deviation of anglers per day for month, day-type combination
n_{mt}	Number of days measured for that month, day-type combination for the number of anglers
N_{mt}	Total number of days of each type in each month.
$total(A_{mt})$	Estimated total number of angler trips for that month-day type combination. $total(A_{mt}) = N_{mt}\overline{A}_{mt}$
$se[total(A_{mt})]$	Estimated standard error for the total number of angler trips for that month-day type combination. $se[total(A_{mt})] = N_{mt}\sqrt{\frac{s(A_{mt}.)^2}{n_{mt}}\left(1-\frac{n_{mt}}{N_{mt}}\right)}$
$total(A_{m}.)$	Estimated total number of angler trips for that month. $total(A_{m}.) = total(A_{m,we}) + total(A_{m,wd})$
$se[total(A_{m}.)]$	Estimated standard error for total angler trips in that month $se[total(A_{m}.)] = \sqrt{se[total(A_{m,wd})]^2 + se[total(A_{m,we})]^2}$
$total(A..)$	Estimated grand total over all month. $total(A..) = total(A_{jan}.) + ... + total(A_{dec}.)$
$se[total(A..)]$	Estimated standard error for grand total over all months $se[total(A..)] = \sqrt{se[total(A_{jan,}.)]^2 + ... + se[total(A_{dec,}.)]^2}$

The following procedure should be followed to estimate the yearly total and estimated se.

Step	Example
1. Total the information from all parties interviewed at a particular landing. The resulting table should have one line for each site-month-daytype-date combination	See table 1 in attached spreadsheet. $A_{june,we,10\,june} = 26$

2. Compute the average number of angler trips over the replicate day-types within that month and site. Also compute the standard deviation and the number of replicates of that day-type in that month-site combination. This can be done using a pivot-table in Excel.	$\overline{A}_{june,we} = 33.5$ $s(A_{june,we\bullet}) = 10.61$ $n_{june,we} = 2$
3. Determine total number of days of each day-type in each month.	$N_{june,we} = 8$
4. Estimate total number of angler-trips for that month for each day type. Multiply the mean from step 2 by the total number of days of that day-type.	$total(A_{june,we}) = 33.5 \times 8 = 268.0$
5. Estimate the se for estimate in step 4.	$se[total(A_{june,we})] = 8\sqrt{\frac{10.607^2}{2}\left(1-\frac{2}{8}\right)} = 52.0$
6. Estimate total number of angler-trips for that month over both day types. Add together both estimates from Step 4.	$total(A_{june\bullet}) = 280.0 + 268.0 = 548.0$
7. Estimate the se for estimate in step 6 by adding the sum of SQUARES of the individual standard errors and then taking the sqrt.	$se[total(A_{m\bullet})] = \sqrt{65.8^2 + 52.0^2} = 84$
8. Estimate the grand total over all months by adding the totals from each month	$total(A_{\bullet\bullet}) = 548 + ... + 171$
9. Estimate se for grand total in a similar fashion as in Step 7.	$se[total(A_{\bullet\bullet})] = \sqrt{84^2 + ... + 48^2} = 187$

Because all sites were surveyed on the same days, estimates of total for combinations of sites are done exactly as above EXCEPT you must find the day totals in Step 1 OVERALL SITES TO BE COMBINED. The reason that the sites must be combined before further analysis is that by surveying all sites on the same day, the readings over sites are no longer independent. For example, if a particular day happens to be very pleasant, it might be expected that more anglers than normal would be fishing that day on all sites.

If the estimated need to be multiplied by a adjustment-factor to account for sites not visited etc, simply multiply the estimate and the se by the same adjustment-factor. The se should likely be increased to account for uncertainty in the adjustment-factor, but there is currently no information available on the precision of this adjustment factor.

The same series of computations are done for each variable in the study. A summary of the results for 2003 are shown in Table 2.

4. Spreadsheet and SAS program

A sample spreadsheet and SAS program are available from the author.

5. References

Arndt, S. 2002. Arrow Lakes Reservoir Creel Survey and Contribution of Hatchery Production in 1998 and 1999. Columbia Basin Fish and Wildlife Program technical report, File 138-28.

