TRENDS IN ANGLING AND PISCIVORE CONDITION FOLLOWING ELEVEN YEARS OF NUTRIENT ADDITIONS IN ARROW LAKES RESERVOIR

(ARROW LAKES RESERVOIR CREEL SURVEY 2003 – 2009)

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Executive Summary

The Fish and Wildlife Compensation Program - Columbia Basin (FWCP) is a joint initiative of the Province of British Columbia, BC Hydro, and Canada Fisheries and Oceans to conserve and enhance fish and wildlife populations affected by BC Hydro dams in the Canadian portion of the Columbia River basin. Arrow Lakes Reservoir (ALR) is influenced by Hugh Keenleyside dam (completed 1968) near the outlet of the original lakes, and by Mica (1973) and Revelstoke (1984) dams and their associated reservoirs upstream. The FWCP annually funds a large scale nutrient program and kokanee spawning channel on ALR as compensation for footprint dam impacts. Data collected through angler creel surveys are a key component of program evaluation.

Access point angler surveys have been conducted at selected ALR locations as early as 1976 to monitor the effects of BC Hydro dams and fishery compensation efforts including Hill Creek kokanee spawning channel, started in the 1980s, and the nutrient program started in 1999. These surveys provide a valuable long term index of fishing effort and harvest starting from dam construction through to 11 years after the beginning of the nutrient program. In addition to monitoring angling trends, they are useful for evaluating the response of rainbow trout and bull trout populations, which have not been monitored systematically by other methods over this period. This report provides reservoir-wide estimates of angler effort, catch and harvest for 2003 to 2009, and summarizes longer term trends (1987-2009) at three access locations to assess the performance of FWCP compensation initiatives and in particular, to compare the pre-nutrient era (1987-1998) to the eleven years of the nutrient program. Trends in relative condition factor (K_n) are also examined to evaluate the suitability of feeding conditions for apex predators, bull trout and piscivorous rainbow trout, that feed primarily on kokanee.

Creel survey data were collected at three primary access locations (Shelter Bay, Nakusp, Castlegar) for five days per month (three weekdays and two weekend/holidays). For estimation of total reservoir effort and catch from 2003 on, the monthly estimates from the three access locations were expanded using correction factors based on the ratio of access-sampled boats to total boats counted during 48 airplane flights made over the whole reservoir between April 2003 and March 2005. For longer term comparisons, the annual estimates specific to the three sampled access sites were used.

Total annual effort (± 95% confidence limits) from 2003 to 2009 ranged from 14,500 (± 2400) to 17,600 (±3,500) angler days. Annual catch (all species including released fish) ranged from 12,000 to 25,000 with harvest ranging from 8 to 12 tonnes. Angling effort out of the Castlegar access has declined by approximately 50% in recent years due to a substantial decline in the kokanee fishery. Nakusp effort increased significantly shortly after the beginning of the nutrient program and remained above the 1987-1998 range up to 2009. Shelter Bay effort has remained relatively constant since 1987. Annual expenditures wholly attributable to the fishery are about $1 million based on daily values from a federal angler survey, or $3 million including purchases partly attributable to the fishery. Residents of British Columbia comprised about 90% of anglers in all years.

Kokanee harvest from 2003-2009 ranged from 2,300 – 9,000 fish/year (300 - 1,800 kg/year) with average catch rates (CPUE) of < 0.6 fish/h. Recent harvest estimates at the monitored sites are

less than 20% of those from 1990-1996 with associated declines in kokanee-directed effort. Kokanee effort and harvest since 1998 were positively related to mean size of retained kokanee, which was larger in the early years of the nutrient program. Bull trout catch from 2003-2009 ranged from 2,600 – 3,800 fish/year, about half of which were retained for harvests of 3,300 - 5,400 kg/year; CPUE ranged from 0.06 - 0.08 fish/h. Catch of bull trout increased sharply in 2001, three years after the beginning of the nutrient program, and remained at a higher level until 2005. The increase was concurrent with a large increase in kokanee abundance, in particular older age classes, during the early years of the nutrient program. Since then, catch has declined to levels similar to pre-nutrient years, coincident with declines in kokanee spawners. Rainbow trout catch from 2003-2009 ranged from 3,900 – 6,400 fish/year; about two thirds of which were retained for harvests of 2,500 - 4,400 kg/year; CPUE ranged from 0.06 - 0.08. Harvest of piscivorous rainbow trout over 50 cm was in the range of 200-500 fish/year with a catch trend similar to that of bull trout. Hatchery stocked (clipped) bull trout and rainbow trout made up less than one percent of the harvest in most years, suggesting low survival to catchable size. Burbot comprise a much smaller, but relatively stable, fishery with catch ranging from 400 - 700 fish/year and harvest ~700 kg/year.

Mean annual condition factors (K_n) of piscivorous rainbow trout and bull trout were closely correlated ($R^2 = 0.81$), as would be expected given the similarities in diet. A period of enhanced K_n from 2002 to 2005 paralleled catch trends. Mean K_n was also positively related to several measures of fishery quality (e.g., total annual catch, catch of larger fish, CPUE) supporting the notions that: recruitment and survival of piscivores are strongly influenced by suitable feeding conditions, and angler catch trends are valid indices of piscivore abundance. Mean K_n did not appear to be related to hydroacoustic estimates of total density or biomass of all age classes of kokanee in the same year; however, relationships to kokanee spawner escapement were quite strong ($R^2 = 0.73$ and 0.60 for bull and rainbow respectively) suggesting that optimal feeding conditions are related to the abundance of larger (older) kokanee. For piscivorous rainbows, there was also some evidence of a dome-shaped relationship to prey size after accounting for spawner abundance, with optimal K_n occurring when kokanee spawner size was ~ 23 cm.

Increases in piscivore catch rate, harvest, size and condition factor suggest a strong positive response to nutrient additions reaching to the upper trophic levels during the first seven years of the program, at least in the upper basin of the reservoir. Declines in more recent years suggest trophic efficiency has been reduced, for reasons that are as yet unclear. The recent decline in kokanee angling may be related at least partially to the reduction in size and vulnerability to angling that accompanies increased density. Reductions in kokanee catch limits (from 15 to 5 since 1995) may also be a factor in the reduced effort and harvest for this species.

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The Fish and Wildlife Compensation Program - Columbia Basin is a joint initiative of the Province of British Columbia, Canada Fisheries and Oceans, and BC Hydro to conserve and enhance fish and wildlife populations affected by BC Hydro dams in the Canadian portion of the Columbia River basin. Funding is provided by BC Hydro as a requirement of their water licences for dams in the region.

Table of Contents

Executive Summary ... ii
Acknowledgements ... iv
Table of Contents ... v
List of Tables and Figures ... vi

1.0 INTRODUCTION ... 1

2.0 METHODS ... 2
2.1 Access Sampling ... 2
2.2 Overflight Boat Counts ... 5
2.3 Analyses ... 5
2.3.1 Logistical Constraints ... 5
2.3.2 Effort and Catch Estimation ... 6
2.3.3 Catch per Unit Effort and Fin Clips ... 8
2.3.4 Condition Factor of Piscivorous Rainbow Trout and Bull Trout and Relationship to Attributes of the Kokanee Population ... 8

3.0 RESULTS AND DISCUSSION ... 10
3.1 Fishery Overview ... 11
3.2 Angling Effort and Potential Expenditures ... 14
3.3 Harvest, Size Distribution, and Catch Rates ... 16
3.3.1 Bull Trout ... 16
3.3.2 Rainbow Trout ... 20
3.3.3 Kokanee ... 26
3.4.4 Burbot ... 30
3.4 Piscivore Condition Trends and Implications ... 34
3.4.1 Trends ... 36
3.4.2 Relationship to Kokanee Population Structure ... 37
3.5 Hatchery Contribution to the Fishery ... 39

4.0 CONCLUSIONS ... 42
4.1 Recommendations ... 44

5.0 REFERENCES ... 46

6.0 APPENDICES ... 50

1. Estimating the Precision of the Creel Surveys on Arrow Lake.
2. Monthly correction factors and standard errors pooled over daytypes and all years from the ratio of overflight boat counts and interviewed anglers at 3 access points.
3. Angler residence composition from 1976 to 2009.
4. Arrow Lakes creel survey annual estimates using a common monthly correction factor applied to all zones to adjust for boats returning to non-sampled access sites
5. Arrow Lakes creel survey annual estimates using separate monthly correction factors for each site/zone combination to adjust for boats returning to non-sampled access sites.
6. Size statistics for bull trout, rainbow trout, kokanee, and burbot in the Arrow Lakes Reservoir creel survey from 1998 to 2009.
7. Locations of fishing boats on Arrow Lakes Reservoir for 48 flights made between April 2003 and March 2005.

List of Tables and Figures

Table 1. Spatial and temporal strata for the Arrow Lakes Reservoir creel surveys from 2003 - 2009 3
Table 2. Sampled rod-hours, harvest, catch, and catch rates (fish/hour) of boats returning to the Edgewood and Fauquier ramps compared to Castlegar and Nakusp access locations in 1998 6
Table 3. Three measures of estimated angling effort (± 95% confidence limits) for Arrow Lakes Reservoir from 2003 to 2009 15
Table 4. Bull trout angler catch and harvest (± 95% confidence limits) statistics for Arrow Lakes Reservoir from 2003 to 2009 17
Table 5. Rainbow trout angler catch and harvest (± 95% confidence limits) statistics for Arrow Lakes Reservoir from 2003 to 2009 21
Table 6. Kokanee catch and harvest (± 95% confidence limits) for Arrow Lakes Reservoir from 2003 to 2009 27
Table 7. Estimated number of burbot caught and retained (± 95% confidence limits), percentage of fish kept, and harvested weight for Arrow Lakes Reservoir from 2003 to 2009 32
Table 8. Burbot catch rate comparison from creel surveys in four Kootenay Region Lakes.......................................32
Table 9. Comparison of Arrow Lakes Reservoir burbot harvest to other North American lakes 32
Table 10. 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 2003 to 2009 40
Table 11. Sample location, reported clip, possible year of stocking and length of marked fish in 2003 to 2009 creel surveys on ALR 41
Table 12. Summary of fish harvest from Arrow Lakes Reservoir from 2003 to 2009 42

Fig. 1. Map of Arrow Lakes Reservoir showing three sampled access locations and zone boundaries used for assigning overflight boat counts 4
Fig. 2. Proportion of angling effort (sum of sampled angler days) by species sought...11
Fig. 3. Catch of harvested and released fish by month and species at three access locations on Arrow Lakes Reservoir in 2009...13
Fig. 4. Number of angler days by month at three access locations on Arrow Lakes Reservoir in 2009. 14
Fig. 5. Trends in annual angler days for three access locations on Arrow Lakes Reservoir from 1987 – 2009. 15
Fig. 6. Trends in (a) fish harvested (b) targeted rod-hours, and (c) catch rate for bull trout from three access locations in Arrow Lakes Reservoir from 1987 - 2009...18
Fig. 7. Fork length distributions of harvested bull trout from the Arrow Lakes Reservoir creel survey from 1998 to 2009 19
Fig. 8. Trends in the (a) number of fish kept, (b) directed rod-hours, and (c) catch rate for rainbow trout from three access locations in Arrow Lakes Reservoir from 1987-2009 22
Fig. 9. Fork length distributions of harvested rainbow trout from the Arrow Lakes Reservoir creel survey from 1998 to 2009 23
Fig. 10. Number of rainbow trout greater than 50 cm sampled at three access locations during the Arrow Lakes creel survey from 1998 to 2009..25
Fig. 11. Number of rainbow trout weighed at Nakusp by size category from 1977 to 2009......................................25
Fig. 12. Trends in (a) number of fish kept, (b) directed rod-hours, and (c) catch rate for kokanee anglers from three access locations in Arrow Lakes Reservoir from 1987-2009 28
Fig. 13. Fork length distributions of harvested kokanee from the Arrow Lakes Reservoir creel survey from 1998 to 2009 29
Fig. 14. Relationship between the amount of fishing effort for kokanee and length of harvested kokanee in Arrow Lakes Reservoir from 1998 to 2009 30
Fig. 15. Trends in the (a) number of fish kept, (b) directed rod-hours, and (c) catch rate for burbot anglers from Nakusp access location in Arrow Lakes Reservoir from 1987-2009...31
Fig. 16. Length frequency distributions of burbot angled in Arrow Lakes Reservoir from 1998 to 2002 33
Fig. 17. Comparison of annual mean relative condition factor (K_n) for bull trout and rainbow trout over 50 cm in Arrow Lakes Reservoir from 1996 to 2009 34

Fig. 18. Graphs showing positive relationships between mean annual condition factor (K_n) and catch rate , total catch , and catch of larger fish for bull trout and piscivorous rainbow trout from Arrow Lakes Reservoir 1998-2009 35
Fig. 19. Mean annual (± 95% confidence limits) condition factor (K_n) relative to the average weight of pre-nutrient fish (K_n=1) for all bull trout and for bull trout over 60 cm in Arrow Lakes Reservoir from 1991 to 2009 36
Fig. 20. Mean annual (± 95% confidence limits) condition factor (K_n) relative to the average weight of pre-nutrient fish (K_n=1) for piscivorous rainbow trout in Arrow Lakes Reservoir from 1994 to 2009 37
Fig. 21. Relationships between bull trout and piscivorous rainbow trout condition (K_n) and kokanee population structure 38
Fig. 22. Residuals from linear regressions using kokanee spawner abundance to predict annual median K_n of bull trout and piscivorous rainbow trout plotted versus the average size of kokanee spawners 39

1.0 INTRODUCTION

Arrow Lakes Reservoir (ALR) extends from Revelstoke to Keenleyside Dam near Castlegar in the West Kootenay Region of British Columbia. It has a total surface area (upper and lower basins) of 46,450 ha at full pool (Pieters et al. 2003), and is affected by three dams, one at the reservoir outlet (Hugh L. Keenleyside Dam) and two upstream (Mica and Revelstoke dams). Impacts to fish populations include the loss of stream spawning and juvenile rearing habitats in the lower reaches of tributaries and upstream of Revelstoke Dam, and changes in nutrient levels, water clarity and primary productivity due to upstream dams (Matzinger et al. 2007, Moody et al. 2007, Hagen 2008, Arndt 2009a, 2009b). The fish community in ALR includes 24 species (McPhail and Carveth 1992) with the most abundant in anglers' catch being kokanee *Oncorhynchus nerka*, bull trout *Salvelinus confluentus*, rainbow trout *Oncorhynchus mykiss*, and burbot *Lota lota*. Rainbow trout occur in at least two different ecotypes, a slower growing (mostly insectivorous) form reaching a maximum length of about 45 cm, and a piscivorous ecotype that can exceed 90 cm (Arndt 2004b).

Early attempts to compensate for dam impacts focused on replacing juvenile production from lost stream habitat. Hill Creek Spawning Channel, located north of Nakusp, was started in the early 1980s to provide spawning and juvenile rearing habitat for kokanee and rainbow trout (Lindsay 1982, Barney 2009). Annual kokanee fry production from the channel has ranged from less than 1 million to over 20 million (MOE/FWCP file data). The channel also has high use by rainbow trout for spawning and juvenile rearing (Porto and Arndt 2006). A fish hatchery, operated at the same site for production of bull trout and rainbow trout, was discontinued after 2000 due to poor survival of released fish (Arndt 2004a). However, small releases of piscivorous rainbow trout were made from 1995 to 2002 by Selkirk College, and from 2005 to 2009 the Freshwater Fisheries Society of BC has released triploid rainbow trout yearlings on an experimental basis. 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 during the period covered by this study.

In 1999, another large-scale compensation project commenced to address the issue of nutrient loss in upstream reservoirs. Limiting nutrients (phosphorus and nitrogen) are distributed in the upper basin during the growing season with the goal of increasing reservoir primary productivity (Pieters et al. 2003, Schindler et al. 2006). This in turn is expected to translate into higher kokanee production and improved growth and survival of bull trout and piscivorous rainbow trout in the lake phase of their life history. Productive fish stocks are expected to provide angling opportunities and economic benefits to the local communities and province. Funding for Hill Creek Spawning Channel and the nutrient program is provided by BC Hydro through the Fish and Wildlife Compensation Program - Columbia Basin (FWCP), a joint initiative of BC Hydro, the provincial government, and Fisheries and Oceans Canada.

Angler surveys have been conducted annually at selected access points on ALR since the 1970s to monitor the effects of the dams on fish populations and recreational fisheries, and the success of compensation efforts. These surveys provide a valuable index of angling effort and harvest trends, and the only long-term data on piscivorous fish species in the reservoir. Sebastian et al. (2000) summarized creel trends to 1997 and Arndt (2002a, 2004b) from 1998 to 2002. This report provides detailed estimates of angler effort and catch from 2003 to 2009, and summarizes longer term trends starting in 1987 to allow a comparison of years before and after the beginning of the nutrient program. It differs from the previous reports in that the 2003 to 2009 access point data were expanded to whole-reservoir estimates using a correction factor based on airplane counts of the total fishing boats.[1]

Two categories of data are provided by the survey: angler effort and catch, and population metrics (size structure, condition) of the harvested species. By combining the two (changes in catch/harvest and changes in size/condition), it is possible to test hypotheses about ecosystem function and limiting factors to better understand how to optimize compensation benefits. Questions and corresponding objectives include the following:

Question	Objective
• What is the recreational, food, and approximate economic value of the ALR fishery?	Provide annual estimates of angler effort, catch, and harvest in the reservoir as a measure of recent recreational, food and economic benefits, and as a baseline for comparison to other large lakes.
• How has the fishery changed (catch, harvest, effort, catch-per-unit-effort) since the beginning of the nutrient program in 1999?	Evaluate the success of the major compensation initiatives, particularly at the upper trophic levels, over the 11 years of the nutrient program in terms of the recreational fishery.
• What fish population conditions contribute to increased angler use and community benefits, and are there other factors that could affect angler behaviour and interpretation of before/ after nutrient addition effects?	Determine the relationships between angler effort and fishery characteristics such as catch rate and size distribution of the harvest to assist with adaptive management for increased benefits. Examine changes in regulations and the potential influence on angler effort (i.e., kokanee).
• Have feeding conditions for apex predators improved since the beginning of the nutrient program?	Evaluate prey suitability for apex predators (bull trout and piscivorous rainbow trout) since the beginning of the nutrient program.
• What prey conditions seem optimal for transfer of nutrient benefits to upper trophic levels of fish production?	Investigate relationships between apex predators (abundance, size, condition) and the abundance and population structure of kokanee prey to better understand what optimizes transfer efficiency to their trophic level.

2.0 METHODS

2.1 Access Sampling

Anglers were interviewed by creel clerks at three primary access sites (Shelter Bay, Nakusp, Castlegar) for five days per month from January 2003 to December 2009 (Table 1; Fig. 1). Three weekdays (WD) and two weekend/holidays (WE) were sampled in each month. This provided coverage of approximately a sixth of the total days in the survey period including a quarter of

[1] Earlier reports either did not expand the site estimates or expanded them using a correction factor based on professional judgement.

weekend days. Sampling was randomized within the day types and sampled days were the same at all access points so that aerial boat counts could be calibrated against boats returning to the three monitored sites. In keeping with past surveys, sampled weekdays included one randomly-selected Monday in each month, although for analysis purposes all weekdays were combined (Arndt 2002a).

Creel clerks monitored the access points from two hours after official sunrise to one half hour after sunset, and the number of interviews was assumed to be the total effort for a given access point and day.[2] Interviews took place at the completion of the fishing trip. Recorded information for each angling party included start and end time of the fishing trip, fish species sought, number of fish harvested and released (by species), number of anglers and rods used, and angler residence. Fork length (FL) and weight were recorded for a subsample of harvested kokanee with the stipulation that all fish from a given boat be measured. Size measurements were recorded for all harvested bull trout and rainbow trout and all were examined for the presence of hatchery fin clips (contingent on angler permission).

At the Shelter Bay and Nakusp access sites, there is only one active boat ramp, and all returning angling parties can usually be contacted. At the Castlegar location near the south end of the reservoir, there were three ramps in close proximity up to 2008 (Scotties Marina, Syringa Marina, Syringa Provincial Park) and 2 ramps afterward (Syringa Marina closed). During winter months when angling effort is lower, complete coverage of all Castlegar ramps was possible by waiting in a vehicle at the most northerly ramp and following returning boats to other ramps if necessary. During summer high activity periods, the Castlegar clerk interviewed as many boats as possible, although it was not always possible to interview every returning party.

Table 1. Spatial and temporal strata for the Arrow Lakes Reservoir creel surveys from 2003 - 2009.

Access Location	**Description**	**Sampling Frequency**
1. Shelter Bay	Shelter Bay Provincial Park boat ramp (shifts to nearby ferry ramp if park ramp is inaccessible due to snow)	5 days per month (3 weekdays and 2 weekend/ statutory holidays)
2. Nakusp	Nakusp government wharf in the Town of Nakusp	
3. Castlegar	Scotties Marina, Syringa Marina, Syringa Park public boat launch at the south end of the lower basin of the reservoir	

[2] Start times were slightly different at the Shelter Bay boat ramp and park because it is located about one hour drive from the nearest community and required the clerk to arrive by hourly ferry. Survey start time was 8:00 AM from April to March when the Shelter Bay campsite is open, and 10:00 AM from November to March (campsite closed).

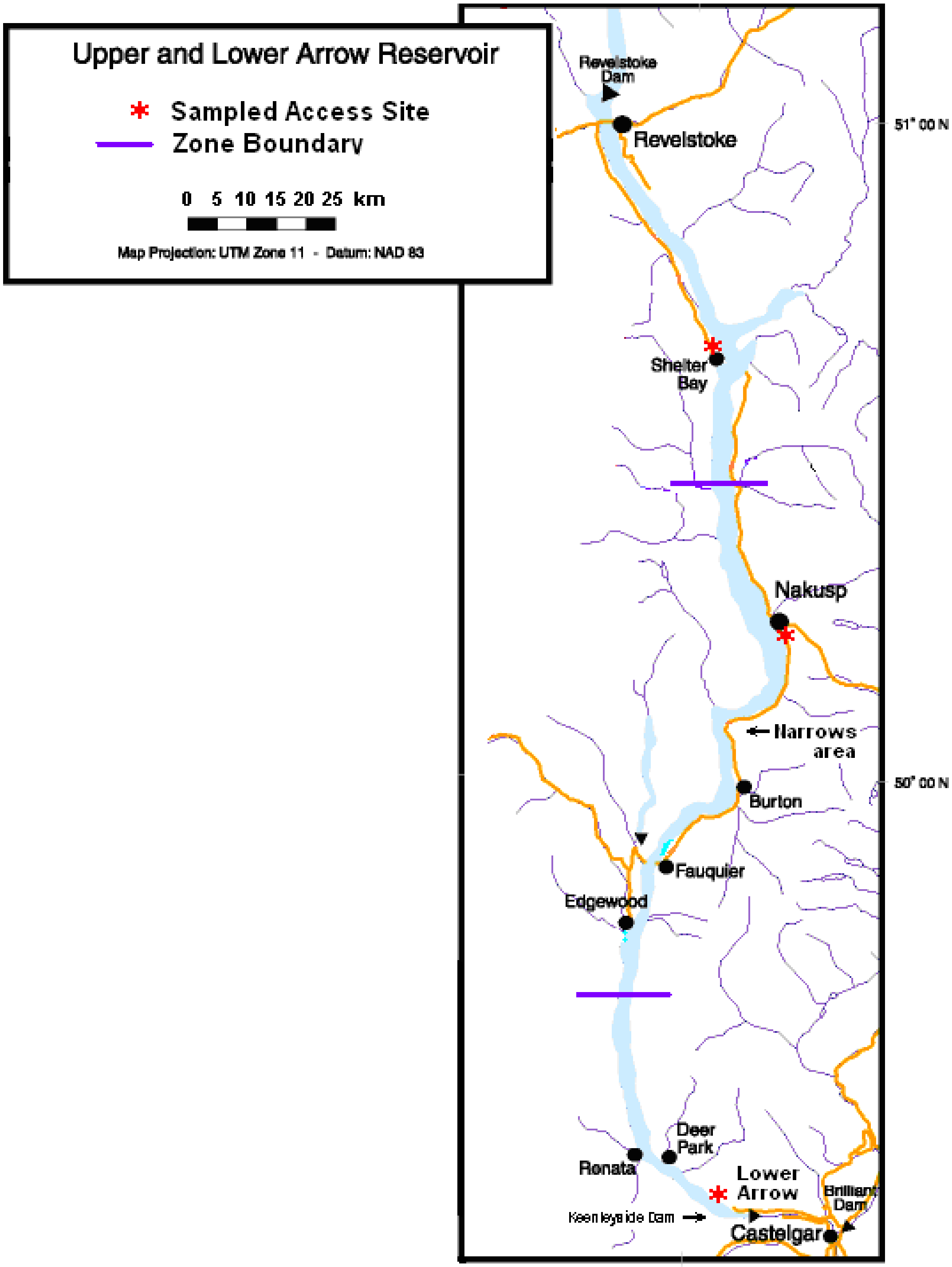

Fig. 1. Map of Arrow Lakes Reservoir showing three sampled access locations and zone boundaries used for assigning overflight boat counts. Shelter Bay zone extends from Revelstoke south to the mouth of Halfway River, Nakusp zone from Halfway River south to the mouth of Van Houten Creek, and Castlegar zone from Van Houten Creek to Keenleyside Dam. Shore angling in the northern part of Revelstoke Reach was outside the scope of the study.

2.2 Overflight Boat Counts

Forty-eight overflight boat counts were conducted between April 2003 and March 2005 (Appendix 7) on days when access interviews were also conducted. Counts were done during or near the period of peak daily angling activity (as determined in previous years) rather than randomly to reduce the likelihood of flights during periods of zero activity (Dauk and Schwarz 2001). The location of boats on the reservoir was recorded on map datasheets to allow counted boats to be assigned to three fishing zones in relation to the monitored access sites (Fig. 1). Non-fishing boats were tallied separately and not included in calculations. A large forest fire adjacent to the reservoir prevented completion of all 12 months in the 2003-04 fiscal. Under-sampled or missing months were completed in the 2004-05 fiscal such that a minimum of three flights were available for all 12 months (although in most cases the flights were done over more than one year). Flights began in Revelstoke, heading south to Keenleyside Dam and then returning. For each flight a separate count was made for the southbound and northbound flights with start and end times recorded for each. A low number of shore-based anglers were recorded during the flights (primarily in the northern end of the reservoir near Revelstoke) but this effort was considered to be outside the scope of the study since there were no interview data from this area and shore anglers are only rarely observed at the monitored sites.

2.3 Analyses

2.3.1 Logistical Constraints

Arrow Lakes Reservoir is approximately 230 km in length and is divided into two main basins by a narrows about 16 km south of the Town of Nakusp (Fig. 1). Access site creel surveys on the lakes began in 1976, but the number of sampled sites has changed periodically due to changes in funding allocations. The three public access sites used in this study have the highest usage and were sampled most years since 1978, providing a valuable long term data series on the fishery. Other private and public launch sites are used to a lesser extent because they are difficult or impossible to use at low reservoir levels, not ploughed in winter, and in more remote, less sheltered locations. Two of these (public launches at Fauquier and Burton) were sampled intermittently up to 1998, after which they were discontinued due to funding constraints and low use relative to the other sites.

Prior to the flights in this study, there was limited information on the spatial distribution of boat and shore angling in the reservoir, and it was expected that the three sampled access sites would intercept the majority of boat effort on the reservoir in most months, with relatively little angling occurring in the middle and northern parts of the lower basin that are far from the three sampled locations. Flights showed higher than expected angling effort in this area in warmer months, particularly on days of fair calm weather (FWCP file data). Access may have been from two un-monitored public launches (see below) as well as a provincial park and some private docks in the area. These non-sampled anglers complicated the analysis because the characteristics of the fishery could only be inferred from limited data collected at Edgewood and Fauquier prior to the 2003 – 2009 study period (Table 2). The data suggest that the fishery in this area is intermediate between Nakusp and Castlegar sites (i.e., kokanee catch rates were a fifth of Castlegar but ten times Nakusp, bull trout catch rates were more similar to Nakusp, and rainbow catch rates more similar to Castlegar). Therefore, if Castlegar catch rates are applied to these boats, kokanee harvest may be overestimated and bull trout underestimated, but if Nakusp catch rates are applied, kokanee and rainbow trout may be underestimated. Consequently two different methods of analysis were used as described below.

Table 2. Sampled rod-hours, harvest, catch, and catch rates (fish/hour) of boats returning to the Edgewood and Fauquier ramps compared to Castlegar and Nakusp access locations in 1998.

	Castlegar		Edgewood and Fauquier Combined		Nakusp	
	Total	**Catch rate**	**Total**	**Catch rate**	**Total**	**Catch rate**
Rod hours	2316	-	386	-	1507.5	-
Kokanee harvest	1223	0.528	44	0.114	15	0.010
Kokanee catch	1223	0.528	49	0.127	21	0.014
Bull trout harvest	31	0.013	12	0.031	63	0.042
Bull trout catch	31	0.013	14	0.036	98	0.065
Rainbow trout harvest	114	0.049	19	0.049	30	0.020
Rainbow trout catch	120	0.052	26	0.067	45	0.030

2.3.2 Effort and Catch Estimation

Angler interview data were entered into an Access database using a form specifying allowable entries for non-numeric and some numeric categories to minimize data entry errors. Further quality assurance came from examining annual maximum values for each numeric category (e.g., number of anglers and species catch per party) and verifying or correcting unusual values. Data were then transferred to SAS for estimates of effort, catch and harvest, or Systat (Version 10) for analysis of fish biometric data. SAS programming was done at Simon Fraser University. Monthly site-specific estimates (and standard errors) for angler effort, catch and harvest were computed by expanding the average for each daytype (WD or WE) in each month by the number of days of that daytype (see Appendix 1 for further description).

To obtain total monthly and annual estimates adjusted for active boats not interviewed at the sampled sites, the monthly site-specific estimates were multiplied by a correction factor derived by combining overflight boat counts with fishing times recorded in access site interviews on the same day. First, information from both daily flights (southbound and northbound) was pooled with the corresponding number of interviewed boats to compute a daily correction factor for each counted day. For example, if on the first count 10 boats were sighted from the air and 5 interviewed boats were recorded as fishing during the count, and on the return count, 5 boats were sighted and 3 were recorded as active in the interview data (the same boats could be active on both flights), the combined daily correction factor for both flights was (10+5)/(5+3) = 15/8 (Dauk and Schwarz 2001, equation 4). Daily correction factors were highly variable (especially over different seasons) but did not seem to differ between day types (WE or WD) when compared within the same month and zone so were pooled as described below.

Monthly correction factors (R) and standard errors (*se*) were computed from the daily data (pooled WE and WD) using a ratio estimator approach where the number of boats counted in the overflight divided by the number of interviewed boats active during the overflight are the Y, X data. Since we were finding a common ratio over all years for each month or month-zone combination, there were several Y,X pairs from different dates in each case, and the correction factor was calculated as sum(y)/sum(x) for the relevant pairs. For example, if there were three flights for a particular month-zone combination with (Y,X) = (10,4),(9,3),(5,3) as the data from each flight, then R = (10+9+5)/(4+3+3) = 24/10 = 2.40. The standard error of the ratio is computed as outlined in Cochran (1977; section 4.8.1).

Site-specific creel estimates (Est_{site}), $se(Est_{site})$ for angler effort, catch and harvest were combined with R, and $se(R)$ as follows to obtain expanded creel estimates (Est_{exp}) that were (approximately) adjusted for uncertainty in the correction factors:

$Est_{exp} = Est_{site} \times R$; and

$se(Est_{exp}) = \sqrt{(se(Est_{site})^2 \times R^2 + (Est_{site})^2 \times se(R)^2)}$ using the usual rule for the variance of a product of two random quantities.

Final standard errors of the expanded estimates are only approximate because the same data was used twice (in Est_{site} and the estimation of R) and there is a need to account for some covariance between the creel estimate and R. The covariance effect is likely small because the creel data is based only on the data in one year, whereas R is based on several flights possibly over three years so only a small portion of the data overlaps. Approximate 95% confidence intervals were computed as the estimate +/- 2 standard errors.

Due to the higher than expected number of un-sampled boats, especially in the northern parts of the lower basin (see Section *2.3.1*), the expanded estimates were computed in two ways (Appendices 4, 5). The first used a common correction factor for all zones that varied by month (monthly count data pooled for all years over the whole reservoir), with the exception that 1.0 was used as a minimum if the computed correction value was < 1.0 (Appendix 2). For example, in January, the computed correction factor was 0.76 but 1.0 was used so the estimates would not be reduced from the site-specific creel estimates initially produced. For February, the correction factor was 1.56, so all site-specific estimates for February were multiplied by 1.56. The use of 1.0 as a minimum expansion factor assumes that the error was in the overflight count if it was less than the number of active interviewed boats (i.e., boats were in locations where the flight observer did not see them). In all other cases (i.e., where the computed ratio was > 1.0) we assumed that observer efficiency in the overflight was 100%. Standard errors from the expanded monthly estimates were then pooled to yearly estimates with uncertainty bounds including the correction factor using the rule for the standard error of a sum of independent estimates: $se(est_1 + est_2) = \sqrt{se(est_1)^2 + se(est_2)^2}$.
Because this method applies the same correction factor to all site-specific estimates, it in effect assumes that the effort and catch characteristics of unsampled fishing boats were proportional to the three sampled sites.

The second analysis method applied separate correction factors to each zone in each month (pooled over all years; Appendix 2). Because the correction factor when applied to all zones is not the simple average of the 3 zones, the results may not be consistent when aggregated up. For example, the estimated total for all zones when pooling over the access sites may be different than the sum of the estimated total of Castlegar + Nakusp + Shelter Bay estimates (Appendix 5). The difference is usually small and is an artefact of the small sample sizes. Similarly, when pooling over the three zones, the correction factor will tend to have a smaller standard error than the separate correction factor for the individual zones and so the *se* of the pooled total may be considerably less than the individual *se*'s from each zone).

This dual approach (i.e. compute an estimate using the pooled sites and then compute separate estimates for each site) was used because the zones were mostly measured on the same day and the same overflights were used for the individual zone correction factors. Consequently, there is no simple way compute the correct standard errors that takes into account data that is reused in the estimates from each site.

A key assumption of the aerial-access survey methodology is that the catch characteristics of boats from the closest sampled site are representative of all boats in the associated zone. However, as noted above (Section 2.3.1) there were in some cases a fairly high proportion of boats fishing in areas remote from the sampled sites (especially for zone 3) that may have different catch statistics. The separation of the data into three basins may give a more accurate estimation of the spatial distribution of the effort (by zone), although estimates of the uncertainty for the estimates at the reservoir lake total are not easily computed.

In both cases above, we assumed that the expansion factor calculated from the 2003-2005 overflights could be applied up to 2009. Although this cannot be verified since there were no overflights after 2005, there were no significant changes in the number or quality of available boat ramps on the reservoir between 2003 and 2009 to our knowledge. Upgrades to several ramps are scheduled for 2010 as part of BC Hydro Water Use Plan commitments, and it will be necessary to reassess the relationship between sampled and total fishing boats for future creel surveys on ALR.

2.3.3 Catch per Unit Effort and Fin Clips

To track angler success rates over time, the mean annual catch rate (fish per hour) was determined for each access point/species combination using the ratio of means method, as recommended by Malvestuto (1996) for access surveys. Number of fish caught was divided by the total hours of targeted effort for that species. If 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 of angling effort seeking bull trout and rainbow trout, the 5 hours were included for both species totals. This results in lower catch rates than if the hours were divided between the species, but avoids arbitrary proportioning of hours between species.

For years prior to 1998 released fish were not recorded, therefore the catch rate includes kept fish only and is designated as harvest-per-unit-effort (HPUE). From 1998 on, released fish were recorded and both HPUE and catch-per-unit-effort (CPUE) including released fish were calculated. Early HPUE values may actually be quite comparable to more recent CPUE, because few fish were released prior to the late 1990s (Glen Olson, creel technician, 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).

2.3.4 Condition Factor of Piscivorous Rainbow Trout and Bull Trout and Relationships to Attributes of the Kokanee Population

To evaluate the effects of nutrient additions on prey availability at upper trophic levels, changes in size structure and length-weight relationships were investigated for bull trout and piscivorous rainbow trout, the apex predators in the ALR feeding primarily on kokanee (Arndt 2004b). Fish condition indices (weight at a given length) are an indicator of body lipid content and are frequently used to make inferences about feeding conditions and predator-prey dynamics (Weatherley and Gill 1987, Liao et al. 1995, Blackwell et al. 2000, VanDeValk et al. 2008).

Diet studies in ALR have shown that rainbow trout over 50 cm feed almost exclusively on kokanee, whereas angled rainbow trout below this threshold are mostly a slower-growing, primarily insectivorous ecotype with a lower condition factor (Arndt 2004b). Therefore only rainbow trout over 50 cm were used for evaluating prey availability. Annual totals of sampled fish >50 cm were also used as an index of piscivorous rainbow harvest (although it is recognized that the harvest of fish < 50 cm includes an unknown number of immature piscivores).

This study used the relative condition factor (K_n) described by Anderson and Neumann (1996) as an index of "fatness" where:

$$K_n = (W/W'),$$

W is the weight of an individual fish, and *W'* is the length-specific mean weight for that fish as predicted by a weight-length equation for a reference population. The reference population used for this study was fish sampled prior to the beginning of the nutrient addition program in 1999. The practical advantage of K_n is that it compensates for allometric growth; although K_n can change with size, average fish of all lengths have a value of one in relation to the reference population. Furthermore, by using pre-nutrient-addition fish as the reference population, the meaning of an increase or decrease is easily interpreted. For example, a fish with K_n of 1.20 is 20 percent heavier than the average pre-nutrient fish of that length.

Length-weight data for the period prior to the beginning of the nutrient program were obtained from archived creel survey datasheets (1994 to 1997) and the existing FWCP creel database (1998). Additional length-weight records were obtained from a bull trout diet study done in 1991-1993 (MOE/FWCP data on file). All post-nutrient data were from the FWCP database. Annual length-weight plots were first visually examined to detect and eliminate obvious errors prior to analysis, after which the seasonal pattern in the length-weight relationship was examined using monthly box plots of Fulton's condition factor *K* (Anderson and Neumann 1996). For piscivorous rainbow trout there was evidence of a significant post-spawning effect in the months of June and July; consequently fish caught in these months were excluded from further analyses. For bull trout, a post-spawning decline in condition was not evident, so all months were retained in the dataset.

A total of 747 pre-nutrient samples were available for bull trout representing the years from 1991 to 1998. Annual sample size varied from 33 to 190, and the slope of the length-weight relationship calculated for each year ranged from 2.57 to 3.28. In order to derive a pre-nutrient equation that was not unduly biased by the un-equal annual sample sizes, length-weight equations for each year were used to generate predicted weights for the smallest and largest lengths in the sample and each 10 cm interval between. Resulting lengths and predicted weights were then used together to compute a pre-nutrient reference equation for bull trout: $W' = 0.0099(FL)^{3.006}$, R^2=0.99. A slope of 3.0 indicates that shape does not change as the fish grows, whereas slope > 3.0 indicates fish are becoming more rotund as length increases and < 3.0 indicates becoming less rotund as length increases (Anderson and Neumann 1996). Sebastian et al. (2000) reported a similar equation of $W = 0.012(FL)^{2.96}$ using a sample of 341 bull trout collected from 1987 – 1997. For piscivorous rainbow trout, only two pre-nutrient years had samples of ≥ 5 and the range of lengths was too small to be representative for most years. Therefore length-weight equations for 1997 (n=26) and 1998 (n=13) were used as above to derive a reference equation of: $W' = 0.0034(FL)^{3.3028}$, R^2=0.99.

Using the above reference equations, the relative condition factor K_n was computed for each individual bull trout and rainbow trout and yearly mean and median K_n calculated for each of the years in the study. For analysis of post-nutrient trends, K_n samples from upper and lower basins were pooled due to small sample sizes from the lower basin site. Telemetry studies on piscivorous rainbow trout in nearby Kootenay Lake (Andrusak and Thorley 2010) indicate these fish are highly mobile and hence more likely to move between the two basins over the course of a year. Bull trout movement may be more restricted in large reservoirs (Andrusak and Thorley 2010), but the majority of bull trout weight samples for bull trout were from the upper basin. Due to the larger sample size for bull trout, K_n was summarized in two categories: all bull trout, and bull trout over 60 cm. Comparisons of K_n to other parameters (angling effort, harvest, kokanee size and abundance) were made initially using simple x-y plots and lines of best fit in Excel.

Further investigation of the relationship between K_n and kokanee spawner abundance and size was done as follows. The yearly mean or median K_n for each species was regressed against an index of kokanee spawner abundance in ALR, or the spawner index for upper basin streams only, or the mean length of spawning kokanee in the same year (linear and quadratic models), or a combination of spawner abundance and length. Models for the four combinations of mean/median and species (bull, rainbow) were ranked using the Akaike Information Criteria (AIC) corrected for small sample size (Akaike, 1974; Burnham and Anderson, 2002) and model weights computed. The AIC paradigm ranks the models on the tradeoff between fit (smaller residuals) and complexity (number of parameters) and can be used to rank and compare non-nested models (e.g. using the two indices). Given the limited number of years of data available (16 for bull trout; 13 for rainbow trout), only these very simple models were considered. Residual plots and other diagnostic plots were examined to check that the assumptions of the models were satisfied.

3.0 RESULTS AND DISCUSSION

A total of 5,802 angler parties were interviewed from 2003 to 2009, ranging from 779 to 911 per year. The monthly ratio of overflight boat count/interviewed boats active at the time of the flight varied from 1.00 to 2.82 and was highest from June to August when additional access points were used by more anglers (Appendix 2). Fishing boats were distributed throughout the reservoir but the majority were typically within 20 km of a monitored access location (Appendix 7). On some dates there were a number of boats in the middle and northern parts of the lower basin far from any sampled access; however, these typically comprised less than 10% of either the middle or lower zone counts on a given day, and rarely made up 30% of either zone. Since this is a relatively low proportion of the total effort, the lack of sampling between Deer Park and the narrows should not cause a strong bias of the overall results (also see Table 2, Section *2.3.1*).

Annual effort and catch estimates presented in this section for the whole reservoir from 2003 to 2009 are based on the expansion using a common correction factor for all three zones that varied by month. Expanded estimates using the above method and using separate correction factors for each zone by month are provided in Appendices 4 and 5.[3] For comparing long term trends including years prior to the nutrient program, only the site-specific estimates (Est_{site}) for boats returning to Shelter Bay, Nakusp, and Castlegar are used, because the applicability of the overflight correction factor for missed boats becomes less certain as time increases from the flight years. Site-specific data for 1987-1997 are from MFLNRO/FWCP files and 1998-99 from Arndt (2002a).

[3] Expansion using separate correction factors by zone (Appendix 5) gives slightly higher angler effort totals and higher kokanee catch estimates. See section *2.3.1* for details.

3.1 Fishery Overview

The recreational fishery in ALR is focused primarily on rainbow trout, bull trout, and kokanee with a small component of burbot (Figs. 2 and 3). Other species (e.g., whitefish, *Prosopium* spp., northern pikeminnow, *Ptychocheilus oregonensis*) are occasionally reported but insignificant to harvest or effort. Rainbow trout effort and harvest includes anglers targeting the smaller ecotype (often combined with kokanee) and those seeking piscivorous rainbow trout (often combined with bull trout). Trolling is the favoured method of fishing for larger rainbows and bull trout, and for kokanee and smaller rainbows. Some fly and spin casting occurs at stream mouths for rainbow trout, and burbot fishing is typically by jigging. The majority of kokanee angling occurs in the lower basin, although in 2001 a large component of kokanee angling occurred in the upper basin when the kokanee season was first re-opened in the early years of the nutrient program. In that year, kokanee in the upper basin were larger than they have been in most recent years (Section *3.3.3*) and half of the measured kokanee effort was from Nakusp (Arndt 2004a).

Proportion of catch by species varied among the monitored access locations (Fig. 3). Shelter Bay was dominated by bull trout and rainbow trout with a small proportion of kokanee. Castlegar was primarily kokanee with a small percentage of rainbow trout and bull trout. Nakusp had the most diverse fishery with the four main species represented at significant levels; rainbow trout and bull trout combined made up about half or more of the catch in all months, with kokanee comprising about half during May to August, and a smaller proportion of burbot present in all months.