Pollock, K. H., Jones, C. M. and Brown, T.L. (1994). Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25, Bethesda.

APPENDIX II. Angler residence composition on Arrow Lakes Reservoir from 1976 to 2002. Data up to 1996 are from Hill Creek Hatchery creel records (Thorp 1995); 1995 to 1997 were not available.

Year	Total # Anglers Interviewed	Resident (%)	Non Resident Canadian (%)	Non Resident Alien (%)
1976	852	97.0	2.0	1.0
1977	1,084	97.1	1.7	1.2
1978	1,006	95.1	3.0	1.9
1979	959	94.0	5.0	1.0
1980	1,253	93.0	5.0	2.0
1981	1,060	86.9	11.8	1.2
1982	977	90.0	8.0	2.0
1983	887	90.0	9.0	1.0
1984	751	89.0	10.0	1.0
1985	1,387	90.3	8.4	1.3
1986	916	85.0	12.0	3.0
1987	1,129	85.0	11.0	4.0
1988	1,089	88.0	8.0	4.0
1989	963	89.1	9.8	1.1
1990	900	88.6	9.8	1.6
1991	841	92.4	6.7	0.9
1992	898	87.9	10.7	1.4
1993	649	91.4	8.3	0.3
1994	807	90.0	9.3	0.7
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	1,463	95.6	3.4	1.0
1999	1,264	96.4	2.5	1.1
2000	1,071	94.3	4.2	1.5
2001	1,847	93.6	5.0	1.4
2002	1,694	94.8	4.3	0.9

APPENDIX III. Estimated angler-hours (± 95% confidence limits) on Arrow Lakes Reservoir by access point and month for 2000 to 2002.

Location	Month	2000	2001	2002
Shelter Bay	J	0 ± 0	101 ± 110	166 ± 294
	F	10 ± 19	0 ± 0	219 ± 68
	M	574 ± 586	714 ± 373	454 ± 220
	A	1,497 ± 1,147	632 ± 635	1,287 ± 760
	M	1,851 ± 487	1,009 ± 706	972 ± 392
	J	379 ± 565	1,256 ± 708	690 ± 456
	J	352 ± 40	1,250 ± 850	203 ± 225
	A	648 ± 634	1,698 ± 416	1,408 ± 775
	S	633 ± 793	1,822 ± 763	925 ± 442
	O	383 ± 179	976 ± 792	624 ± 470
	N	190 ± 244	453 ± 76	396 ± 204
	D	0 ± 0	73 ± 21	234 ± 148
	Sub-total	**6,518 ± 1,828**	**9,985 ± 1,914**	**7,578 ± 1,486**
Nakusp	J	1,473 ± 884	2,050 ± 1,199	1,839 ± 760
	F	1,204 ± 1064	2,009 ± 872	1,828 ± 1,200
	M	1,076 ± 740	2,179 ± 1,303	2,203 ± 1,237
	A	285 ± 105	2,331 ± 1,557	2,363 ± 1,330
	M	894 ± 251	1,673 ± 643	1,916 ± 543
	J	1,067 ± 938	4,800 ± 1,923	1,426 ± 582
	J	433 ± 356	2,791 ± 873	1,892 ± 696
	A	420 ± 513	2,159 ± 597	2,128 ± 364
	S	720 ± 409	2,031 ± 572	1,701 ± 536
	O	987 ± 568	1,445 ± 330	1,450 ± 444
	N	321 ± 205	1,073 ± 365	1,536 ± 312
	D	1,687 ± 1,682	2,015 ± 1,859	2,041 ± 811
	Sub-total	**10,566 ± 2,678**	**26,557 ± 3,946**	**22,324 ± 2,794**
Castlegar	J	228 ± 99	NA	933 ± 82
	F	506 ± 257	NA	767 ± 662
	M	375 ± 365	NA	820 ± 462
	A	645 ± 268	837 ± 719	1,292 ± 693
	M	1,091 ± 748	449 ± 349	1,720 ± 375
	J	2,293 ± 500	1,799 ± 968	2,066 ± 1,591
	J	2,041 ± 522	1,468 ± 695	1,640 ± 528
	A	812 ± 458	1,889 ± 682	1,157 ± 378
	S	613 ± 412	1,427 ± 697	989 ± 422
	O	248 ± 153	295 ± 357	719 ± 499
	N	182 ± 337	451 ± 301	332 ± 246
	D	203 ± 372	317 ± 426	256 ± 273
	Sub-total	**9,237 ± 1,664**	**8,932 ± 1,846**	**12,693 ± 2,190**
Annual Total Estimate		**26,334 ± 4,196**	**45,474 ± 5,452**	**42,594 ± 2,262**