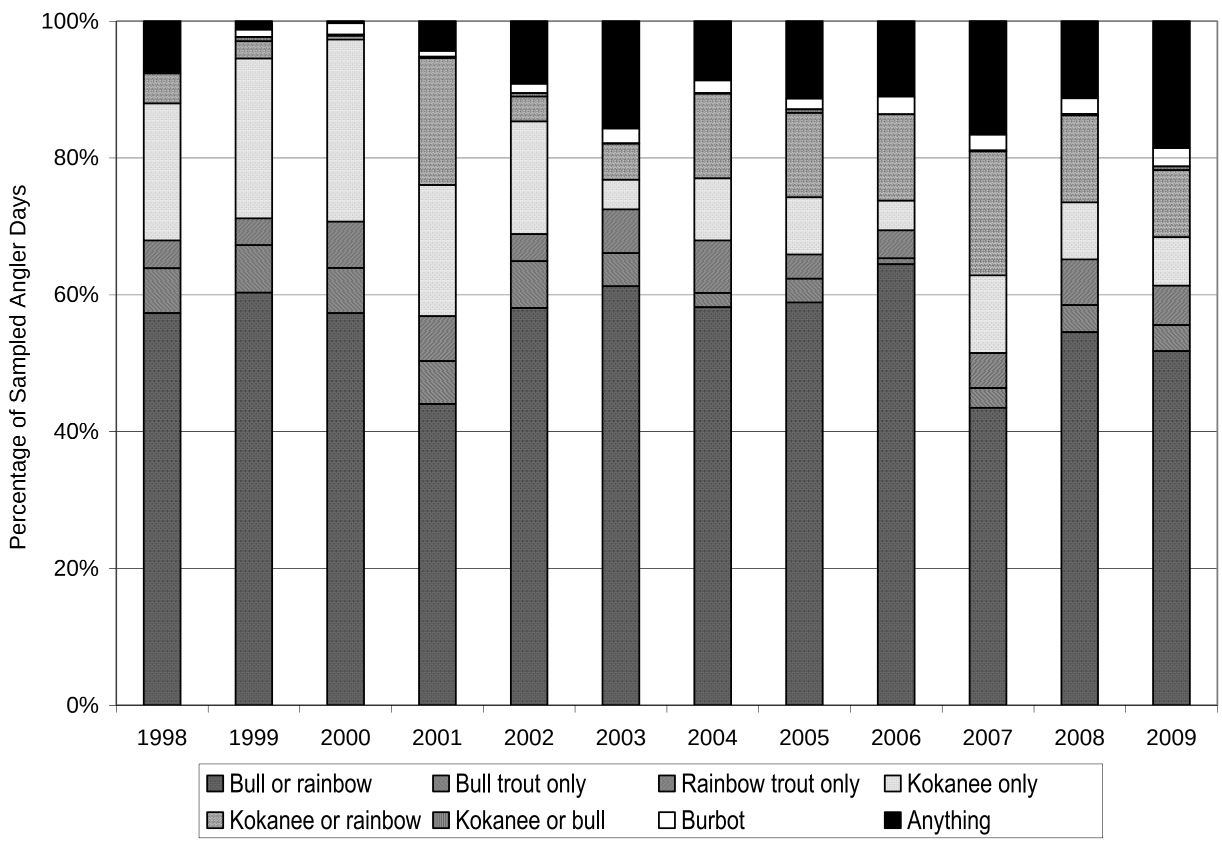

Fig. 2. Proportion of angling effort (sum of sampled angler days) by species sought for anglers sampled at three access locations in Arrow Lakes Reservoir from 1998 to 2009. The kokanee season was closed in the upper basin (Shelter Bay, Nakusp) in 1999 and 2000.

Fishing occurred year round (Figs. 3 and 4) with effort and catch in warmer months targeted more towards kokanee and smaller (non-piscivorous) rainbow trout, and fall and winter anglers targeting mainly larger rainbows and bull trout. Bull trout fishing was mainly from September to May with the majority of recorded catch coming from Nakusp and Shelter Bay in the upper basin of the reservoir (Fig. 3). Piscivorous rainbow trout catches occurred mainly from the fall through to February although some were caught in all months of the year; again the majority were recorded at upper basin sites. Almost all reported burbot catch was from the Nakusp area.

The number of anglers interviewed per year (including repeat contacts) ranged from 1,535 to 1,896 between 2003 and 2009. About 90% were BC residents, with non-resident Canadians making up most of the remainder and persons from outside Canada about 1%. Nakusp typically had the highest percentage of anglers from outside of the province (8-20%), likely because of local charter fishing operations and hot springs resorts nearby. These results are similar to long term trends except that the percentage of non-resident Canadians was about 10% across all sites in the 1980s and early 1990s (Appendix 3).

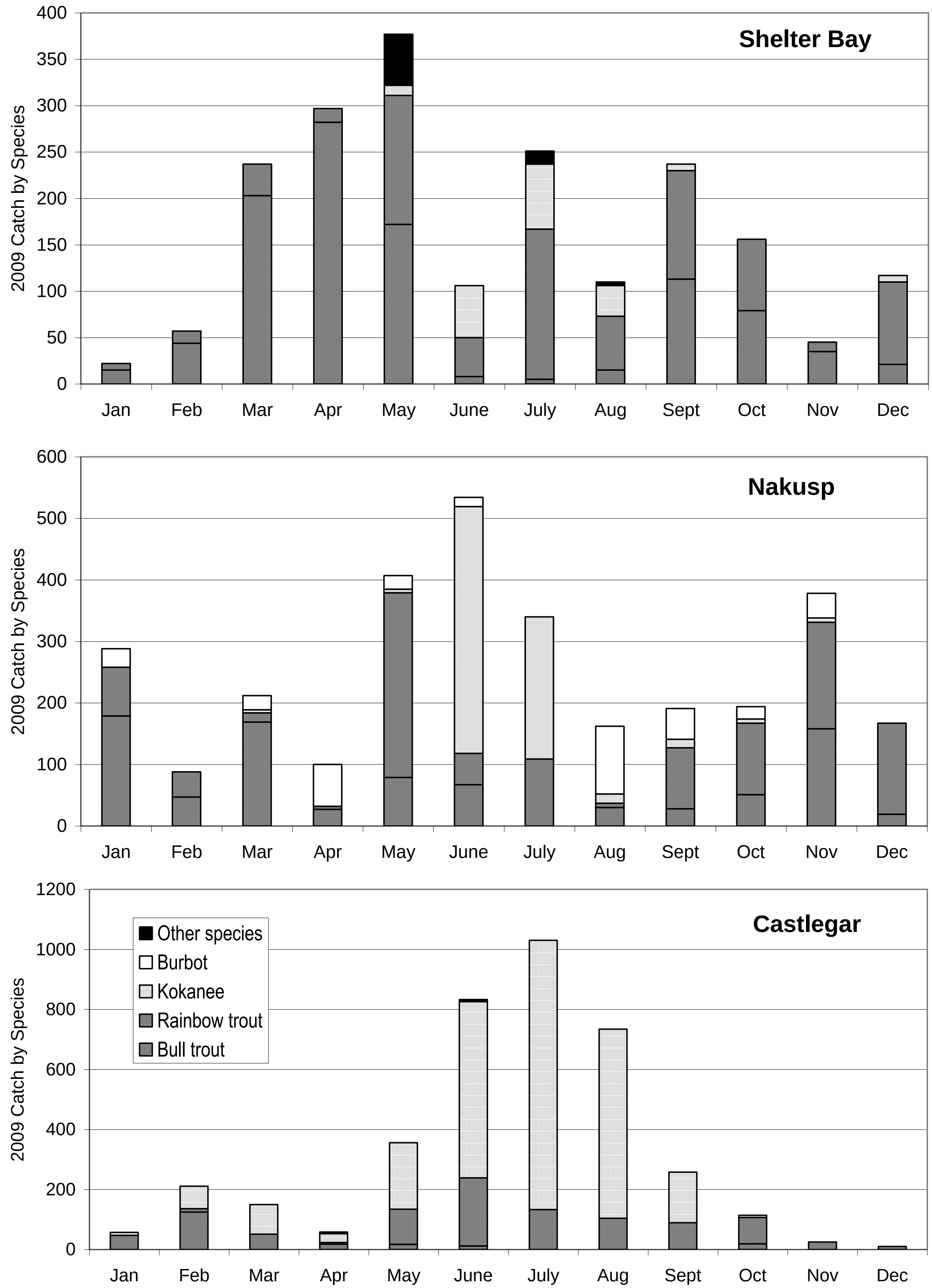

Fig. 3. Catch of harvested and released fish by month and species at three access locations on Arrow Lakes Reservoir in 2009.

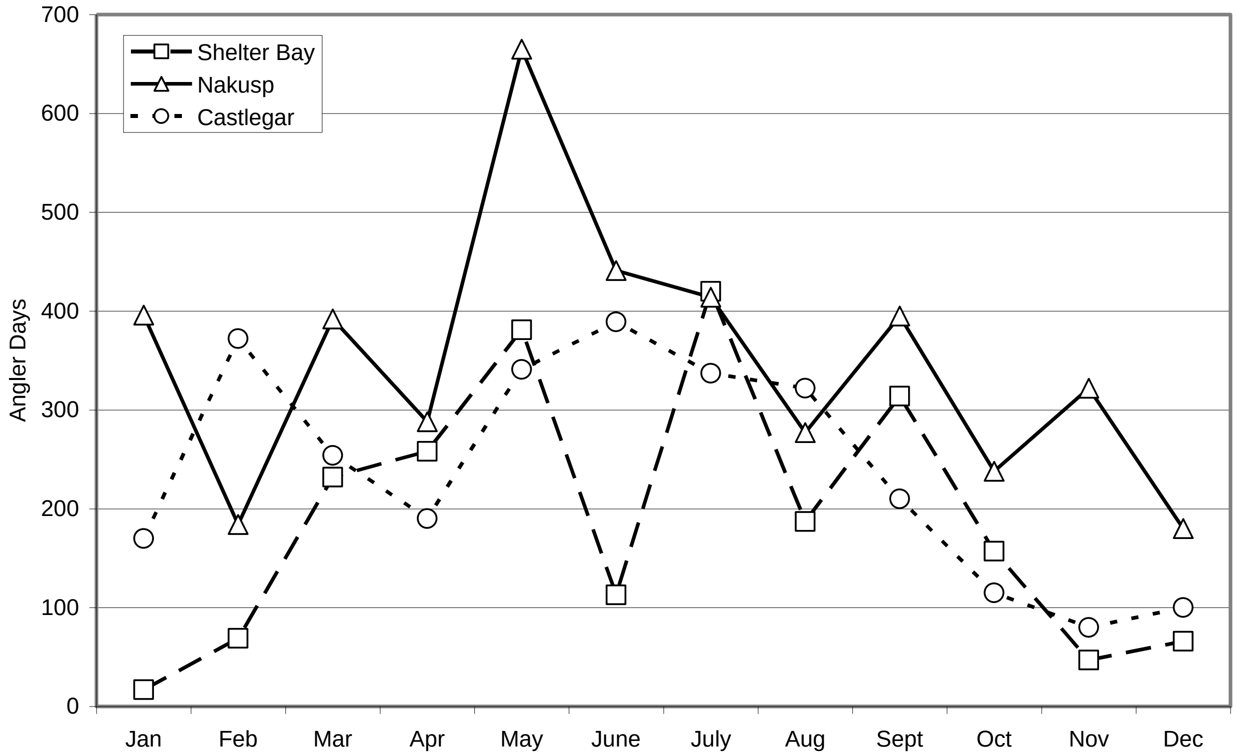

Fig. 4. Number of angler days by month at three access locations on Arrow Lakes Reservoir in 2009.

3.2 Angling Effort and Potential Expenditures

Total angling effort estimates for the reservoir between 2003 and 2009 ranged from 14,500 to 17,600 angler-days, and 74,000 to 89,000 rod-hours (Table 3). Using average angler-day values from the Survey of Recreational Fishing in Canada (Canada Fisheries and Oceans 2005), annual economic activity related to the ALR fishery is estimated at ~ $0.8 million for direct expenditures (transportation, food, lodging, fishing services and equipment) and $3.0 million including major purchases wholly or partly attributable to recreational fishing (fishing, boating and camping equipment, special vehicles, land, buildings).[4] This estimate of direct expenditures is almost certainly low for ALR, because the average value in the federal survey ($51/day) includes anglers fishing from shore and in small lakes and rivers that do not require motorized boats. The ALR survey is comprised mainly of boat anglers almost all of which require fuel for transportation to the reservoir as well as for fishing once on the water. The size of the reservoir requires boats capable of handling rough waves and reaching shelter quickly unless fishing very close to an access point.

[4] Average direct ($51.38) and total ($171.41) expenditures per angler day were calculated from the total number of freshwater fishing days reported for British Columbia non-resident and resident anglers and "direct recreational fishing expenditures" and "major purchases and investments wholly or partially attributable to recreational angling" in the *Survey of Recreational Fishing in Canada in 2005* (Canada Fisheries and Oceans. 2005; http://www.dfo-mpo.gc.ca/stats/rec/can/2005/index-eng.htm, accessed May 26, 2010).

Table 3. Three measures of estimated angling effort (± 95% confidence limits) for Arrow Lakes Reservoir from 2003 to 2009. Rod-hours are higher than angler-hours because a single angler in a boat is permitted to use up to two rods.

Year	Angler-days	Angler-hours	Rod-hours
2003	14,500 (± 2,400)	68,300 (± 12,200)	74,100 (± 12,900)
2004	17,600 (± 3,500)	83,400 (± 16,100)	89,300 (± 17,000)
2005	15,900 (± 2,900)	76,800 (± 15,000)	81,900 (± 16,000)
2006	14,600 (± 3,000)	72,600 (± 15,100)	74,700 (± 15,500)
2007	16,800 (± 3,300)	82,100 (± 17,200)	82,600 (± 16,600)
2008	15,200 (± 3,100)	69,700 (± 13,500)	72,800 (± 13,800)
2009	15,400 (± 2,800)	77,000 (± 14,500)	77,900 (± 14,300)

Long term trends at the three monitored access locations show a significant increase in angler effort at Nakusp since the beginning of the nutrient program in 1999, relatively stable effort at Shelter Bay, and a substantial decline at Castlegar (Fig. 5). Considering the three sites together, recent angler effort has been below 1987 to 1995, but higher than the years just prior to nutrient additions. Effort changes are most likely related to differences in the quality of the primary fisheries out of these locations as is discussed below by species but may also be influenced by regulation changes over this period, particularly for kokanee (section *3.3.3*).

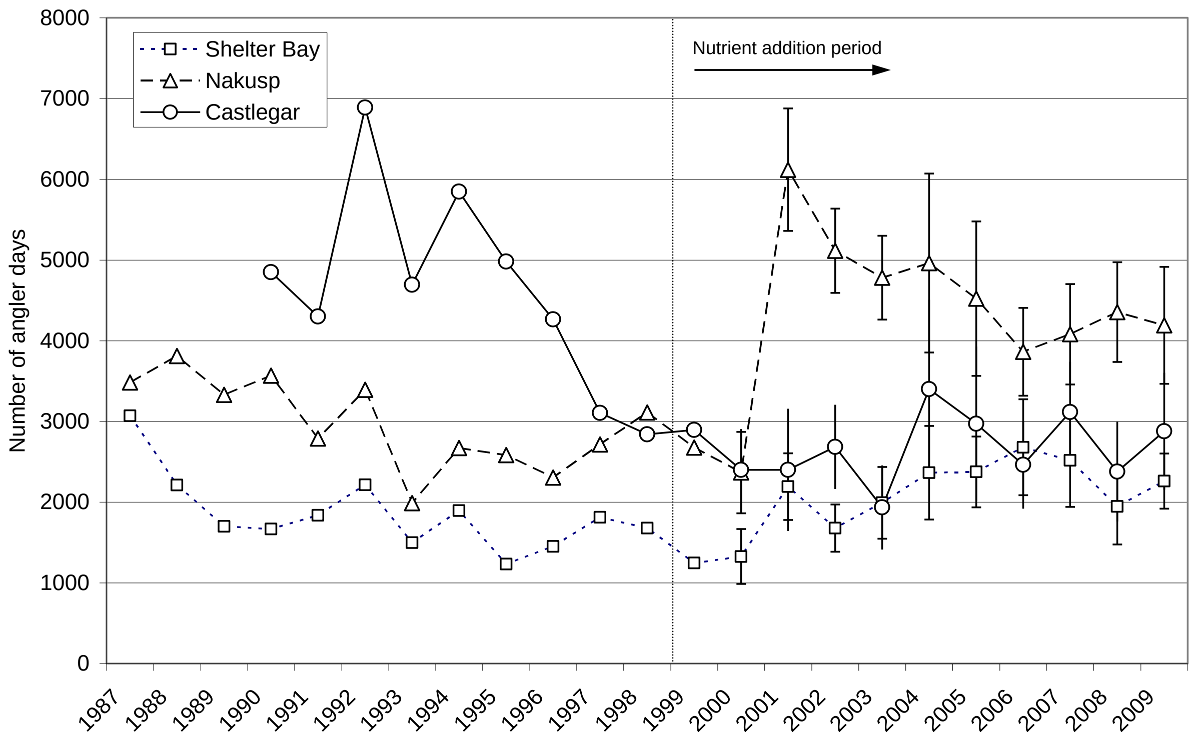

Fig. 5. Trends in annual angler days for three access locations on Arrow Lakes Reservoir from 1987 – 2009. Bars indicate 95% confidence limits starting in 2000. Castlegar records were not available for 1987-1989.

3.3 Harvest, Size Distribution, and Catch Rates

3.3.1 Bull Trout

Annual catch of bull trout in the reservoir ranged from 2,600 to 3,800 fish between 2003 and 2009, slightly more than half of which was retained resulting in harvest estimates of 3,300 – 5,400 kg/year (0.07 – 0.12 kg/ha) (Table 4). Longer term trends (Fig. 6) for the three sampled locations show bull trout harvest was lowest in 1989-1990 and 1999. Harvest increased sharply after the beginning of the nutrient program, peaked from 2001 to 2005, and then declined to levels similar to the pre-nutrient levels (Fig. 6a). Although released fish were not recorded prior to 1998, it is likely that the percentage of fish harvested was closer to 100% in the late 1980s and early 1990s than it currently is (50-60%). This implies that the proportional increase in catch (including kept and released fish) in the post-nutrient years could be greater than the available harvest data shows. A shift has occurred in the location of the harvest and targeted effort, with Nakusp being much more dominant in the post-nutrient years and decreases at Castlegar and Shelter Bay (Fig. 6a,b). Overall effort for bull trout has been slightly higher since 1999 for the three sites combined.

Catch rate (CPUE, HPUE; Fig. 6c) increased at the two upper basin sites (Shelter Bay and Nakusp) starting in 2001, but remained relatively stable and low at Castlegar, assuming that the majority of bull trout were retained before 1998 (i.e., assuming HPUE in early years is comparable to recent CPUE). Therefore the increased bull trout effort in the upper basin is likely related to improved catch rate there. The effort decrease in Castlegar does not seem to be related to a significant decrease in the catch rate using the available data. A CPUE of 0.06 to 0.08 fish/rod-hour in ALR (all sites combined, Table 4) equates to 12 to 16 rod-hours of effort to catch a bull trout. This is less than reported for bull trout in Revelstoke Reservoir (0.14 fish/rod-hour in a May to September creel survey in 2000 (Bray and Campbell 2001)[5], but similar to a September to March survey on Kootenay Lake (daily range of 0.06 – 0.15 fish/hour; Schwarz 2010).

Length frequency distributions of bull trout (Fig. 7) show recruitment into the fishery occurs at a length of 40-50 cm with most harvested fish in the 50-70 cm range. Shifts in size distributions since 1998 suggest changes in recruitment, mortality, and/or growth rates over the last 12 years. Average weight of retained fish is typically 2.0 - 2.5 kg with some fish over 10 kg in 2001 and 2004 (Appendix 6).

[5] 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).

Table 4. Bull trout angler catch and harvest (± 95% confidence limits) statistics for Arrow Lakes Reservoir from 2003 to 2009.

Year	**Number Caught**[1]	**Number Kept**[1]	**% Kept**	**Harvest**[2] **(kg)**	**CPUE**[3] **(fish/h)**
2003	3,800 (± 800)	2,000 (± 400)	53	4,500	0.081
2004	3,400 (± 800)	2,000 (± 500)	59	5,400	0.065
2005	3,300 (± 800)	1,900 (± 500)	58	5,000	0.069
2006	3,600 (± 900)	1,800 (± 500)	51	4,400	0.075
2007	3,000 (± 700)	1,800 (± 400)	61	4,200	0.067
2008	2,600 (± 700)	1,400 (± 400)	55	3,300	0.064
2009	2,900 (± 700)	1,600 (± 400)	56	4,100	0.061

[1] Estimates are expanded to whole reservoir using overflight boat counts as described in Methods, therefore are higher than the sum of the three sites shown in Figure 6.
[2] Number kept x mean weight of sampled fish.
[3] Three sampled locations combined.