Appendix IV. Estimated harvest and total catch (± 95% confidence limits) and catch per unit effort (CPUE; fish/rod-hour) by access point, month, and species for the Arrow Lakes Reservoir creel survey from 2000 to 2002. The months of January to March 2001 were missing for Castlegar. Site estimates do not always sum exactly to the total for all sites due to separate analyses for individual sites and the whole lake.

2000

Location	Rainbow Trout			Bull Trout			Kokanee			Burbot [b]		
	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]
Shelter Bay	541 ± 310	603 ± 332	0.0888	246 ± 110	426 ± 216	0.0627	14 ± 18	148 ± 116	--	0 ± 0	0 ± 0	--
Nakusp	772 ± 264	1,042 ± 342	0.0973	395 ± 166	603 ± 220	0.0520	6 ± 10	230 ± 220	--	133 ± 244	258 ± 332	0.4694
Castlegar	417 ± 134	453 ± 156	0.0115	105 ± 80	117 ± 94	0.0192	5,664 ± 1,276	5,764 ± 642	0.8288	0 ± 0	0 ± 0	--
Total all sites	**1,735 ± 456**	**2,104 ± 518**	**0.0962**	**746 ± 230**	**1,146 ± 322**	**0.0539**	**5,692 ± 1,036**	**6,142 ± 1,118**	**0.8288**	**133 ± 224**	**258 ± 332**	**0.4694**
X 1.3 for assumed missed effort	**2,256**	**2,734**		**970**	**1,490**		**7,400**	**8,056**		**166**	**323**	

2001

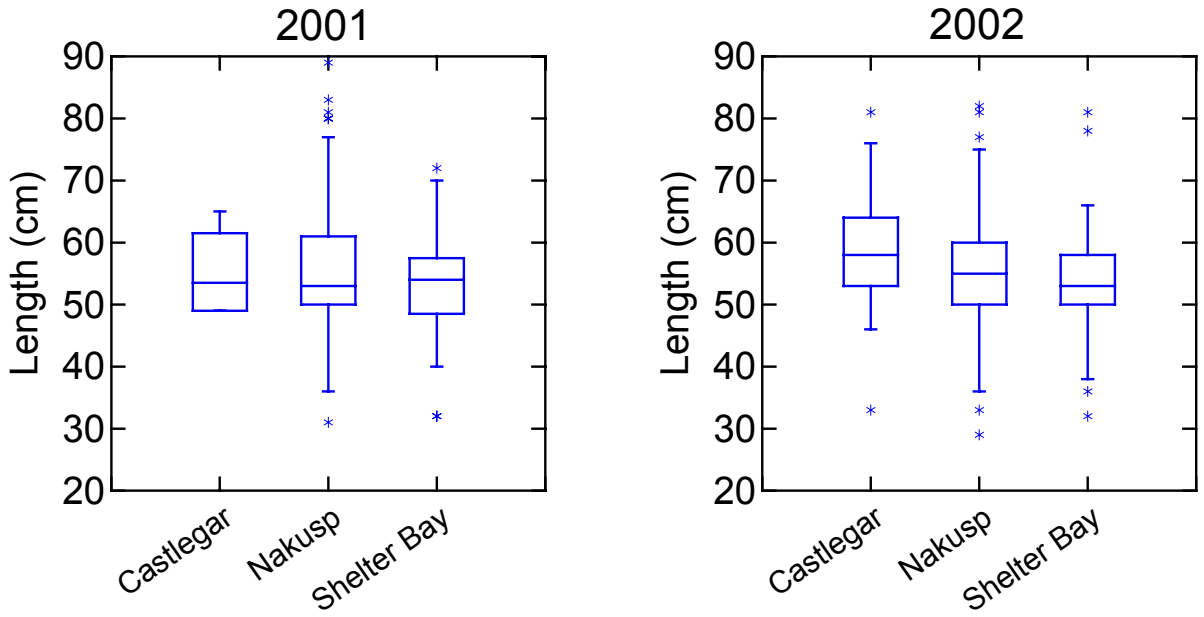
Location	Rainbow Trout			Bull Trout			Kokanee			Burbot		
	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]
Shelter Bay	985 ± 270	1,464 ± 568	0.1420	361 ± 116	650 ± 206	0.0826	791 ± 452	1,496 ± 646	0.6985	7 ± 14	30 ± 42	0.5455
Nakusp	1,406 ± 398	1,657 ± 412	0.0685	903 ± 270	1,409 ± 336	0.0799	3,140± 782	3,921 ±1,054	0.3882	253 ± 156	253 ± 156	0.8636
Castlegar	528 ± 254	586 ± 278	0.1483	39 ± 40	39 ± 40	0.0131	3,745± 776	4,465 ±1,192	0.6594	0 ± 0	0 ± 0	--
Total all sites	**2,919 ± 578**	**3,707 ± 830**	**0.0951**	**1,303 ± 322**	**2,098 ± 390**	**0.0754**	**7,676± 1,550**	**9,881 ± 2,336**	**0.5182**	**260 ± 158**	**283 ± 176**	**0.8000**
X1.3 for assumed missed effort	**3,795**	**4,819**		**1,694**	**2,727**		**9,979**	**12,847**		**325**	**354**	

2002

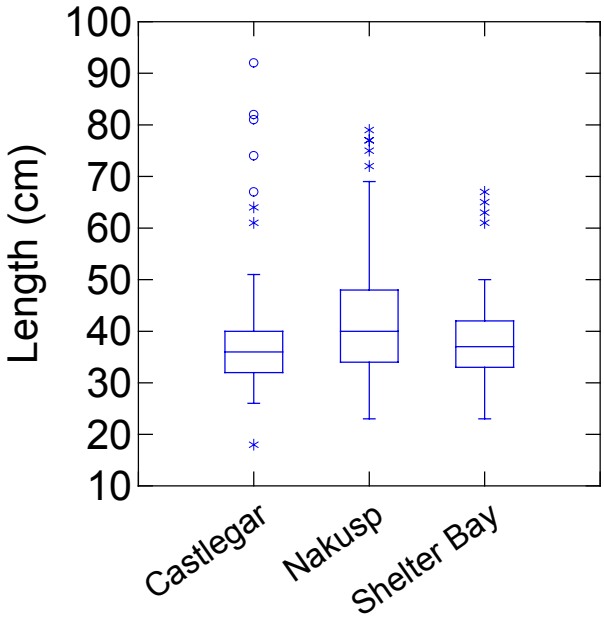
Location	Rainbow Trout			Bull Trout			Kokanee			Burbot		
	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]	Harvest	Catch	CPUE[a]
Shelter Bay	399 ± 198	554 ± 230	0.0675	370 ± 68	774 ± 176	0.0942	34 ± 40	192 ± 158	0.3852	5 ± 8	5 ± 8	--
Nakusp	1,432 ± 406	1,961± 504	0.0766	860 ± 186	1,354 ± 298	0.0688	485 ± 93	652 ± 234	0.1979	421 ± 228	421 ± 228	0.7598
Castlegar	319 ± 164	356 ± 178	0.0774	163 ± 64	187 ± 84	0.0077	4,216 ± 1,012	6,734 ± 1,918	0.8906	0 ± 0	0 ± 0	--
Total all sites	**2,151 ± 500**	**2,871 ± 606**	**0.0744**	**1,394 ± 246**	**2,315 ± 400**	**0.0710**	**4,735 ± 1,092**	**7,579 ± 1,986**	**0.7652**	**426 ± 228**	**426 ± 228**	**0.7598**
X1.3 for assumed missed effort	**2,796**	**3,734**		**1,812**	**3,009**		**6,156**	**9,851**		**532**	**532**	