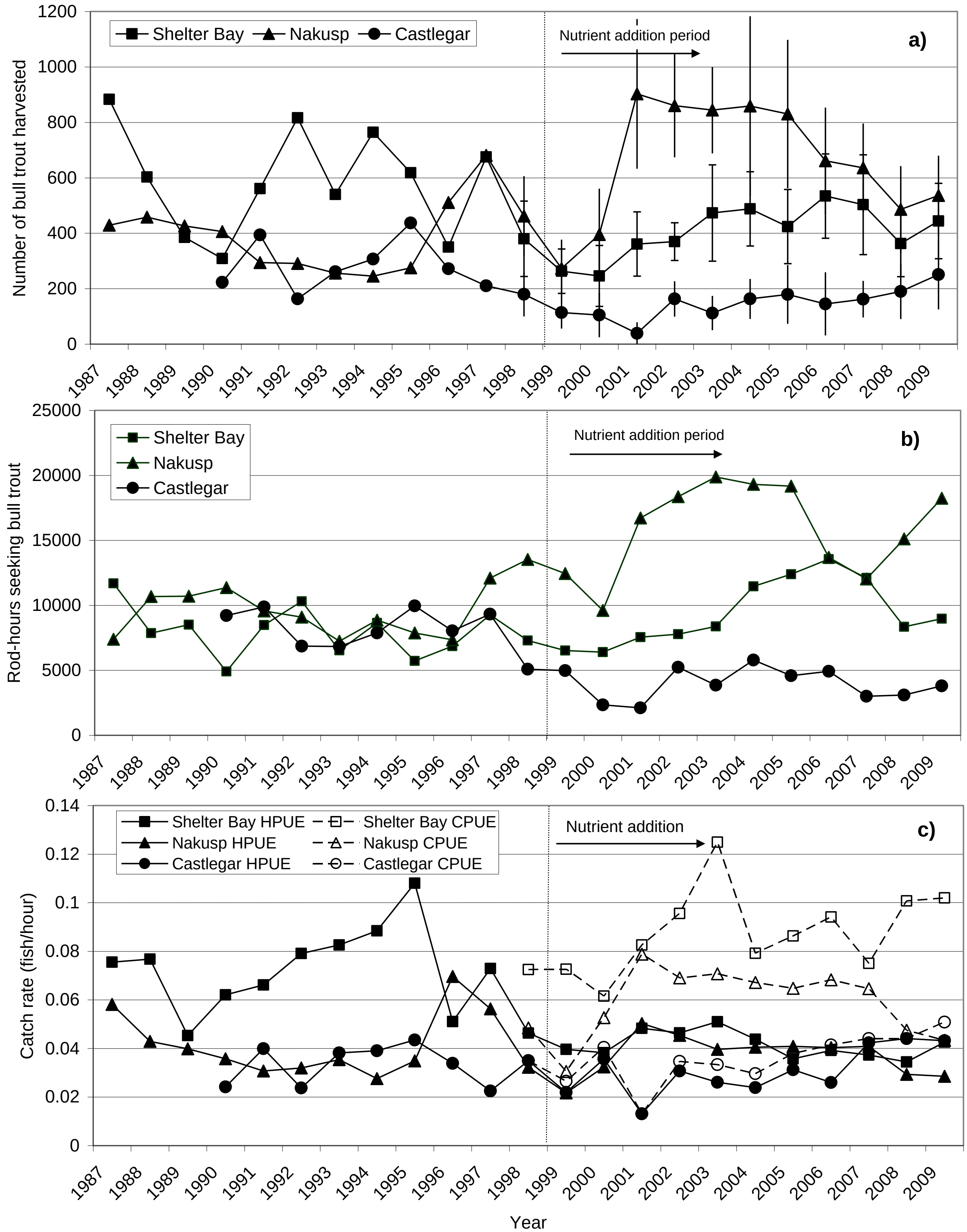

Fig. 6. Trends in (a) fish harvested (b) targeted rod-hours, and (c) catch rate for bull trout from three access locations in Arrow Lakes Reservoir from 1987 - 2009. Bars around harvest estimates after 1998 indicate 95% confidence limits. Catch rate after 1998 is shown for both harvested fish only (HPUE) and for harvested and released fish combined (CPUE). Castlegar records are not available for 1987-1989. Data to 1997 are from MFLNRO/FWCP files and 1998-99 from Arndt (2002a).

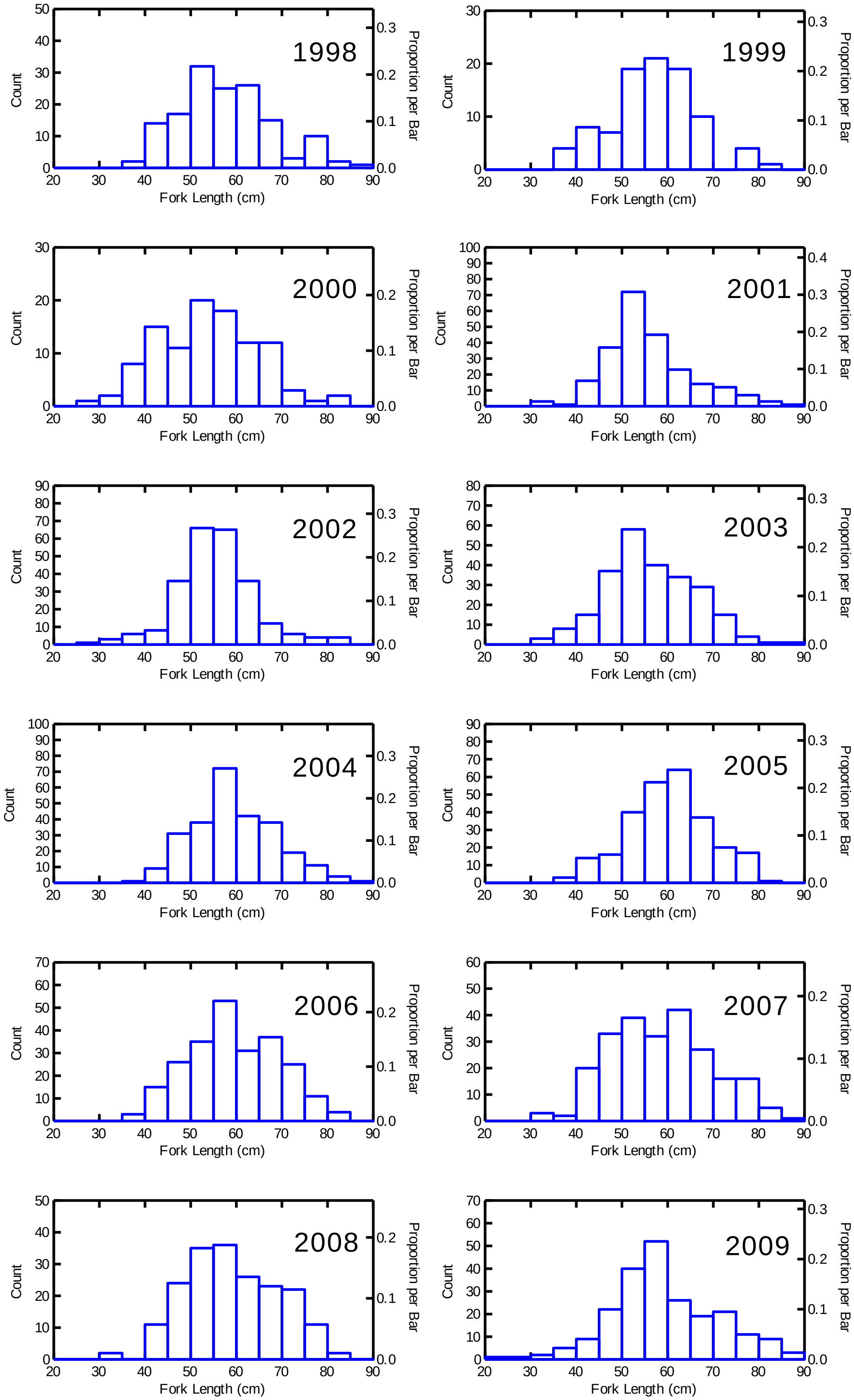

Fig. 7. Fork length distributions of harvested bull trout from the Arrow Lakes Reservoir creel survey from 1998 to 2009.

3.3.2 Rainbow Trout

Annual catch of rainbow trout ranged from 3,900 to 6,400 fish over the 2003 to 2009 period, about two thirds of which was retained, resulting in a harvest by weight of 2,500 – 4,400 kg/year (0.05 – 0.09 kg/ha) (Table 5). Long term trends at the three sampled locations are similar to bull trout with a drop in harvest in the late 1990s followed by a peak in both harvest and directed effort between 2001 and 2005 (Fig. 8a,b). Recent harvest levels (three sites combined) are slightly less than 1987 to 1996, with Nakusp being the dominant location both before and after 1999 (Fig. 8a). Post-1999 rod-hours for rainbow trout in the upper basin locations (especially Nakusp) were well above the pre-nutrient years during 2001-2005 and remain so up to 2009 although they have dropped slightly (Fig. 8b). As previously mentioned, data on released fish are not available prior to 1998, but it is likely that the percentage of fish harvested was closer to 100% in the late 1980s and early 1990s than it currently is (65-75%). This implies that the total rainbow trout catch in the post-nutrient years (including kept and released fish) might be more similar to the pre-nutrient period than harvest trends show.

Interestingly, catch rates for rainbow trout have decreased in the post-nutrient years for the Nakusp site from ~0.15 to 0.05 fish/rod-hour (Fig. 8c), while rainbow-directed rod-hours have increased (Fig. 8b). The other two locations have remained relatively stable at 0.03 – 0.08 fish/rod-hour except for a peak in 2000-2001 (Fig. 8c). Catch rates for the three sites combined (Table 5) are similar to Revelstoke Reservoir where rainbow trout CPUE was 0.07 fish/hour in 2000 (Bray and Campbell 2001).[6] The lack of a relationship between rainbow trout catch rate and directed fishing effort, particularly in Nakusp, is probably because the available data cannot distinguish between effort targeted at piscivorous rainbow trout and effort for the smaller ecotype. Catch rates for the larger ecotype are typically much lower than for the smaller fish; therefore an increase in piscivore catch (such as occurred from 2002-2005, see below) can stimulate a significant increase in directed effort for the species, which lowers overall catch rate.

Length frequency distributions (Fig. 9) show recruitment to the fishery begins at a length of 20 cm with most harvested fish in the 30-45 cm range. Average weight of retained fish is typically 0.6 - 1.0 kg with some exceeding 10 kg in 2004 (Appendix 6b).

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

Table 5. Rainbow trout angler catch and harvest (± 95% confidence limits) statistics for Arrow Lakes Reservoir from 2003 to 2009.

Year	**Number Caught**[1]	**Number Kept**[1]	**% Kept**	**Harvest**[2] **(kg)**	**CPUE**[3] **(fish/h)**
2003	3,900 (± 1,000)	2,800 (±900)	72	3,200	0.056
2004	6,400 (± 1,500)	4,200 (± 1,200)	66	4,400	0.064
2005	5,100 (± 1,500)	3,300 (± 1,100)	64	3,200	0.063
2006	5,400 (± 1,500)	3,600 (±1,200)	67	2,500	0.067
2007	5,400 (± 1,100)	3,800 (± 1,000)	71	2,600	0.076
2008	5,000 (±1,600)	3,700 (± 1,400)	74	3,300	0.073
2009	4,500 (± 1,100)	3,200 (± 800)	71	3,000	0.060

[1] Estimates are expanded to whole reservoir using overflight boat counts as described in Methods and are therefore higher than the sum of the three sites shown in Figure 8.
[2] Number kept x mean weight of sampled fish.
[3] Three sampled locations combined.

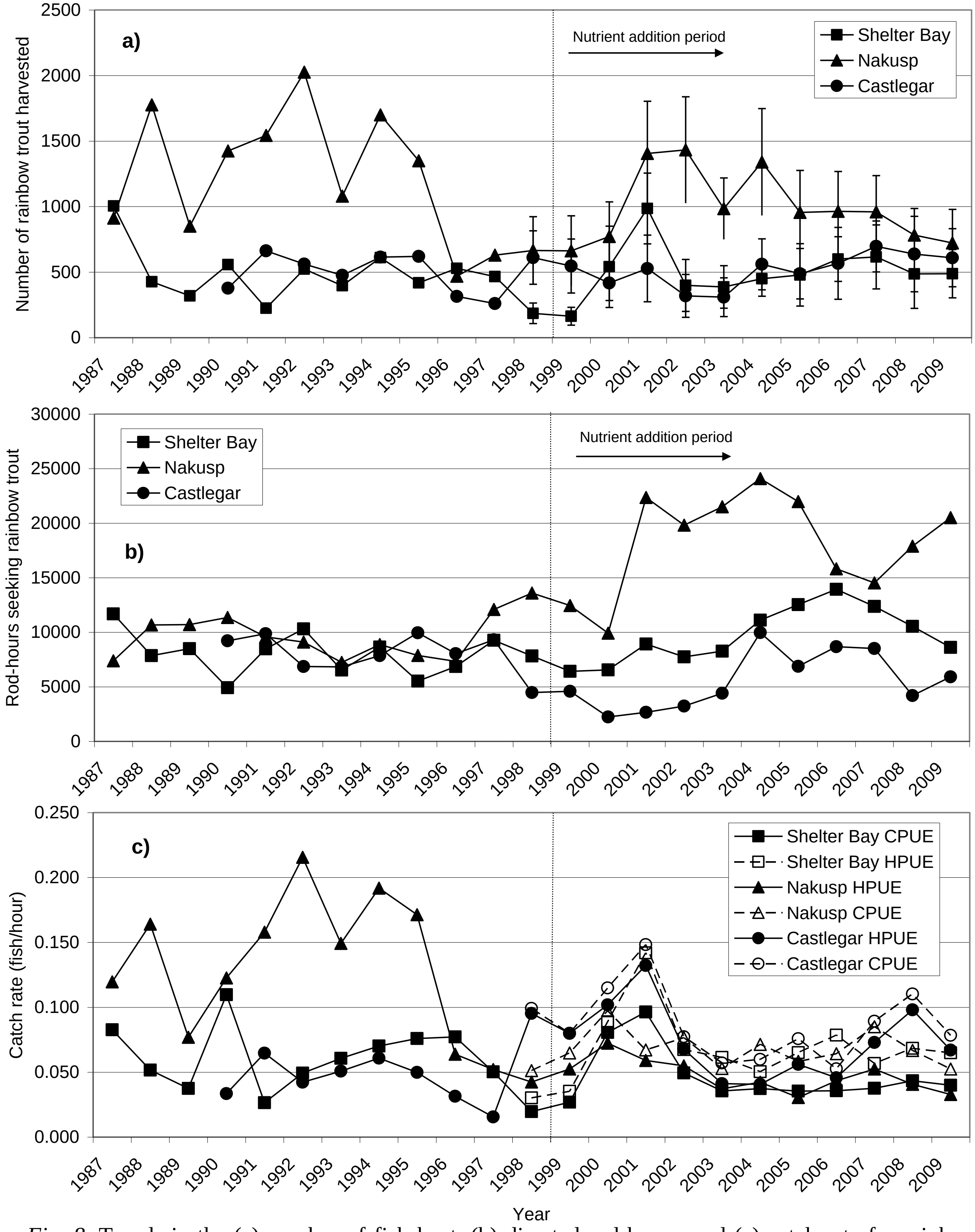

Fig. 8. Trends in the (a) number of fish kept, (b) directed rod-hours, and (c) catch rate for rainbow trout from three access locations in Arrow Lakes Reservoir from 1987-2009. Bars around harvest estimates after 1998 indicate 95% confidence limits. Catch rate after 1998 is shown for both harvested fish (HPUE) and for harvested and released fish combined (CPUE). Castlegar records are not available for 1987-1989. Data to 1997 are from MFLNRO/FWCP files and 1998-99 from Arndt (2002a).

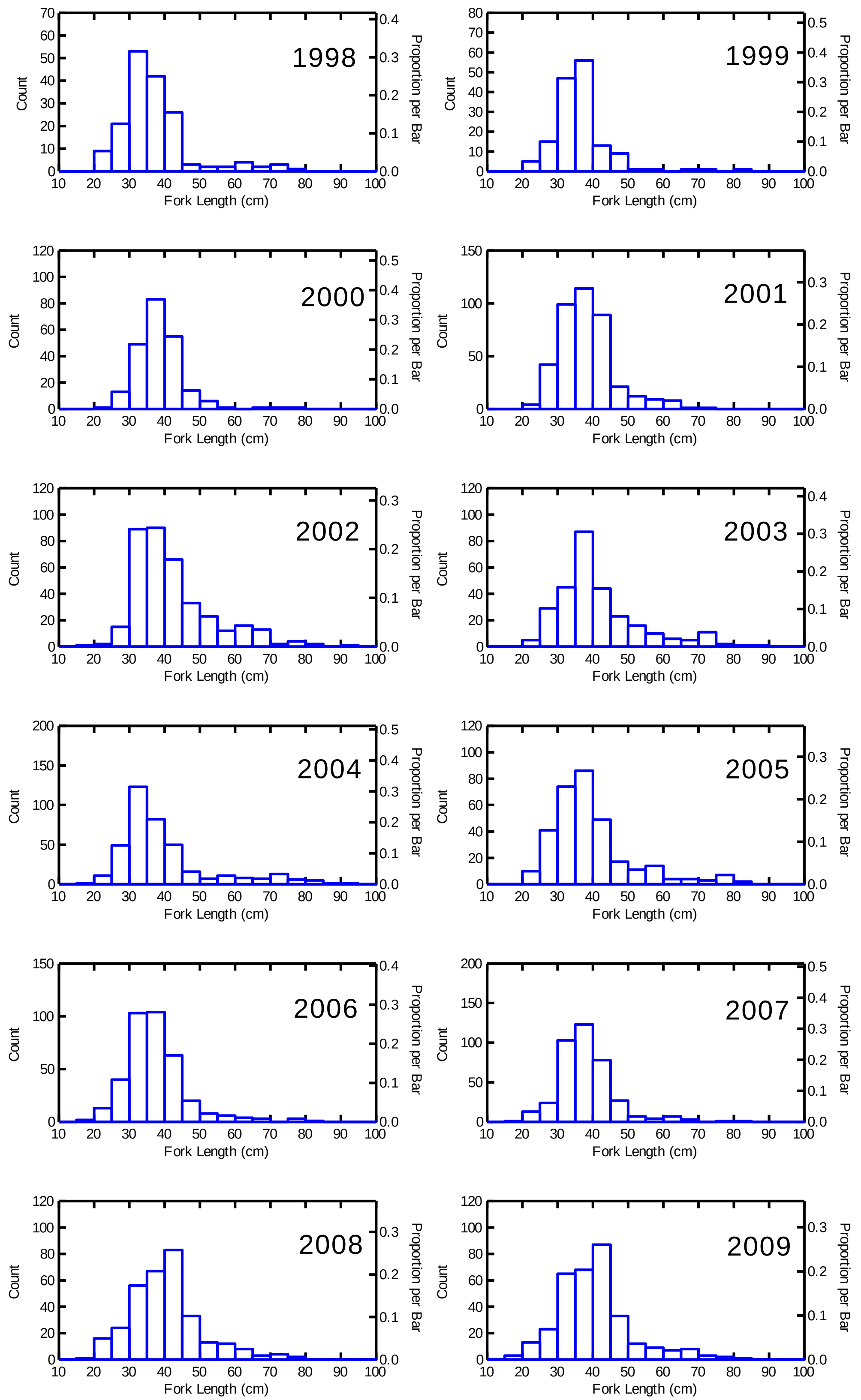

Fig. 9. Fork length distributions of harvested rainbow trout from the Arrow Lakes Reservoir creel survey from 1998 to 2009.

Piscivorous ecotype

Annual numbers of sampled rainbow trout >50 cm provide an index of piscivorous rainbow trout harvest at the three sampled sites (Fig. 10). Since contract-stipulated collection of length data began in 1998, there is just one year prior to the nutrient program for this direct comparison. A longer term, but perhaps less certain, trend was developed for the Nakusp site by combining 1997–2009 creel weight records with weigh-in records kept at the local tackle store from 1977 to 1995 (MFLNRO/FWCP file data). The older records represent fish brought voluntarily to the store for weighing, which was open from 8:30 AM to 5:30 PM seven days weekly except for Sunday afternoons from mid-November through January or February when it closed around noon.[7] The 1997-2009 creel data are from 60 sampled days per year monitored from 2 hours after sunrise to a half hour after sunset (Section 2.1). In an attempt to make the two datasets roughly comparable, the creel data were expanded to a full year by the ratio of 365/60 sampled days (Fig. 11). This equalizes the number of days sampled, however, given the shorter "sampled" day length and voluntary aspect of the store records, counts for these years are likely underestimated to some degree in relation to the expanded creel data.

The post-nutrient harvest trend for piscivorous rainbow trout was similar to bull trout, with a sharp increase starting the third year of the nutrient program, peak years from 2002 to 2004, a decline to 2007, followed by a return to intermediate levels (Figs. 10, 11). The longer term graph (Fig. 11) shows cycles in piscivore harvest occurred both before and after the nutrient program. Fish over 9 kg (20 lb) are recorded in both periods, and catches of the largest fish occurred mainly in years of higher harvest. Numbers in the nutrient period exceeded the 1997 and 1998 pre-nutrient samples for most years after 2001, and harvest during the 2002-2004 peak years was probably the highest in the last 3 decades (Fig. 11). A crude estimate of >50 cm rainbow harvest for 2003-2009 would be in the range of 200 to 500 fish annually.[8] Lindsay (1991, cited by Sebastian et al. 2000) estimated an annual harvest of about 100 fish >2.3 kg (5 lb) in 1989.

[7] Glen Olson, former store owner, Nakusp (pers. comm.); the store is located adjacent to the boat ramp monitored by the creel survey.
[8] Obtained by expanding the number of sampled fish in Fig. 10 by 365 days/60 sampled days in a year x the average of the yearly expansion factors for all overflight days pooled in 2003-2005 (1.36).