[a] calculated as total fish caught/total hr of directed effort for the species; missing CPUE values indicate no directed effort for that species
[b] expanded by 1.25 instead of 1.3, see methods for further explanation

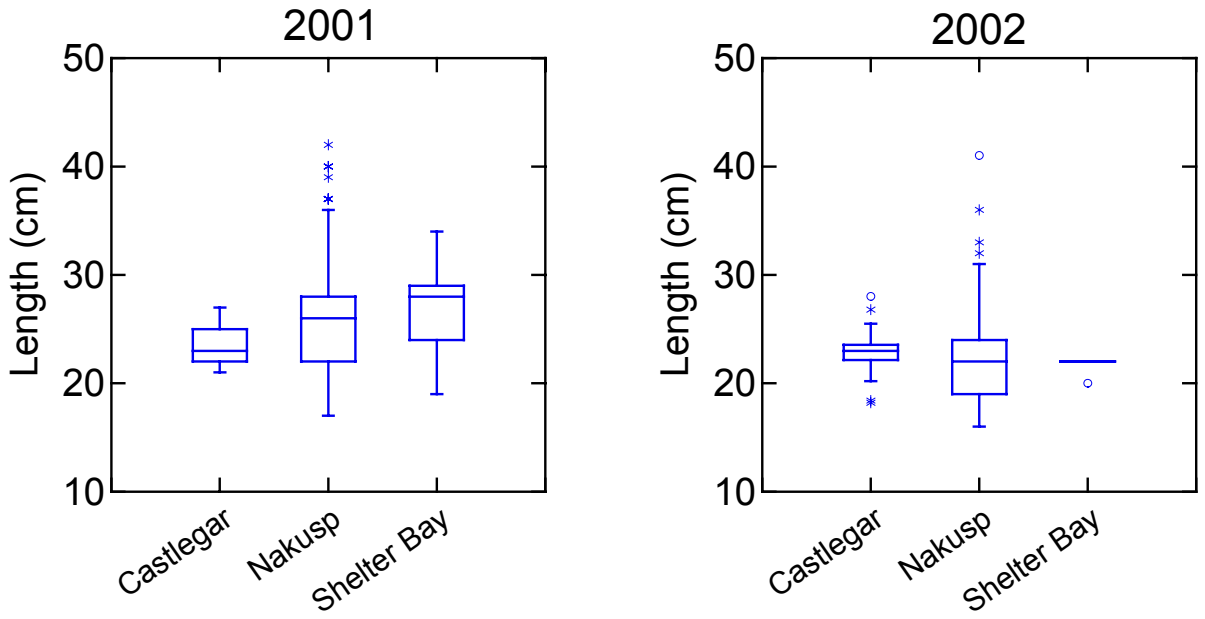
APPENDIX V. Box plot comparisons of length distribution among the three access points for bull trout, rainbow trout, and kokanee. Centre horizontal line indicates the median; box includes values between the 25th and 75th percentiles, and whiskers extend to 1.5 times the interquartile range. Outside values are shown by '*' or 'o'.



Va. Box plots of bull trout length in 2001 and 2002 by site.



Vb. Box plots of rainbow trout length in 2002 by site. (Not enough measurements at Castlegar for 2000 or 2001 comparison.)



Vc. Box plots of kokanee length in 2001 and 2002 by site.

APPENDIX VI. SAS output summaries for 2000 to 2002.