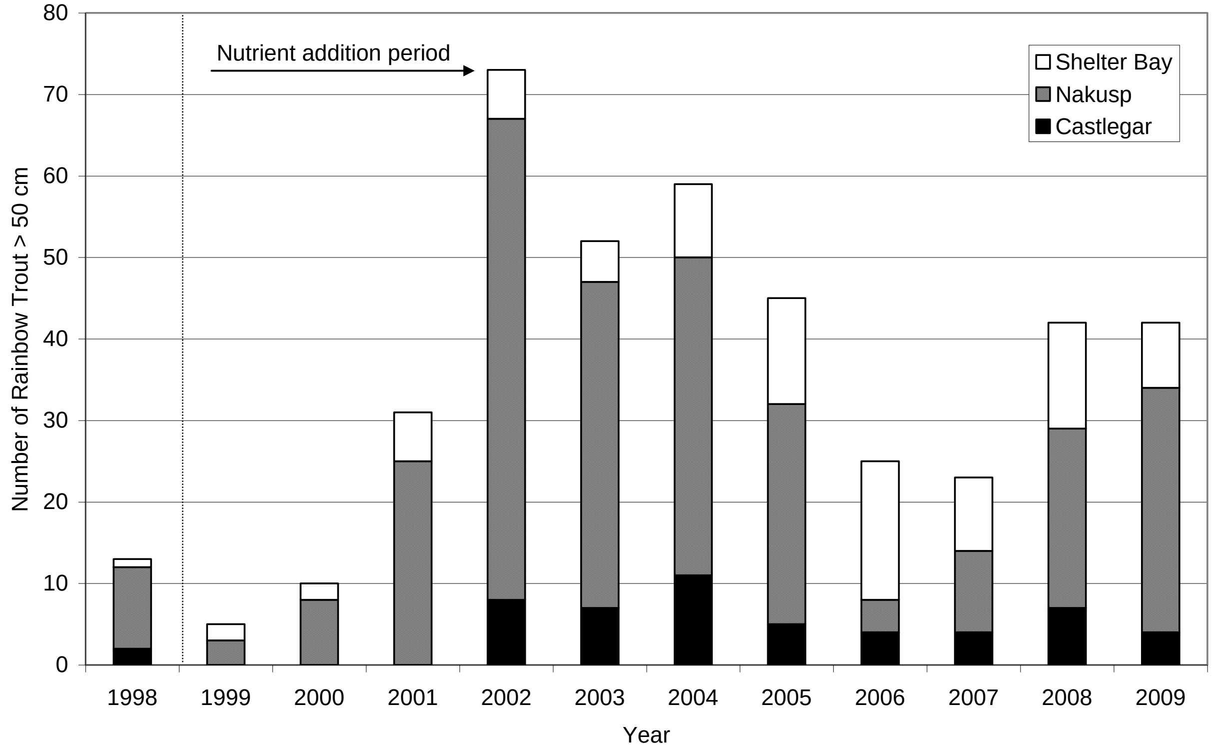

Fig. 10. Number of rainbow trout greater than 50 cm sampled at three access locations during the Arrow Lakes creel survey from 1998 to 2009. Length data are not available for all sites prior to 1998.

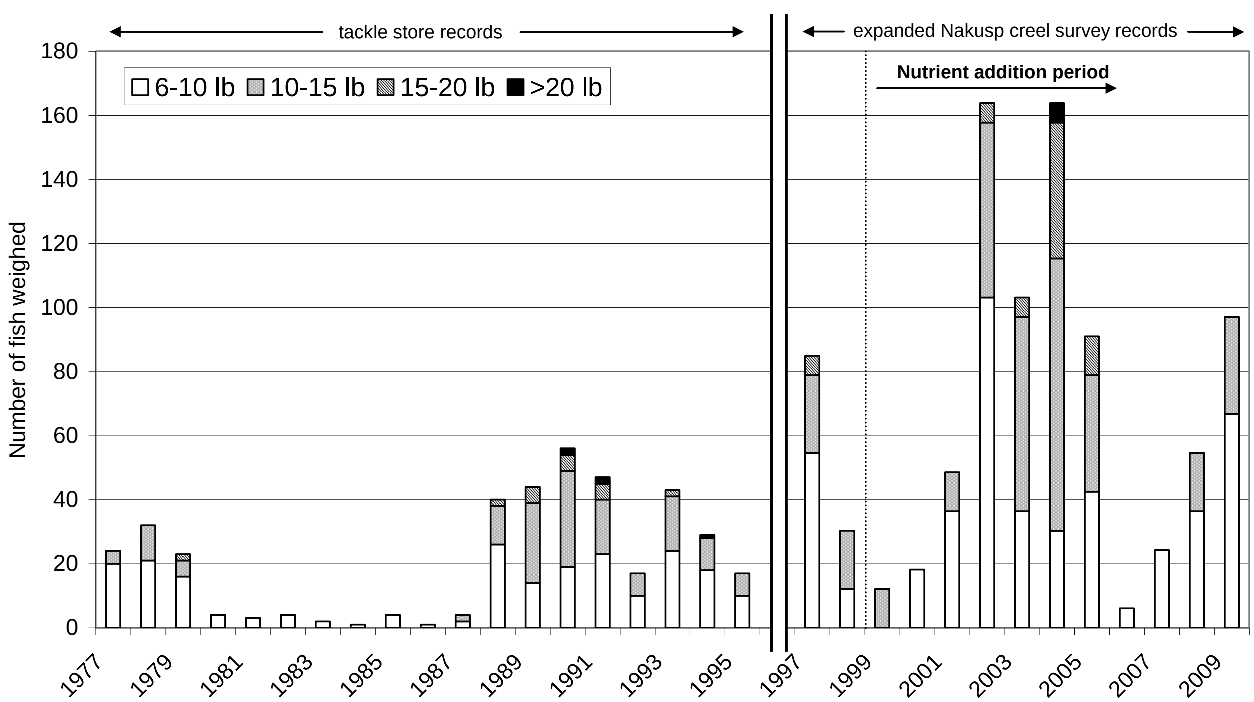

Figure 11. Number of rainbow trout weighed at Nakusp by size category from 1977 to 2009. Data up to 1995 are from weigh-in records at the local tackle store and later years are from creel survey data expanded to a full year. See text for further explanation. Imperial units are used to be comparable to the older records.

3.3.3 Kokanee

Annual catch of kokanee (3,200-15,100) and percent retained varied widely over the 2003-2009 period, leading to harvest by weight estimates from 300 to 1,800 kg (0.006-0.039 kg/ha) (Table 6). Long term trends at the three sampled locations show post-nutrient harvest to be about a tenth of most pre-nutrient years shown in Figure 12, although it should be noted that kokanee effort and numerical harvest were much higher starting in the mid 1980s than they were in the 1970s (Lindsay 1986; Sebastian et al. 2000). Harvest at all locations was already substantially reduced by 1997 (two years prior to the nutrient program) but declined even further in following years. Largest declines occurred in Castlegar and to a lesser extent Nakusp. Shelter Bay has not had a strong kokanee fishery at any time in the last 25 years. Harvested kokanee from 2003 – 2009 comprise a very minor component (<1% - 3.6%) of the adults in ALR when compared to index stream spawner counts (MOE/FWCP file data) for the same year.

Kokanee directed effort also decreased substantially in the post-nutrient period, with the exception of 2001 in Nakusp (Fig. 12b). Size of kokanee was larger that year with about half of the harvest exceeding 25 cm in length (Fig. 13). These larger kokanee provided a strong incentive for kokanee angling and targeted effort that year increased to nearly 10,000 rod-hours, more than double the pre-1999 average for Nakusp. An increase in Castlegar effort in 2007 (Fig. 12b) also corresponds to a size shift towards larger fish (Fig. 13).

Catch rates declined substantially at all locations during the post nutrient period (Fig. 12c). Recent CPUE of less than 0.6 fish/hour is similar to a 2000 survey on Revelstoke Reservoir (0.30 fish/hour)[9], however, the average size of Revelstoke fish was much larger (309 mm, 357 g) and about 90% of Revelstoke rod-hours were targeting kokanee (Bray and Campbell 2001).

Kokanee in ALR are retained starting at a length of 18-20 cm depending on the year. In some years, there appears to be two year classes represented in the harvest (Fig. 13). Overall there was a positive relationship between kokanee effort and kokanee size (Fig. 14), but no correlation between rod-hours of effort and CPUE (R=0.08, p>0.80). Thus the decrease in kokanee angling effort in recent years appears to be at least partially related to a decrease in kokanee size. The opposite has occurred previously in ALR, as Lindsay (1986) observed a sharp increase in upper Arrow kokanee fishing associated with increases in average size of retained fish starting in 1984 (24.6 cm) and 1985 (27.5 cm). Reductions in daily catch limits may also have an important influence on kokanee effort and harvest, particularly when fish are smaller. Daily harvest limits were reduced from 15 fish to 10 in 1995, and from 10 to 5 in 2000 (D. Sebastian, MFLNRO, pers. comm.).

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

Table 6. Kokanee angler catch and harvest (± 95% confidence limits) statistics for Arrow Lakes Reservoir from 2003 to 2009.

	Number Caught[1]	**Number Kept**[1]	**% Kept**	**Harvest**[2] **(kg)**	**CPUE**[3] **(fish/h)**
2003	3,800 (± 1,100)	2,800 (± 900)	73	300	0.357
2004	15,100 (± 4,600)	8,600 (± 2,400)	57	1,300	0.558
2005	11,400 (± 4,200)	6,800 (± 2,700)	59	1,200	0.476
2006	3,200 (± 1,300)	2,300 (± 900)	73	500	0.140
2007	11,800 (± 3,400)	9,000 (± 2,600)	76	1,800	0.375
2008	6,000 (± 2,200)	5,200 (± 1,800)	87	1,100	0.243
2009	8,200 (± 2,200)	5,800 (± 1,500)	71	1,100	0.391

[1] Estimates are expanded to whole reservoir using overflight boat counts, and therefore are higher than the sum of the three sites in Figure 12.
[2] Number kept x mean weight of sampled fish
[3] Three sampled locations combined.

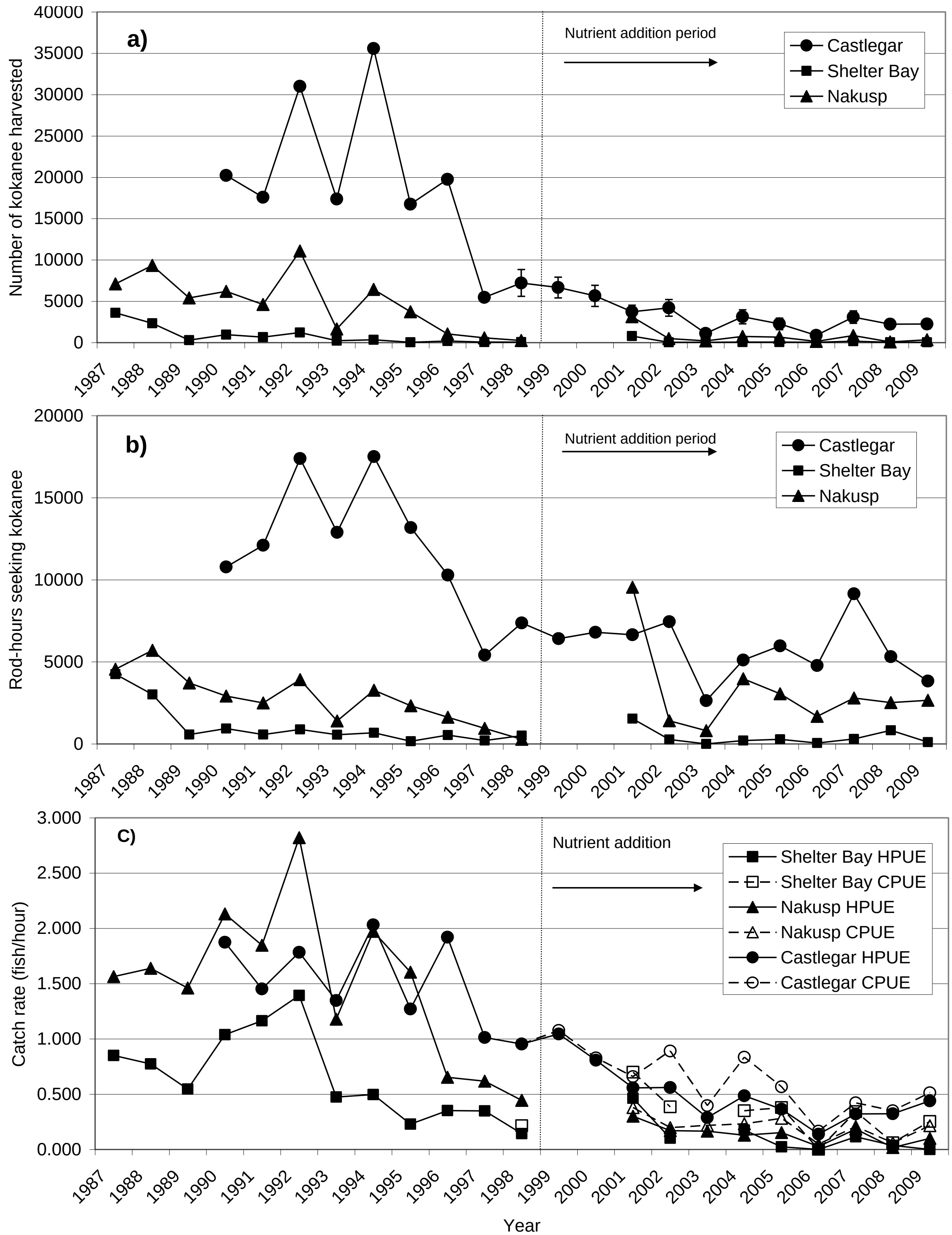

Fig. 12. Trends in (a) number of fish kept, (b) directed rod-hours, and (c) catch rate for kokanee anglers from three access locations in Arrow Lakes Reservoir from 1987-2009. Bars around harvest estimates after 1998 indicate 95% confidence limits. Catch rate after 1998 is shown for both harvested fish (HPUE) and including released fish (CPUE). The kokanee season was closed in the upper basin (Shelter Bay, Nakusp) in 1999 and 2000.

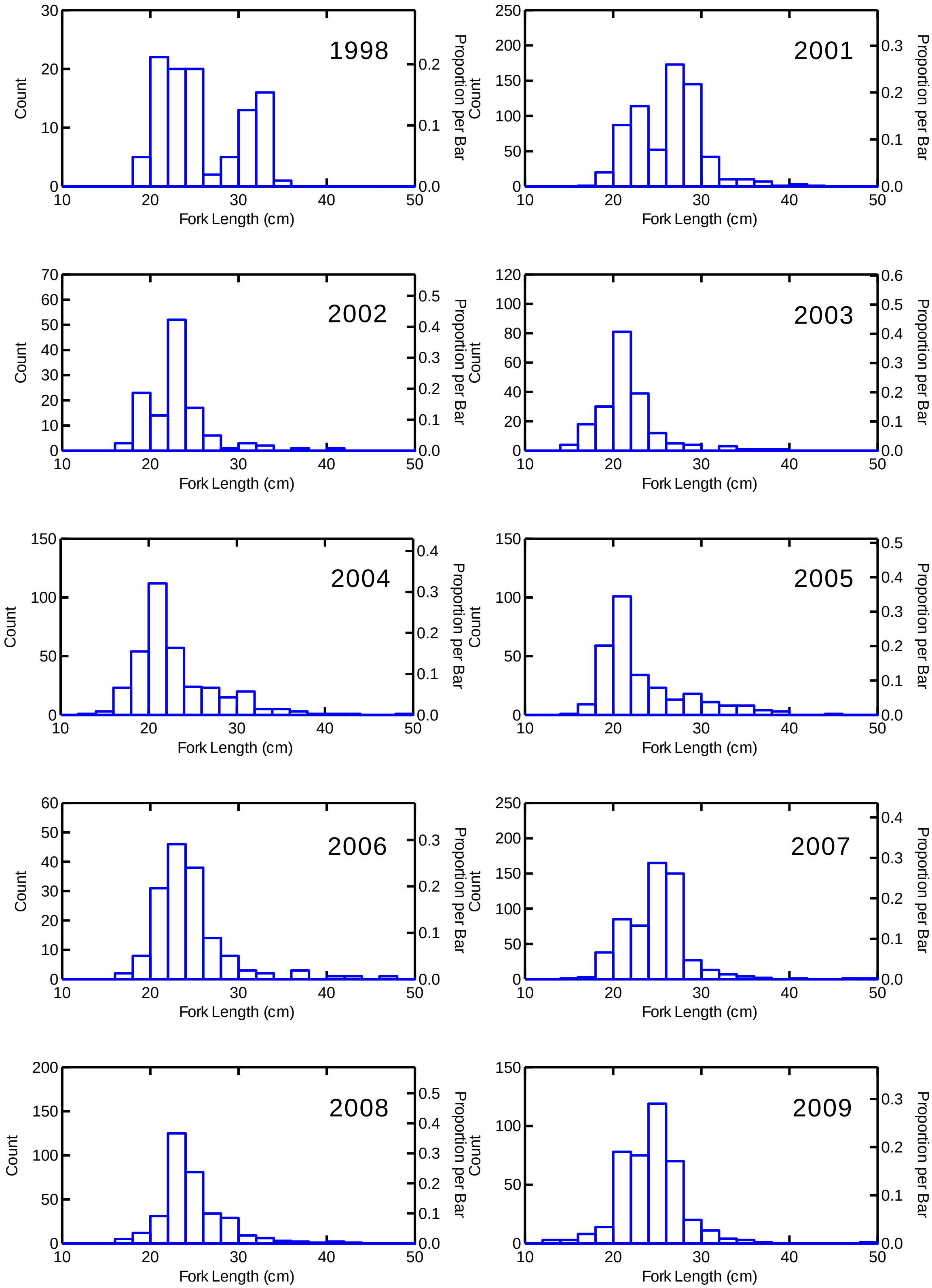

Fig. 13. Fork length distributions of harvested kokanee from the Arrow Lakes Reservoir creel survey from 1998 to 2009. Samples for 1998 and 2001 are all from the upper basin. Data are not available for 1999 and 2000.

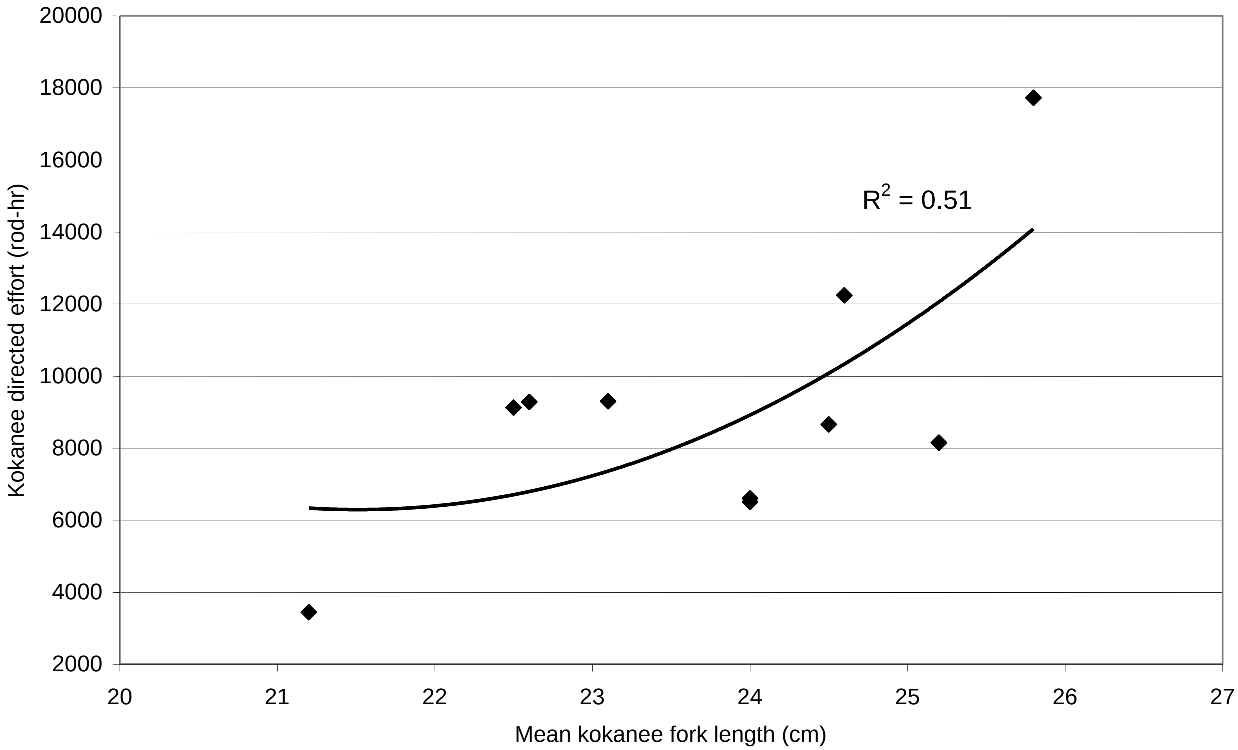

Fig. 14. Relationship between the amount of kokanee-directed fishing effort (Castlegar, Nakusp, and Shelter Bay combined) and mean length of harvested kokanee in Arrow Lakes Reservoir from 1998 to 2009.

3.3.4 Burbot

Burbot angling was recorded in all months at low levels for the Nakusp access during 2003-2009 but very rarely at the other monitored access locations, even though the species is widely distributed in the reservoir and abundant at other locations (Arndt and Baxter 2006). Annual catch estimates for 2003-2009 ranged from 500 to 750 fish with about 80% or more retained; wide confidence limits are due to the low number of burbot reported. Harvest by weight was fairly stable at 700 - 1000 kg (Table 7).

Longer term trends suggest a possible decrease in harvest (Fig. 15a) from the late 1980s to 1997, followed by an increase to the current relative stability. Reported burbot effort has also increased substantially since 1999 (Fig. 15b), whereas catch rate may have decreased (Fig. 15c). These trends should be interpreted with caution. It is possible that non-successful burbot anglers did not report their targeted species in earlier years, which would lead to an overestimation of catch rate and underestimation of effort. Even in recent years, some burbot harvest occurs for parties that report fishing for “anything”. Catch rates of slightly less than 0.5 fish/rod-hour are fairly similar to those for burbot in other lakes of Kootenay Region (Table 8). Available size data suggest relatively stable recruitment to the population near Nakusp, with the majority of harvested fish being between 55 and 70 cm (Fig. 16). Burbot harvest (kg/ha) in Arrow Lakes Reservoir is relatively low in comparison to other lakes (Table 9). Fall trapping in the narrows area where most of the angling occurs had average catch rates (number of burbot/overnight trap set) of 4.5 in 2003 and 8.5 in 2004 (Arndt and Baxter 2006), but around 1.0 for sets in 2008 and 2010 (Glova et al. 2009, Robichaud et al. 2011).

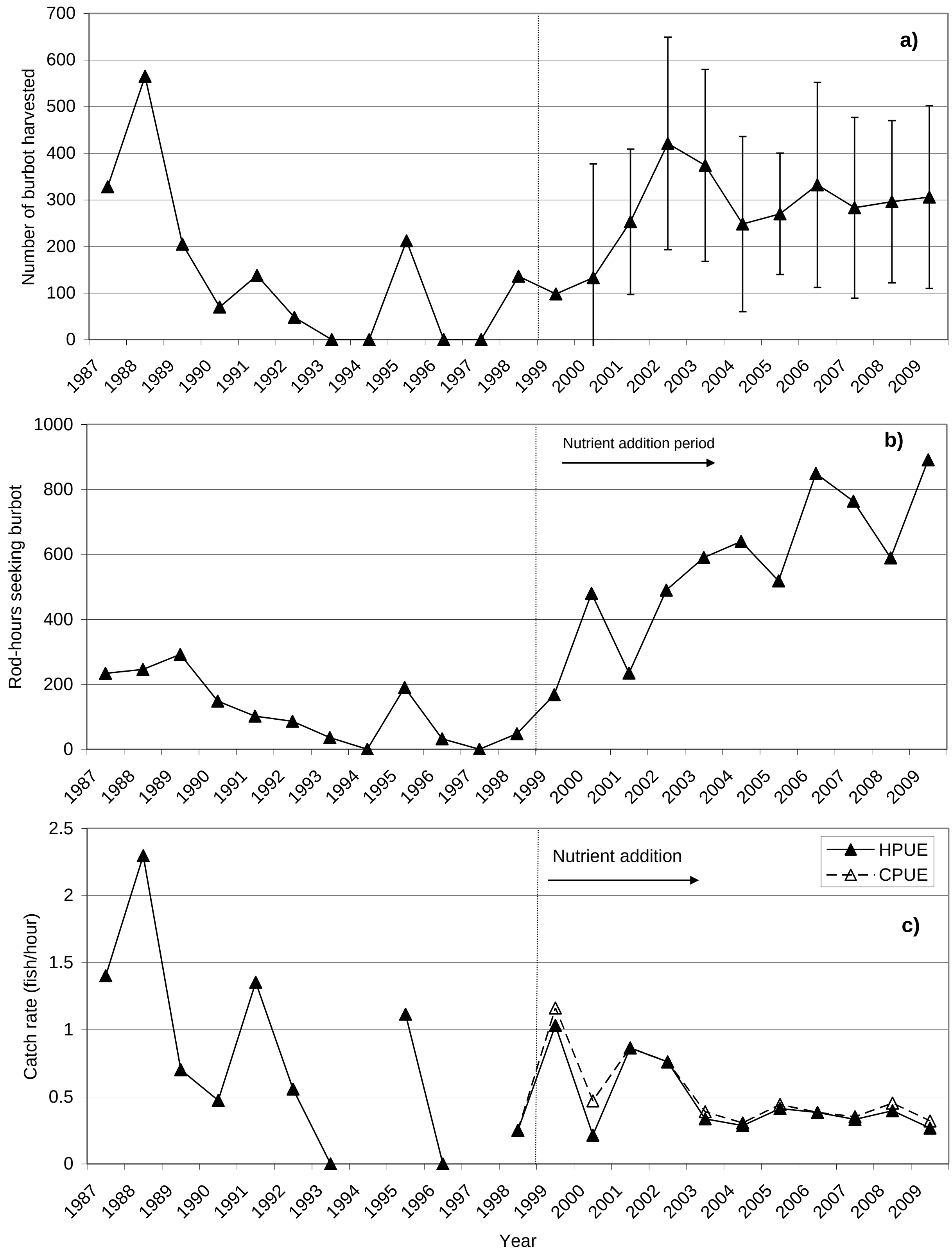

Fig. 15. Trends in the (a) number of fish kept, (b) directed rod-hours, and (c) catch rate for burbot anglers from Nakusp access location in Arrow Lakes Reservoir from 1987-2009. Bars around harvest estimates after 1998 indicate 95% confidence limits. Catch rate after 1998 is shown for both harvested fish (HPUE) and including released fish (CPUE).

Table 7. Estimated number of burbot caught and retained (± 95% confidence limits), percentage of fish kept, and harvested weight for Arrow Lakes Reservoir from 2003 to 2009.

Year	Number Caught[1]	Number Kept[1]	% Kept	Harvest[2] (kg)
2003	740 (± 370)	660 (± 370)	89	1,050
2004	470 (± 300)	450 (± 310)	95	800
2005	390 (± 210)	370 (± 200)	95	720
2006	520 (± 380)	520 (± 380)	100	870
2007	480 (± 330)	470 (± 340)	96	790
2008	580 (± 380)	450 (± 280)	79	710
2009	580 (± 490)	460 (± 330)	78	710

[1] Estimates are expanded to whole reservoir using overflight boat counts, and therefore are higher than in Figure 15.
[2] Number kept x mean weight of sampled fish

Table 8. Burbot catch rate comparison from creel surveys in four Kootenay Region Lakes.

Lake	Years	CPUE (fish/hr)	Season
Arrow Reservoir	2003 - 2009	0.30 – 0.45	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	0.24 – 0.50	Winter
Kootenay Lake West Arm[3]	1967 - 1976	0.28 - 1.48	February to June

[1] Arndt (2002b)
[2] Westover (2007), Prince and Cope (2008), Neufeld and Spence 2009)
[3] Martin (1976)

Table 9. Comparison of Arrow Lakes Reservoir burbot harvest to other North American lakes.

Lake	Size (ha)	Harvest		Period Measured
		Fish/ha	Kg/ha	
Arrow Lakes Reservoir	46,450	0.007 - 0.014	0.015- 0.022	2003-2009
Columbia Lake, BC[1]	2,574	0.02 – 0.19	0.02 – 0.15	1995-2001
North basin Moyie Lake, BC[2]	583	0.25 – 0.62	0.42 – 1.00	2007-2009
Windermere Lake, BC[1]	1,584	0.020	0.010	1996-1997
Moosehead Lake, Maine[3]	30,308	0.07 – 0.23	0.03 – 0.17	1985-1999
Moose/Tulsona Lakes, Alaska[4]	260	0.08 – 2.63	NA	1987-1997
Susitna/Tyone Lakes, Alaska[4]	4,205	0.01 – 0.18	NA	1987-1997
Lake Louise, Alaska[4]	6,519	0.04 – 0.15	NA	1987-1990
Harding Lake, Alaska[5]	1,000	0.00 – 0.42	NA	1983-1998

[1] Arndt (2002b); [2] Westover 2007, Prince and Cope 2008, Neufeld and Spence 2009; [3] Quinn (2000); [4] Taube (2000); [5] Doxey (2000)

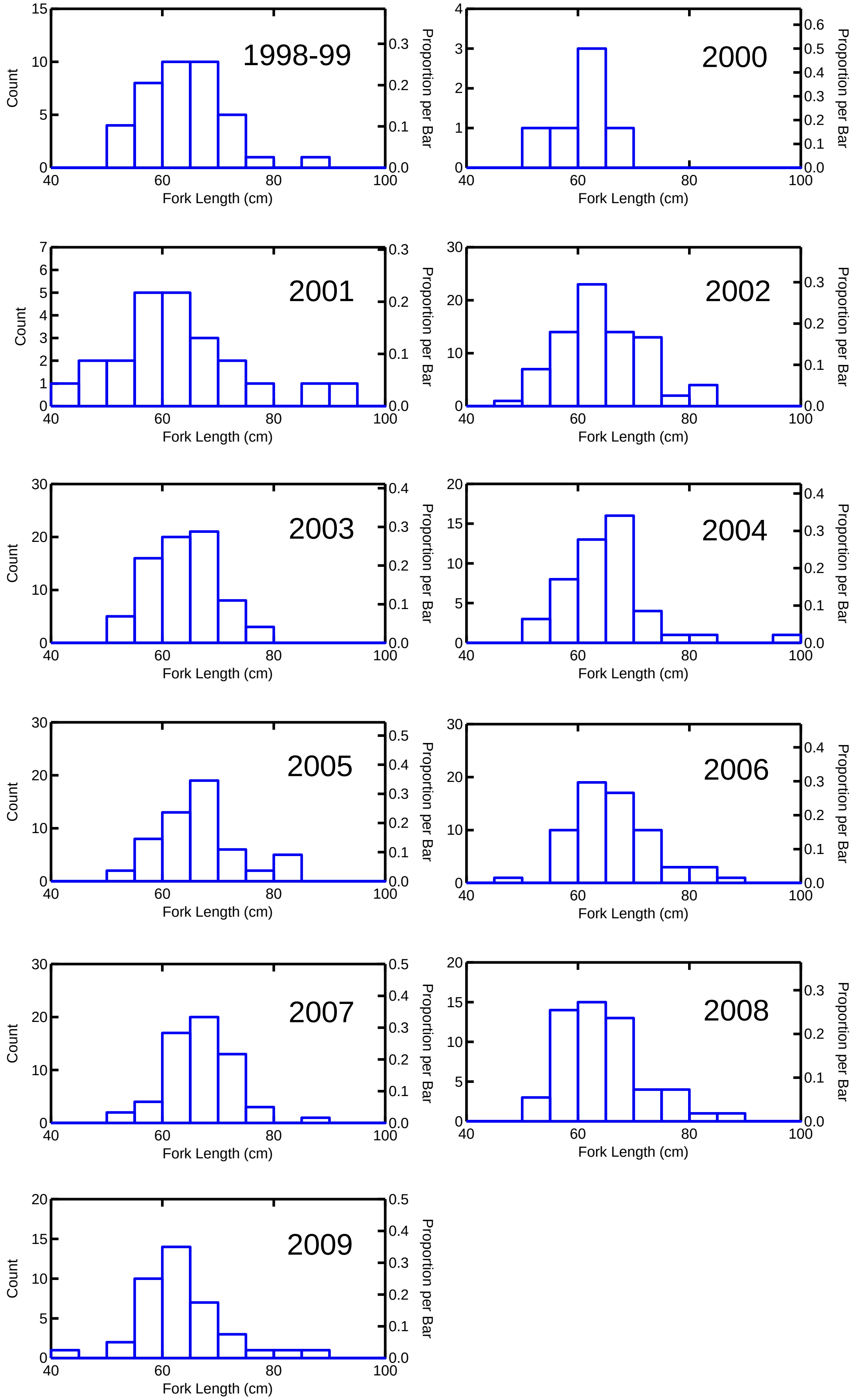

Fig. 16. Length frequency distributions of burbot angled in Arrow Lakes Reservoir from 1998 to 2009.

3.4 Piscivore Condition Trends and Implications

Calculation of piscivore condition allows testing of important unknowns related to creel survey interpretation and the success of the nutrient and spawning channel programs. First, the close relationship between K_n of bull trout and piscivorous rainbow trout (Fig. 17) supports the premise that K_n is a valid indicator of feeding conditions for apex predators feeding on kokanee in ALR. Second, K_n showed positive relationships to catch rate, total catch, and catch of larger fish (e.g., > 5 kg) for both apex species (Fig. 18). This has two relevant implications. One, it supports the notion that angler catch rate and harvest trends are generally valid indices of predator population abundance. If catch rates were dominated by mechanisms where predators were more vulnerable to angling during periods of low prey availability, an inverse relationship would be expected between fishing success and K_n. This is clearly not the case for the ALR fishery. If there is indeed a positive relationship between K_n and predator abundance, it implies that recruitment and survival of piscivorous rainbow trout and bull trout may be strongly influenced by suitable feeding conditions in the reservoir (section 4.0).

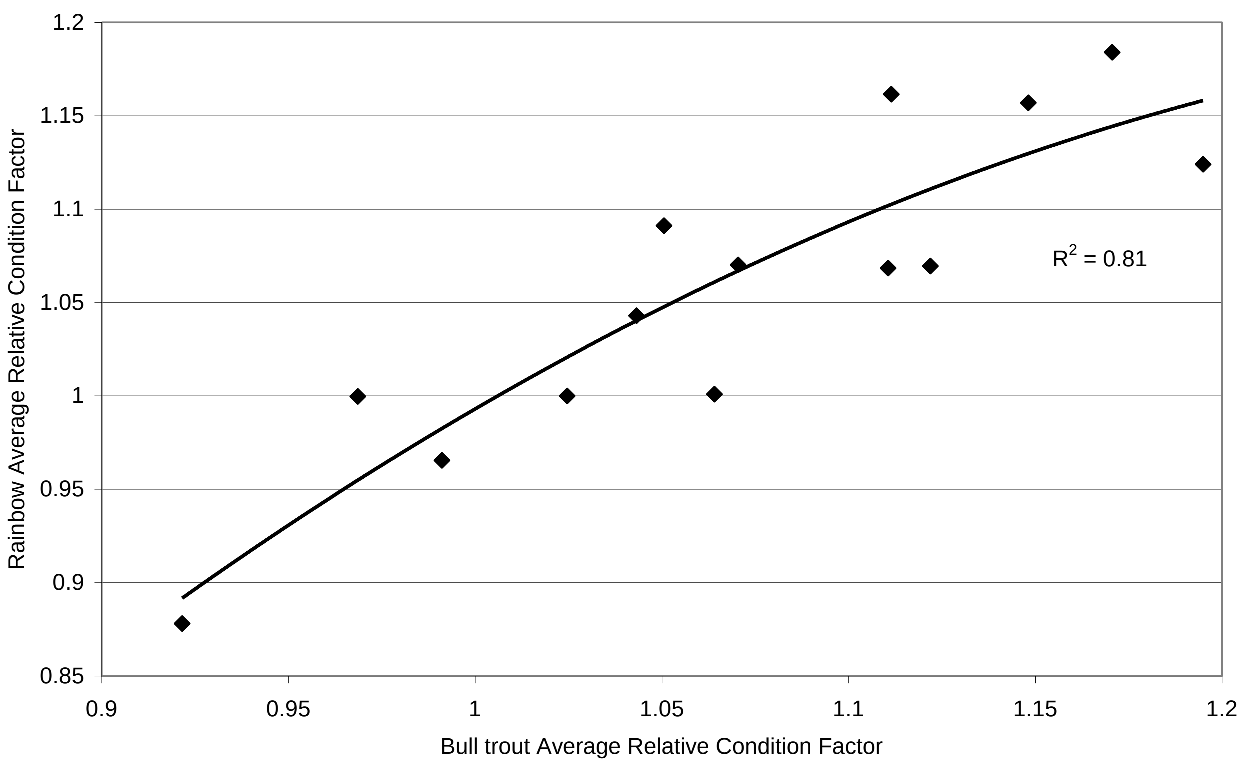

Fig. 17. Comparison of annual mean relative condition factor (K_n) for bull trout and rainbow trout over 50 cm in Arrow Lakes Reservoir from 1996 to 2009.

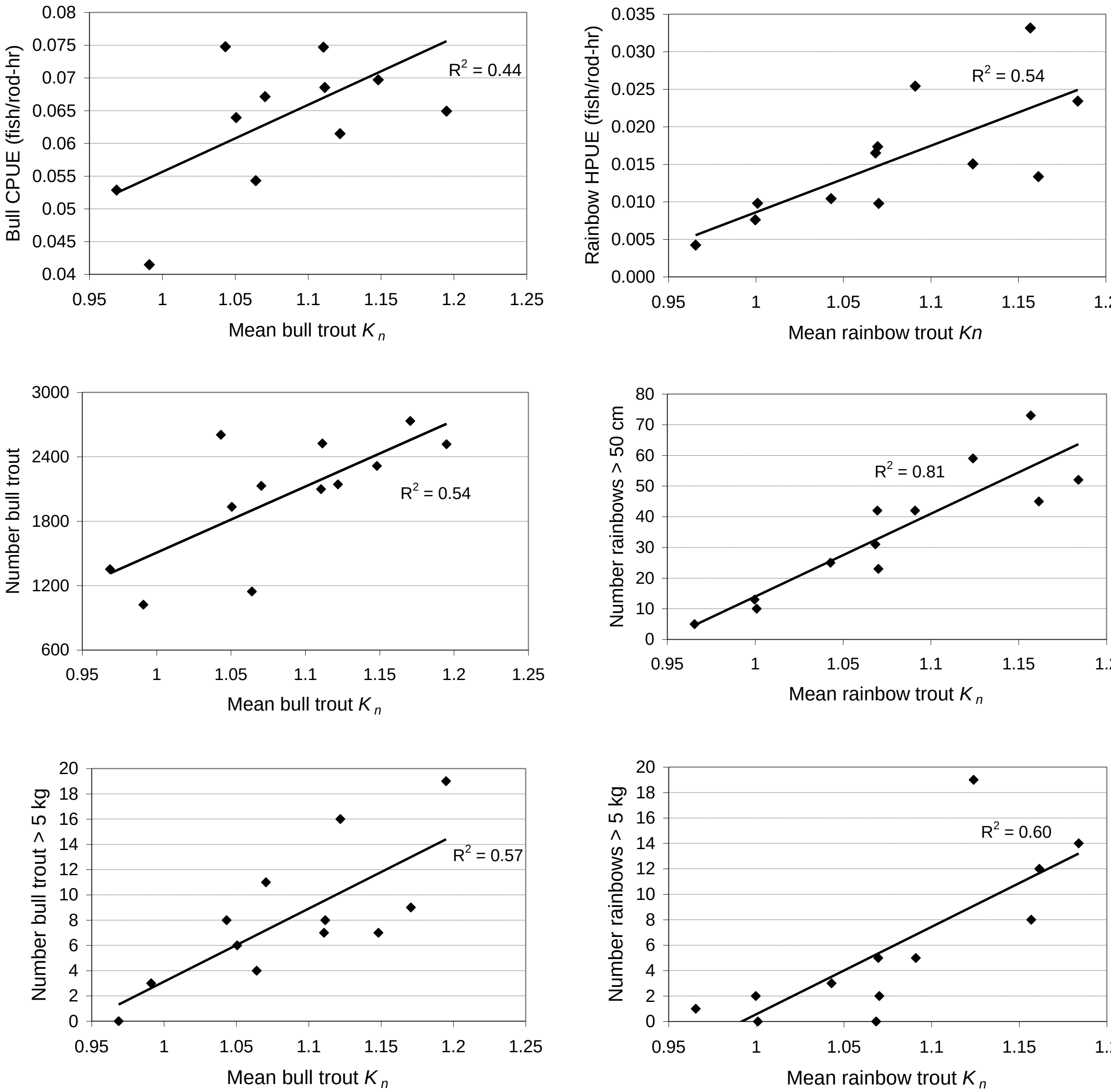

Fig. 18. Graphs showing positive relationships between mean annual condition factor (K_n) and catch rate (top row), total catch (middle row), and catch of larger fish (bottom row) for bull trout and piscivorous rainbow trout from Arrow Lakes Reservoir 1998-2009. Middle plots used the expanded catch estimate for bull trout, and sampled fish >50 cm for rainbow trout (data not available on released fish). Lower plots are sampled catch.

3.4.1 Trends

Average K_n of bull trout increased rapidly after 1999, peaking in 2004, when fish averaged 20% heavier than the pre-nutrient period; this was followed by a decline back to levels similar to the pre-nutrient era from 2006 to 2008, and another increase in 2009. Trends for larger bull trout were slightly more extreme, showing a more extended and higher peak from 2001 to 2004, and a lower average during periods of poorer condition (Fig. 19). Condition of larger fish would be expected to be more closely tied to kokanee population dynamics from a bioenergetics perspective (Kerr 1971a). Piscivorous rainbow trout trends were similar to bull trout with peak years from 2002 to 2005 followed by a reduction to levels closer to the pre-nutrient years (Fig.20). The K_n trends for both species also correspond to harvest trends shown earlier (Figs. 6, 10). Overall, these results indicate the best feeding conditions for apex predators in ALR occurred during the early years of the nutrient program from 2001 to 2005.

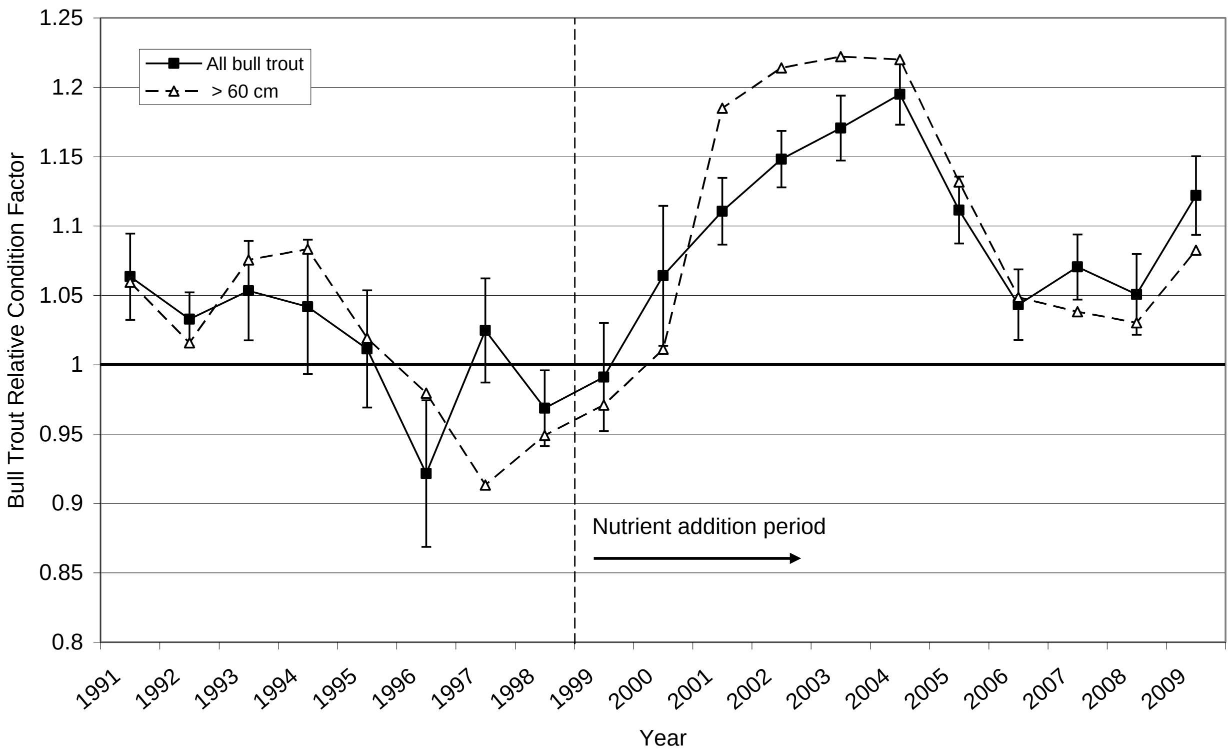

Fig. 19. Mean annual condition factor (K_n) relative to the average pre-nutrient weight (K_n=1) for all bull trout (± 95% confidence limits), and for bull trout over 60 cm in Arrow Lakes Reservoir from 1991 to 2009. Sample ranged from 33 to 267.