2000

	Castlegar		Nakusp		Shelter Bay		Combined Sites	
	Est	**se**	**Est**	**se**	**Est**	**se**	**Est**	**se**
Angler_hr	9237	832	10566	1339	6518	914	26334	2098
Bull Kept	105	40	395	83	246	55	746	115
Bull Released	12	11	208	52	180	64	400	80
Bull Total	117	47	603	110	426	108	1146	161
Burbot Kept	0	0	133	122	0	0	133	122
Burbot Released	0	0	125	112	0	0	125	112
Burbot Total	0	0	258	166	0	0	258	166
Kokanee Kept	5664	638	6	5	14	9	5692	518
Kokanee Released	100	47	224	110	134	59	505	149
Kokanee Total	5764	642	230	110	148	58	6197	559
NumAnglers	2401	194	2366	252	1326	170	6108	423
NumRods	2604	217	2499	265	1395	174	6511	446
Other Kept	0	0	27	25	7	7	34	26
Other Released	0	0	7	7	41	23	48	21
Other Total	0	0	34	26	48	24	82	33
Rainbow Kept	417	67	772	132	541	155	1735	228
Rainbow Released	37	34	270	72	62	20	368	72
Rainbow Total	453	78	1042	171	603	166	2104	259
Rod-hr	9941	904	11114	1384	6884	941	27942	2163
Total_Boat Time	4783	442	5249	615	3032	436	13055	1010

2001

	Castlegar		Nakusp		Shelter Bay		Combined Sites	
	Est	**se**	**Est**	**se**	**Est**	**se**	**Est**	**se**
Angler_hr	8932	923	26557	1973	9985	957	45474	2726
Bull Kept	39	20	903	135	361	58	1303	161
Bull Released	0	0	506	88	289	57	795	102
Bull Total	39	20	1409	168	650	103	2098	195
Burbot Kept	0	0	253	78	7	7	260	79
Burbot Released	0	0	0	0	23	20	23	20
Burbot Total	0	0	253	78	30	21	283	88
Kokanee Kept	3745	388	3140	391	791	226	7676	775
Kokanee Released	720	262	781	185	705	167	2206	459
Kokanee Total	4465	596	3921	527	1496	323	9881	1168
No. Anglers	2062	208	6118	379	2192	206	10372	577
No. Rods	2287	227	6550	375	2353	219	11190	572
Other Kept	5	4	0	0	5	4	9	8
Other Released	0	0	0	0	126	50	126	50
Other Total	5	4	0	0	131	53	135	55
Rainbow Kept	528	127	1406	199	985	135	2919	289
Rainbow Released	58	23	252	66	478	202	788	235
Rainbow Total	586	139	1657	206	1464	284	3707	415
Rod-hr	9839	1018	28144	1972	10771	1020	48754	2702
Total_Boat Time	4837	514	11967	842	5070	466	21874	1258

2002

	Castlegar		Nakusp		Shelter Bay		Combined Sites	
	Est	**se**	**Est**	**se**	**Est**	**se**	**Est**	**se**
Angler_hr	12693	1095	22324	1397	7578	743	**42594**	**2262**
Bull Kept	163	32	860	93	370	34	**1394**	**123**
Bull Released	23	15	494	72	404	66	**921**	**102**
Bull Total	187	42	1354	149	774	88	**2315**	**200**
Burbot Kept	0	0	421	114	5	4	**426**	**114**
Burbot Released	0	0	0	0	0	0	**0**	**0**
Burbot Total	0	0	421	114	5	4	**426**	**114**
Kokanee Kept	4216	506	485	93	34	20	**4735**	**546**
Kokanee Released	2518	564	167	62	158	62	**2843**	**557**
Kokanee Total	6734	959	652	117	192	79	**7579**	**993**
No. Anglers	2683	186	5114	261	1678	146	**9475**	**420**
No. Rods	2953	194	5616	280	1852	159	**10420**	**443**
Other Kept	19	14	0	0	0	0	**19**	**14**
Other Released	0	0	0	0	10	9	**10**	**9**
Other Total	19	14	0	0	10	9	**29**	**17**
Rainbow Kept	319	82	1432	203	399	99	**2151**	**250**
Rainbow Released	37	19	529	89	155	40	**721**	**100**
Rainbow Total	356	89	1961	252	554	115	**2871**	**303**
Rod-hr	13693	1101	24427	1473	8441	814	**46561**	**2350**
Total_Boat Time	6624	489	10319	590	3841	367	**20784**	**976**