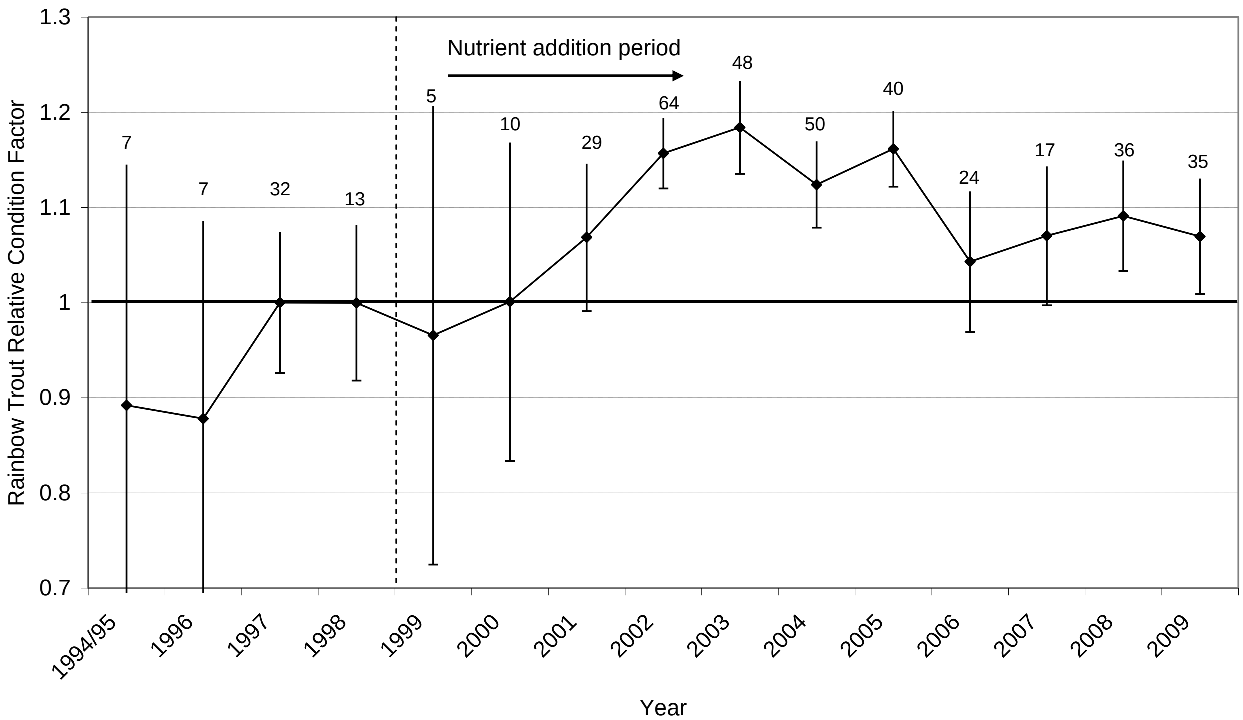

Fig. 20. Mean annual (± 95% confidence limits) condition factor (K_n) relative to the average weight of pre-nutrient fish (K_n=1) for piscivorous rainbow trout in Arrow Lakes Reservoir from 1994 to 2009. Numbers indicate sample size.

3.4.2 Relationship to Kokanee Population

Growth efficiency in fish is a function of prey density, size, and energy content (Kerr 1971a, Stewart and Ibarra 1991, Rand and Stewart 1998). To investigate the prey conditions that provide best feeding opportunities for piscivores, K_n was first plotted versus measures of ALR kokanee abundance and size/age structure from other studies. Neither kokanee density nor biomass (all age classes combined) appeared to have a positive relationship to predator condition since the commencement of the nutrient program (Fig. 21, top two rows). However, a positive relationship was found between K_n and a measure of the abundance of kokanee large enough to spawn, producing a nearly identical curve for both species (r^2=0.73 and 0.60 for bull and rainbow trout respectively; Fig. 21, bottom row). This relationship was stronger using the upper Arrow spawner index than using all ALR index streams (not shown) as would be expected given that the majority of K_n samples came from the upper basin.

In most years, kokanee spawners in ALR are primarily age 3+ (Sebastian et al. 2000). To test the K_n relationship to the kokanee cohorts at age 2+, K_n values were lagged by one year and plotted against the index stream spawner counts in Figure 21 (e.g., K_n in 2008 was compared to 2009 index spawner returns). This produced positive relationships for both species but with lower r^2 values of 0.43 and 0.42 respectively (graphs not shown). Therefore in this preliminary analysis, optimal feeding conditions for apex predators appear to be most closely related to high abundance of the spawning size class of kokanee.

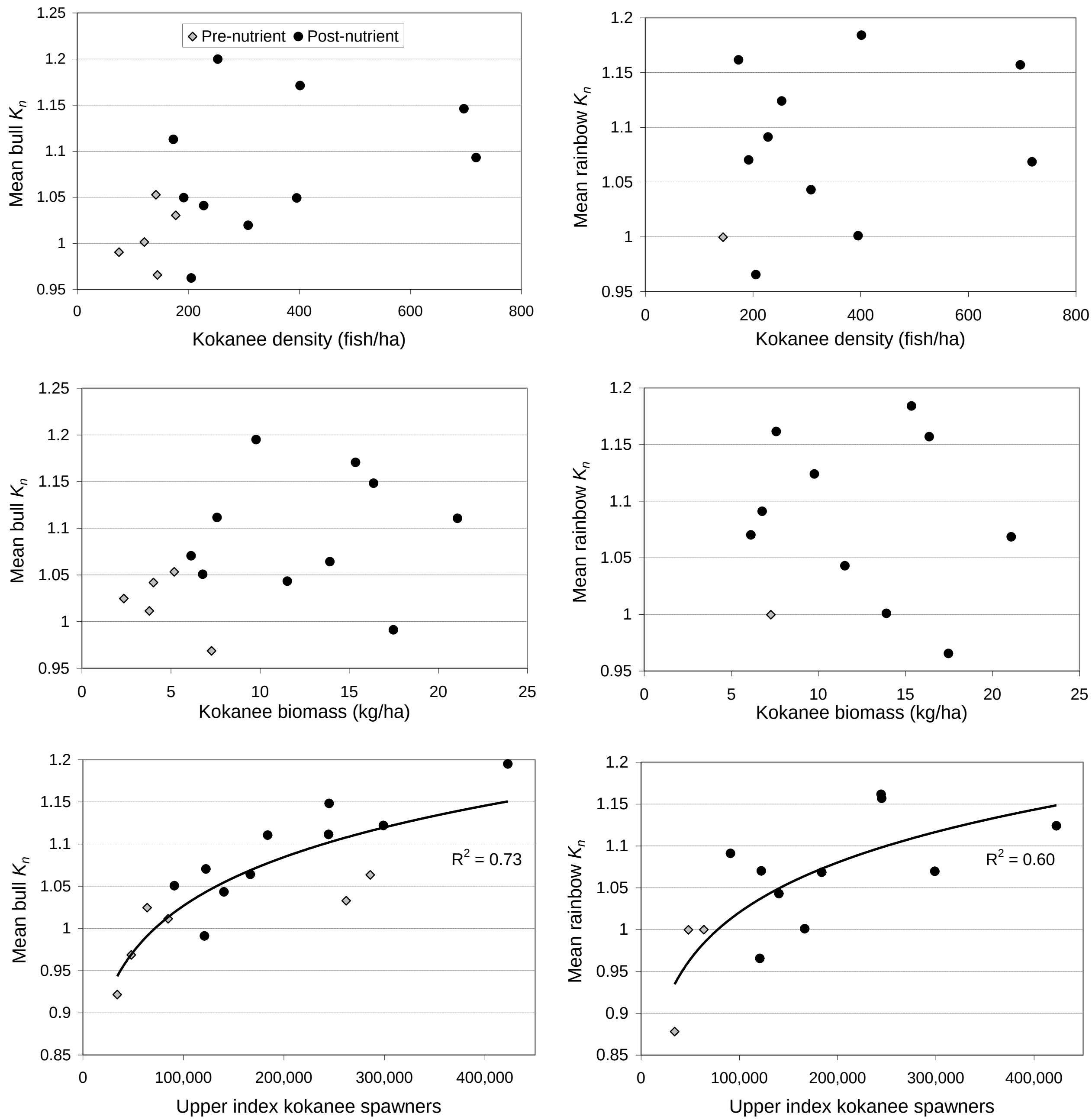

Fig. 21. Relationships between bull trout and piscivorous rainbow trout condition (K_n) and kokanee population structure. Kokanee data in top four panels are from fall hydroacousic surveys (Ministry of Environment/FWCP file data), and in the lower panel from counts of spawners in five index streams in the upper basin of Arrow Lakes reservoir.

Effect of prey size on K_n was further investigated using linear and quadratic models and AIC rankings as described in Methods (Section *2.3.4*). For bull trout, the majority of AIC_c model weight (more than 0.60) was placed on the model using only the single predictor of upper Arrow spawner abundance index for both the mean and median yearly condition factor. The remaining model weight was fairly evenly spread over the other models in the set. Hence this analysis did not support a kokanee size effect on bull trout after accounting for spawner abundance.

For rainbow trout, different models were selected using AIC_c depending on whether it was predicting the mean or median K_n. For mean K_n, the majority of model weight (.53) was placed on the model using the single predictor of upper Arrow spawner abundance index (i.e., a size effect was not supported). However a different model (including spawner abundance index in all Arrow index streams and a quadratic effect of size) was selected for the median condition factor (model weight 0.74). In this case the quadratic term supports a dome-shaped relationship to kokanee size after accounting for spawner abundance, as illustrated in Figure 22. In summary, for rainbow trout there was some support for a prey size effect after accounting for spawner abundance with an optimal spawner size of approximately 23 cm. The evidence was not conclusive with the available data, but may warrant further investigation. Since optimal prey size increases with predator size (Kerr 1971a), some of the variance in the K_n to prey size relationships may be due to annual differences in the size distributions of the predator species; future investigations should consider doing separate analyses for different size categories if sample size is adequate (e.g., He et al. 2008).

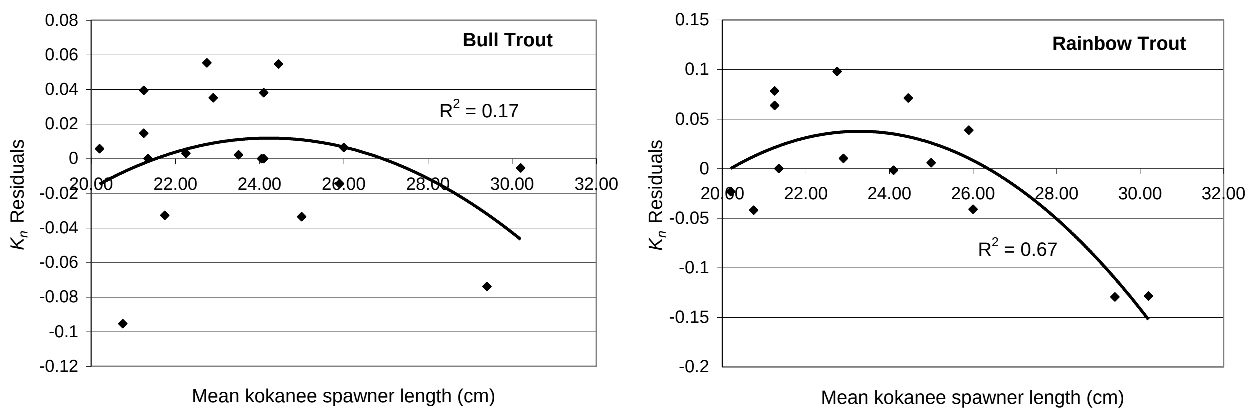

Fig. 22. Residuals from linear regressions using Arrow Lake kokanee spawner abundance to predict annual median K_n of bull trout and piscivorous rainbow trout plotted versus the average size of kokanee spawners in Hill Creek spawning channel. The horizontal line at zero indicates the K_n predicted by kokanee spawner abundance.

3.5 Hatchery Contribution to the Fishery

Annual percentages of clipped fish in the creel were less than 1% for most years 2003 to 2009 (Table 10). Potential year of stocking is listed in Table 11. Some reported clips are questionable because there was no recent match in the stocking records. Maxillary clips (LM and RM) have not been used since 1997. If these are considered to be deformities or hooking injuries, only three rainbow trout and six bull trout of hatchery origin were sampled over the seven year period (n ≈ 2,500 and 1,700 respectively). Low percentages of marked bull trout are consistent with results from previous years, indicating very low survival of stocked fish after release. In pre-nutrient tagging studies (1975-1996), overall recovery of tagged bull trout was 11% while overall recapture of hatchery produced bull trout was much lower at <2% (Sebastian et al. 2000). Clipped bull trout have not been reported since 2006 (Table 10) signifying that the last releases from Hill Creek hatchery are no longer at large.

Over 125,000 yearling Gerrard strain (piscivorous) rainbow trout have been released in the reservoir since 2005 (provincial stocking records). Only two fish with adipose clips matching stocking records have been recorded in the samples (and one fish with an adipose and possibly misidentified RM clip) indicating negligible contributions to the fishery in recent years. In some pre-nutrient years, clip percentages of over 20% were reported for rainbow trout >2.3 kg (Sebastian et al. 2000), although the total catch of piscivorous rainbows in those years was lower than from 2001 to 2005. Clip percentages in these larger fish decreased to 18% in 1998-1999 (Arndt 2002a) and 6% in 2000-2002 (Arndt 2004a). The large increase in harvest of unclipped piscivorous rainbows between 2001 and 2005 (Figs. 10, 11) suggests natural production was providing reasonably good recruitment at that time (Arndt 2004a).

Table 10. 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 2003 to 2009. All reported clips are included in totals, although some do not match marks listed in stocking records and may be natural deformities or injuries. See Table 11 and text for further explanation.

		Bull Trout				**Rainbow Trout**			
Year	**Clipped Fish**	**Shelter Bay**	**Nakusp**	**Castlegar**	**Total**	**Shelter Bay**	**Nakusp**	**Castlegar**	**Total**
2003	Number %	3 3.5	2 1.4	0 0.0	5 2.0 (5)	0 0.0	0 0.0	0 0.0	0 0.0 (2)
2004	Number %	1 1.1	1 0.7	0 0.0	2 0.7 (3)	2 2.6	0 0.0	0 0.0	2 0.5 (2)
2005	Number %	0 0.0	0 0.0	0 0.0	0 0.0 (2)	0 0.0	1 0.6	0 0.0	1 0.3 (2)
2006	Number %	1 1.0	1 0.9	0 0.0	2 0.8 (4)	2 1.8	1 0.9	0 0.0	3 0.8 (2)
2007	Number %	0 0.0	0 0.0	0 0.0	0 0.0 (2)	0 0.0	2 1.1	0 0.0	2 0.5 (2)
2008	Number %	0 0.0	0 0.0	0 0.0	0 0.0 (2)	1 1.1	7 5.0	1? 1.0?	9 2.7 (6)
2009	Number %	0 0.0	0 0.0	0 0.0	0 0.0 (2)	0 0.0	1 0.8	0 0.0	1 0.3 (1)

Table 11. Sample location, reported clip, possible year of stocking and length of marked fish in 2003 to 2009 creel surveys on ALR. All rainbow trout after 1997 have been Gerrard stock. Clips are as follows: AD=adipose; ALM=adipose/left maxillary; ARM=adipose/right maxillary; RM=right maxillary; LM=left maxillary. Maxillary clips (LM and RM) may be misidentified deformities or injuries. Stocking records were obtained at http://a100.gov.bc.ca/pub/fidq/main.do.

Year Captured	Sample Location	Clip	Recent Years Clip Used	Fork Length (cm)
		Bull Trout		
2003	Shelter Bay	LM	No match	55
	Shelter Bay	ARM	1996, 1999	52.5
	Shelter Bay	ARM	1996, 1999	50
	Nakusp	AD	1994, 1998	54
	Nakusp	ARM	1996, 1999	62
2004	Shelter Bay	ALM	1997, 1999	76
	Nakusp	LM	No match	58
2006	Shelter Bay	ARM	1996, 1999	71
	Nakusp	LM	No match	61
		Rainbow Trout		
2004	Shelter Bay	ARM	No match	40
	Shelter Bay	LM	1997	62
2005	Nakusp	RM	1996	45
2006	Shelter Bay	AD	2005, 1996	30
	Shelter Bay	LM	1997	45
	Nakusp	RM	1996	40
2007	Nakusp	LM	1997	39
	Nakusp	LM	1997	35.5
2008	Shelter Bay	RM	1996	34
	Nakusp	AD	2005, 2006	56
	Nakusp	RM & LM	No match	39
	Nakusp	LM	1997	39
	Nakusp	LM	1997	40.5
	Nakusp	LM	1997	40
	Nakusp	RM	1996	32
	Nakusp	RM	1996	50
2009	Nakusp	RM	1996	35

4.0 CONCLUSIONS

Benefits of the Fishery

From 2003 to 2009, ALR supported approximately 15,500 angler days annually, providing important recreational opportunities for local residents and others, and contributing approximately $1 million in direct expenditures to the local and provincial economy. About 10 tonnes of fish were harvested for food each year (Table 12).

Table 12. Summary of fish harvest from Arrow Lakes Reservoir from 2003 to 2009.

Year	Annual Harvest by Species									
	Bull Trout		Rainbow Trout		Kokanee		Burbot		Total	
	Number	kg	Number	kg	Number	kg	Number	kg	Number	kg
2003	2,000	4,500	2,800	3,200	2,800	300	700	1,100	8,200	9,100
2004	2,000	5,400	4,200	4,400	8,600	1,300	400	800	15,300	12,000
2005	1,900	5,000	3,300	3,200	6,800	1,200	400	700	12,300	10,100
2006	1,800	4,400	3,600	2,500	2,300	500	500	900	8,300	8,200
2007	1,800	4,200	3,800	2,600	9,000	1,800	500	800	15,100	9,400
2008	1,400	3,300	3,700	3,300	5,200	1,100	500	700	10,900	8,400
2009	1,600	4,100	3,200	3,000	5,800	1,100	500	700	11,100	8,900

Fishery Trends since the Nutrient Program

The success of the compensation initiatives in terms of the fishery is mixed when post-nutrient years are compared to the 1987-1998 period. Success varies by species, access location, and over time. The kokanee fishery, already substantially reduced when the nutrient program started, continued to decline by all measures (harvest, catch rate, targeted effort) with the exception of a brief increase in Nakusp in 2001. Once a major component of ALR angling, especially in the lower basin near Castlegar, kokanee fishing has declined to about 20% of the total effort in the reservoir. In contrast, harvest and targeted effort for bull trout and rainbow trout (all sizes) increased shortly after the beginning of the nutrient program, remained high until 2005, and then declined. Recent harvests of these species appear to be similar or slightly below the 1987-1998 period. Piscivorous rainbow trout harvest peaked from 2002-2004 (Figs. 10,11); after which it declined and then returned to an intermediate level. Spatially, the Nakusp access point has benefited the most for bull trout and rainbow trout fishing. Burbot catch has remained low but reported angler effort has increased. This may be partly due to a reduction in the regional catch limit from five to two fish in 2003 (i.e., more trips are needed for a local angler to harvest the same number of fish).

Changes in angler effort and harvest estimates at the sampled sites since 1999 are unlikely to be related to large scale shifts of angler access to other locations. Although overflight boat counts observed higher than expected activity in the north part of the lower basin on some fair weather days, the percentage of boats in locations far from our sampled points was not large enough to substantially influence the site results (Section 3.0, first paragraph). Furthermore, there were no significant changes in the number or quality of boat ramps during the last decade that would cause a shift in the preferred angler access. This may change in the near future as a result of new BC Hydro Water Licence Requirement initiatives. Work on new and upgraded ramps will begin in 2010

(Columbia River Water Use Plan Update, April 2010) and future creel survey designs will need to consider this.

Overharvest seems unlikely to be a primary cause of recent declines in piscivorous rainbow trout and bull trout catch, because K_n would be expected to be high when catch rate was low if overharvest was driving abundance down (i.e., kokanee prey supply would increase in relation to predator demand). As noted earlier, data show the opposite to be the case; piscivore catch rate and K_n declined together. Also, high numbers of clipped Gerrard rainbow trout were released during this period with negligible returns to the fishery. If catch was strongly limited by natural recruitment overfishing these stocked fish might be expected to survive at a higher rate, taking the place of natural recruits.

<u>Relationships between Angler Use and Fish Populations</u>

Historical data for ALR indicate the potential for a much larger kokanee fishery than at present. Kokanee effort in ALR appears to be strongly influenced by the presence of larger fish (Fig. 14), and decreased effort may be related to a decrease in size of kokanee since the mid-1980s (Lindsay 1986) and early 1990s. (Unfortunately, data on size of retained kokanee are not available for most of the pre-nutrient years.) The notable reduction in kokanee catch rate since then implies lower fish size because vulnerability of kokanee to angling declines in smaller fish (Rieman and Maiolie 1995). Although records of average spawner size at Hill Creek Spawning Channel and size at age data from trawl surveys do not indicate a sustained size reduction since nutrients began (MFLNRO file data, D. Sebastian, pers. comm.), the actual size of harvested fish remains uncertain; trawl and spawner averages may not be reliable surrogates for harvest size given angler selection for, and greater vulnerability, of larger fish to angling.[10] As previously noted, a reduction in daily kokanee quotas may also be an important contributor to reduced effort, particularly when fish are small, as anglers are likely more inclined to seek smaller fish if they are allowed to retain a higher number.

Size of kokanee is related positively to lake productivity and inversely to fish density (Rieman and Myers 1992). Productivity of ALR at lower trophic levels and average kokanee densities have increased since the beginning of the nutrient program (Schindler et al. 2006), therefore a decrease in kokanee size in some years since 1999 is likely related to the increase in density. In Okanagan Lake, a decline in kokanee size and catch success concurrent with a doubling in density was noted between 1982 and 1992 (Shepherd 1994). Since Hill Creek Spawning Channel has the potential to have a strong influence on kokanee densities in the reservoir, there may be opportunities to modify fry output to approach a more optimal density for angling and prey supply. Rieman and Maiolie (1995) found a dome shaped curve when kokanee density was plotted versus angling yield for lakes and reservoirs in Oregon and Idaho with angling quality declining after the optimum density was exceeded.

Condition factor (K_n) appears to be a useful indicator of feeding conditions for apex predators, and was positively related to angling quality for these species (Section 3.4). Therefore it could be a valuable metric for evaluating the impacts of compensation initiatives, management decisions, and dam operations on angling quality (also see He et al. 2008). High condition factor is typically

[10] An example of the possible discrepancy between Hill Creek spawner size and size of kokanee available for capture is provided by electrofishing data from the upper 8 km of the reservoir below Revelstoke Dam in 1991 and 1992 (R.L.& L. 1994). About 50% of the kokanee captured in that area exceeded 30 cm FL (n=81), whereas average spawner length for those years was 21.8 and 22.3 cm, respectively (MFLNRO file data).

associated with high growth rates (Anderson and Neumann 1996, Arndt et al. 1996), so it is not surprising that high K_n would be associated with high recruitment into the catchable population, as seems to be the case in ALR. Increased survival after spawning may also be a mechanism contributing to increased catch rates of larger fish during periods of high K_n.

Post-Nutrient Feeding Conditions and Predator-Prey Relationships

Trends in K_n indicate inconsistent transfer of nutrient benefits to upper trophic levels of the reservoir. Total density or biomass of all age classes of kokanee do not appear to be good indicators of feeding conditions for apex predators. However, preliminary analyses show a positive relationship between annual K_n and the abundance of kokanee large enough to spawn, and there is some evidence for piscivorous rainbows of an optimal kokanee size after accounting for spawner abundance (Fig. 22). Sebastian et al. (2000) state that bull trout in ALR seldom prey upon kokanee fry or yearlings but rather show a strong preference for sub-adult and adult kokanee. They found only a weak relationship between bull trout size and prey size (as did Arndt 2004b) with small bull trout preying upon fairly large fish (10-22 cm) and larger bull trout easily capable of eating the largest kokanee. Arndt (2004b) found a positive relationship between length of rainbow trout and length of consumed kokanee where trout over 65 cm rarely consumed kokanee less than 15 cm. An in depth investigation of the population dynamics leading to high kokanee survival to spawning size is beyond the scope of this study. The years 2001 to 2005 offer an example of conditions that optimized benefits to bull trout and piscivorous rainbow trout, and occurred when total estimated spawner returns to the Arrow system exceeded 600,000. In general, our results with pelagic bull and rainbow trout parallel those of He et al. (2008) in Lake Huron, where large lake trout *S. namaycush* were found to be more sensitive to prey availability than small lake trout, and chinook salmon *O. tshawytscha* had greater sensitivity to prey (*K*, survival) than char species.

4.1 Recommendations

The creel survey on Arrow Lakes Reservoir should be conducted on a regular basis to monitor the response of the fish community and angling quality to the compensation projects, especially if there are management experiments or operational changes. Given anticipated changes in the number and quality of boat ramps, overflight counts should be included during the next few years to provide an accurate ratio expansion ratio to whole-reservoir estimates, and determine whether new ramps change the spatial distribution of effort. The distribution of fishing effort in overflight results should also be used to evaluate whether the three sampled access locations are still adequate to characterize the fishery; it may be necessary to expand the number of sites monitored, perhaps re-introducing some sampling at Edgewood or Fauquier or sampling at other locales such as Beaten Arm or Revelstoke Reach.

If funding is not available for a full creel survey every year, a collection of length and weight samples from the Nakusp and Shelter Bay sites could allow K_n trends to be tracked at a reduced cost. Based on the correlations in the 2003-2009 period, K_n could serve as an index of feeding conditions, fishing success, and perhaps population abundance for bull trout and piscivorous rainbows.

Sources of natural recruitment for piscivorous rainbow trout need to be identified for Arrow Lakes Reservoir (Spence et al. 2005). Stocking of hatchery fish has not contributed significantly to the fishery in the last decade, however, there appeared to be reasonably good natural recruitment in the early years of the nutrient program based on the large increase in catch of un-clipped fish. Identification of spawning streams and habitat conditions would contribute to determining whether the stream or reservoir phase of their life history is more likely to be limiting. It would also help protect critical habitats, and might highlight opportunities for stream restoration or enhancement. All future releases of hatchery fish should be clipped and monitoring of clipped rainbow trout should be continued in future surveys.

Further analyses of trophic interactions in the ALR food web, including the possible role of operational changes (timing and magnitude of flows through the reservoir) are needed to ensure that targets and methods for the spawning channel and nutrient programs are compatable with provincial objectives, and conducive to high trophic transfer efficiency and fishery benefits. Kerr (1971b) found production efficiency and size composition of exploited lake trout to be suseptible to management through control of the size composition of the supporting prey resource. Predator condition (K_n) in relation to size and abundance of kokanee may be a useful metric to investigate the optimal kokanee fry loading rate for ALR.

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6.0 APPENDICES

APPENDIX 1. 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.

(c) Local fishing derbies are not treated separately but are simply incorporated into the estimates if they occur on a sampled day.

(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 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 adjustment for access points not surveyed will be done using a "ratio estimator" (Cochran 1977, see Methods).

(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.

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.,

[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.

$\overline{A}_{mt} = \sum_d A_{mtd}$	Average number of angler per day for month, day-type combination
$s(A_{mt\bullet})$	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. $se[total(A_{mt})] = N_{mt}\sqrt{\frac{s(A_{mt\bullet})^2}{n_{mt}}\left(1-\frac{n_{mt}}{N_{mt}}\right)}$
$total(A_{m\bullet})$	Estimated total number of angler trips for that month. $total(A_{m\bullet}) = total(A_{m,we}) + total(A_{m,wd})$
$se[total(A_{m\bullet})]$	Estimated standard error for total angler trips in that month $se[total(A_{m\bullet})] = \sqrt{se[total(A_{m,wd})]^2 + se[total(A_{m,we})]^2}$
$total(A_{\bullet\bullet})$	Estimated grand total over all month. $total(A_{\bullet\bullet}) = total(A_{jan\bullet}) + \ldots + total(A_{dec\bullet})$
$se[total(A_{\bullet\bullet})]$	Estimated standard error for grand total over all months $se[total(A_{\bullet\bullet})] = \sqrt{se[total(A_{jan,\bullet})]^2 + \ldots + se[total(A_{dec,\bullet})]^2}$

The following procedure is 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. $A_{june,we,10june} = 26$
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 estimates need to be multiplied by an adjustment-factor to account for sites not visited etc, simply multiply the estimate and the se by the same adjustment-factor (as described in Methods).

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. 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 2. Monthly correction factors and standard errors pooled over day-types and all years from the ratio of overflight boat counts and interviewed anglers at 3 access points.

	Zone									
	All		**Lower**		**Middle and Upper**		**Middle**		**Upper**	
Month	**Corr Factor**	**se (Corr Factor)**	**Corr Factor**	**se (Corr Factor)**	**Corr Factor**	**se (Corr Factor)**	**Corr Factor**	**se (Corr Factor)**	**Corr Factor**	**se (Corr Factor)**
1	0.76	0.11	0.00	0.00	0.88	0.04	0.88	0.03	1.00	1.10
2	1.56	0.15	1.82	0.30	1.46	0.14	1.54	0.14	1.10	0.27
3	1.11	0.10	0.96	0.11	1.21	0.14	1.51	0.24	0.95	0.11
4	1.59	0.59	2.71	0.54	1.58	0.51	1.38	0.38	1.92	1.43
5	1.25	0.20	2.60	0.77	1.06	0.12	1.22	0.19	0.91	0.12
6	2.82	0.79	5.41	1.86	1.59	0.15	1.74	0.13	0.90	0.35
7	2.53	0.31	2.97	0.66	2.70	0.51	2.84	0.66	2.40	0.81
8	1.96	0.42	2.32	0.65	2.06	0.62	2.55	1.10	1.44	0.20
9	1.34	0.17	2.30	0.82	1.19	0.11	1.08	0.13	1.40	0.13
10	1.14	0.16	2.17	0.63	1.02	0.10	1.12	0.08	0.88	0.23
11	1.09	0.23	1.57	0.52	1.03	0.18	1.23	0.21	0.71	0.18
12	1.48	0.27	2.36	0.44	1.45	0.36	1.39	0.37	2.33	0.94

Note: In a few cases when there was a zero boat count in the overflight or zero boats in the access interviews the following procedures were applied. The theoretical treatment of these problems is not well understood. For example, 9 air/0 interview would indicate that potentially many more boats are present compared to the interviews that were collected and the inflation factor is infinite, however, in these cases, the usual "add 1" to numerator and denominator was judged to be a sensible solution, i.e. the correction factor is computed as (9+1)/(0+1)=10/1=10. In the 0/0 situation, adding 1 to the numerator and denominator would give (0+1)/(0+1) or 1 as the correction factor which is "sensible". The cases where the air count is less than the interview count, should, in theory, not happen. We suspect that this is caused by "measurement" error in reporting the interview start/end time or assessing the overlap with the overflight, or by errors in the overflight count such as boats going to places where the overflight did not see them. In this case the correction factor was set to a minimum of 1 for the expansions (i.e., there cannot be less active boats than the number interviewed).

APPENDIX 3. Angler residence composition on Arrow Lakes Reservoir from 1976 to 2009. Data up to 1996 are from Hill Creek Hatchery creel records (Thorp 1995); 1995 to 1997 were not available. Number of access sites monitored was reduced from five to three in 1999.

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
2003	1,540	91.8	7.6	0.6
2004	1,896	92.7	5.8	1.5
2005	1,826	89.9	9.3	0.8
2006	1,624	93.8	5.7	0.5
2007	1,784	90.7	7.3	2.0
2008	1,535	90.4	9.3	0.3
2009	1,700	87.5	11.9	0.6

APPENDIX 4. Arrow Lakes creel survey annual estimates using a common monthly correction factor applied to all zones to adjust for boats returning to non-sampled access sites. See Figure 1 for zone boundaries.

Year 2003	All Sites (Zones)		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	68346	6075	15492	2091	37254	3579	15601	2027	52854	4612
Bull Kept	2004	195	152	44	1207	143	645	126	1852	193
Bull Released	1791	240	42	13	873	120	875	228	1749	238
Bull Total	3795	392	194	48	2081	216	1520	334	3601	388
Burbot Kept	657	183	0	0	657	183	0	0	657	183
Burbot Released	78	42	0	0	78	42	0	0	78	42
Burbot Total	736	198	0	0	736	198	0	0	736	198
Kokanee Kept	2771	440	2307	389	367	117	97	59	464	116
Kokanee Released	1004	197	725	198	178	82	101	57	279	55
Kokanee Total	3775	575	3032	521	545	164	198	109	743	137
Num Anglers	14475	1218	3268	306	8097	801	3110	391	11207	966
Num Rods	15952	1315	3320	299	9277	882	3355	399	12632	1063
Other Species Kept	93	51	8	8	75	49	11	10	86	50
Other Released	25	14	8	8	0	0	17	11	17	11
Other Total	119	54	16	15	75	49	28	15	103	52
Rainbow Kept	2813	438	597	182	1681	288	536	129	2217	335
Rainbow Released	1106	137	162	63	516	93	428	93	944	123
Rainbow Total	3919	478	759	201	2197	289	964	196	3161	390
Rod hours	74127	6447	15693	2022	41843	3911	16591	2041	58434	4981

Year 2004	All Sites (Zones)		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	83434	8033	25867	2584	39654	4794	17913	2308	57567	6059
Bull Kept	2005	251	219	53	1128	189	658	120	1786	243
Bull Released	1404	171	58	34	742	110	605	124	1346	165
Bull Total	3409	376	277	69	1869	244	1263	224	3132	360
Burbot Kept	447	155	0	0	424	154	24	17	447	155
Burbot Released	23	21	0	0	23	21	0	0	23	21
Burbot Total	470	150	0	0	446	149	24	17	470	150
Kokanee Kept	8600	1212	6942	1093	1478	315	180	80	1658	321
Kokanee Released	6540	1135	4998	1014	1384	273	158	65	1542	260
Kokanee Total	15140	2280	11939	2022	2862	548	338	119	3200	528
Num Anglers	17636	1745	6133	650	7881	917	3622	475	11503	1194
Num Rods	18974	1856	6269	662	8746	991	3959	503	12705	1291
Other Species Kept	35	16	22	14	13	9	0	0	13	9
Other Released	135	37	92	28	0	0	42	25	42	25
Other Total	170	43	114	31	13	9	42	25	55	29
Rainbow Kept	4241	593	1002	178	2582	481	657	107	3239	498
Rainbow Released	2171	315	404	100	1543	307	224	58	1767	315
Rainbow Total	6412	772	1406	248	4125	633	881	129	5006	662
Rod hours	89272	8481	26199	2603	43544	5100	19529	2451	63074	6463

Year 2005	All Sites (Zones)		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	76842	7476	23397	3026	35398	4612	18047	2508	53444	6037
Bull Kept	1933	251	236	64	1127	185	569	112	1697	240
Bull Released	1374	209	59	31	600	126	715	169	1314	211

Bull Total	3307	400	295	81	1727	279	1284	241	3011	398
Burbot Kept	369	99	0	0	369	99	0	0	369	99
Burbot Released	19	17	0	0	19	17	0	0	19	17
Burbot Total	388	103	0	0	388	103	0	0	388	103
Kokanee Kept	6761	1329	5146	1008	1469	775	146	76	1615	779
Kokanee Released	4601	1043	2891	865	1378	466	332	149	1710	519
Kokanee Total	11362	2125	8036	1589	2847	1194	478	173	3325	1252
Num Anglers	15939	1445	5302	585	6981	855	3656	492	10637	1126
Num Rods	17096	1553	5435	597	7710	914	3951	541	11662	1206
Other Species Kept	0	0	0	0	0	0	0	0	0	0
Other Released	34	11	27	10	0	0	7	6	7	6
Other Total	34	11	27	10	0	0	7	6	7	6
Rainbow Kept	3271	564	879	203	1648	350	743	180	2392	468
Rainbow Released	1822	235	324	73	960	180	539	114	1499	227
Rainbow Total	5094	738	1203	244	2608	461	1283	273	3891	636
Rod hours	81901	7995	23888	3091	38561	4899	19453	2705	58014	6415

Year 2006	All Sites (Zones)		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	72574	7571	22548	3700	29176	3022	20851	3133	50027	5281
Bull Kept	1817	238	204	87	918	147	694	110	1612	213
Bull Released	1736	271	100	87	678	125	958	211	1635	261
Bull Total	3552	463	304	172	1596	213	1652	297	3248	430
Burbot Kept	515	188	7	6	508	189	0	0	508	189
Burbot Released	0	0	0	0	0	0	0	0	0	0
Burbot Total	515	188	7	6	508	189	0	0	508	189
Kokanee Kept	2308	472	1976	421	258	94	73	36	332	101
Kokanee Released	843	228	313	123	440	164	90	52	530	171
Kokanee Total	3151	629	2289	510	698	200	163	59	861	206
Num Anglers	14576	1524	4370	700	6392	656	3814	507	10206	1030
Num Rods	15110	1555	3936	606	7187	746	3987	535	11174	1140
Other Species Kept	90	52	19	10	71	52	0	0	71	52
Other Released	104	62	76	50	28	25	0	0	28	25
Other Total	195	103	96	51	99	77	0	0	99	77
Rainbow Kept	3635	576	1055	303	1653	309	927	164	2580	381
Rainbow Released	1786	262	105	37	823	193	858	126	1681	240
Rainbow Total	5421	757	1160	325	2476	435	1785	237	4261	545
Rod hours	74726	7774	20659	3434	32396	3380	21670	3235	54066	5737

Year 2007	All Sites (Zones)		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	82059	8599	29513	3823	33050	3946	19495	3914	52546	5873
Bull Kept	1821	218	216	48	971	153	634	124	1605	209
Bull Released	1184	223	5	4	543	159	636	154	1179	223
Bull Total	3005	366	221	49	1514	226	1270	262	2784	354
Burbot Kept	466	169	27	24	439	167	0	0	439	167
Burbot Released	17	15	0	0	17	15	0	0	17	15
Burbot Total	483	165	27	24	456	164	0	0	456	164
Kokanee Kept	9009	1323	6832	1150	1846	457	331	136	2177	540
Kokanee Released	2816	459	2359	426	217	101	240	80	457	133
Kokanee Total	11826	1703	9191	1480	2064	496	571	167	2634	579
Num Anglers	16809	1628	5969	717	7181	861	3659	432	10840	1072

Num Rods	16939	1584	5153	566	7937	946	3849	444	11786	1153
Other Species Kept	23	16	0	0	0	0	23	16	23	16
Other Released	24	17	0	0	0	0	24	17	24	17
Other Total	48	24	0	0	0	0	48	24	48	24
Rainbow Kept	3787	496	1302	245	1620	270	865	180	2485	341
Rainbow Released	1568	259	319	69	809	200	440	81	1249	228
Rainbow Total	5355	561	1621	262	2429	322	1305	206	3734	423
Rod hours	82616	8311	25828	3073	36365	4318	20423	3956	56788	6172

Year 2008	All Sites (Zones)		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	69743	6743	21760	2880	32163	3502	15821	1742	47983	4610
Bull Kept	1437	185	282	79	693	109	463	83	1156	159
Bull Released	1180	205	0	0	409	109	771	152	1180	205
Bull Total	2618	330	282	79	1102	186	1234	212	2336	319
Burbot Kept	454	139	0	0	454	139	0	0	454	139
Burbot Released	122	98	0	0	122	98	0	0	122	98
Burbot Total	576	189	0	0	576	189	0	0	576	189
Kokanee Kept	5249	917	4945	884	219	68	84	38	303	90
Kokanee Released	767	271	314	169	338	126	115	51	453	152
Kokanee Total	6015	1090	5259	963	557	162	199	83	756	214
Num Anglers	15190	1584	4464	581	7661	842	3065	384	10727	1132
Num Rods	15949	1619	4378	569	8366	876	3205	399	11571	1173
Other Species Kept	117	71	111	70	0	0	6	6	6	6
Other Released	22	5	0	0	0	0	22	5	22	5
Other Total	139	71	111	70	0	0	28	7	28	7
Rainbow Kept	3714	704	1396	439	1565	283	753	197	2319	376
Rainbow Released	1292	267	54	29	824	237	414	93	1238	268
Rainbow Total	5006	777	1449	445	2389	405	1167	264	3557	526
Rod hours	72789	6914	21362	2827	34899	3616	16528	1825	51427	4801

Year 2009	All Sites (Zones)		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	76997	7229	23799	3496	34936	3747	18261	2041	53198	4787
Bull Kept	1621	195	360	102	678	104	583	103	1261	153
Bull Released	1267	229	60	15	447	139	760	182	1207	227
Bull Total	2888	355	420	111	1126	198	1343	238	2469	326
Burbot Kept	456	167	0	0	456	167	0	0	456	167
Burbot Released	126	87	0	0	126	87	0	0	126	87
Burbot Total	582	245	0	0	582	245	0	0	582	245
Kokanee Kept	5796	729	4851	765	837	255	108	62	945	278
Kokanee Released	2385	611	1108	290	952	368	326	146	1278	454
Kokanee Total	8182	1124	5959	854	1789	560	434	135	2223	644
Num Anglers	15412	1378	4990	610	6658	706	3765	377	10422	939
Num Rods	15588	1358	4734	568	6882	716	3971	385	10854	965
Other Species Kept	29	21	29	21	0	0	0	0	0	0
Other Released	110	70	0	0	0	0	110	70	110	70
Other Total	139	74	29	21	0	0	110	70	110	70
Rainbow Kept	3215	408	1290	309	1054	202	871	177	1925	243
Rainbow Released	1330	232	310	131	596	152	424	97	1020	142
Rainbow Total	4545	542	1600	372	1650	319	1294	248	2945	329
Rod hours	77884	7131	22899	3367	35866	3780	19119	2039	54986	4898

APPENDIX 5. Arrow Lakes creel survey annual estimates using separate monthly correction factors for each site/zone combination to adjust for boats returning to non-sampled access sites. See Figure 1 for zone boundaries.

Year 2003	All Sites/Zones		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	68346	6075	23065	4011	35678	3818	13944	2680	48452	4183
Bull Kept	2004	195	182	55	1165	147	580	132	1738	178
Bull Released	1791	240	44	15	848	122	799	309	1654	223
Bull Total	3795	392	226	59	2014	222	1379	428	3391	359
Burbot Kept	657	183	0	0	664	203	0	0	595	165
Burbot Released	78	42	0	0	66	33	0	0	62	31
Burbot Total	736	198	0	0	730	211	0	0	658	172
Kokanee Kept	2771	440	3440	713	380	130	79	48	438	111
Kokanee Released	1004	197	1085	350	169	92	64	37	237	51
Kokanee Total	3775	575	4525	968	549	195	143	80	674	136
Num Anglers	14475	1218	4822	630	7715	832	2767	517	10206	859
Num Rods	15952	1315	4887	625	8815	905	2966	538	11476	934
Other Species Kept	93	51	14	12	72	49	8	7	84	50
Other Released	25	14	14	12	0	0	17	12	17	12
Other Total	119	54	27	25	72	49	25	14	102	52
Rainbow Kept	2813	438	854	242	1489	242	522	167	1882	267
Rainbow Released	1106	137	208	81	493	85	376	91	831	103
Rainbow Total	3919	478	1062	271	1982	244	899	240	2712	297
Rod hours	74127	6447	23269	3876	40023	4129	14715	2716	53515	4499

Year 2004	All Sites/Zones		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	83434	8033	38120	4613	38284	4617	16604	3554	52767	5447
Bull Kept	2005	251	326	86	1104	191	663	214	1694	228
Bull Released	1404	171	101	64	704	108	573	167	1251	152
Bull Total	3409	376	427	117	1808	245	1236	370	2945	333
Burbot Kept	447	155	0	0	387	147	23	17	398	141
Burbot Released	23	21	0	0	14	12	0	0	13	11
Burbot Total	470	150	0	0	401	144	23	17	410	139
Kokanee Kept	8600	1212	9178	1773	1356	276	159	88	1399	251
Kokanee Released	6540	1135	6784	1537	1317	274	112	39	1363	234
Kokanee Total	15140	2280	15963	3221	2673	479	271	114	2762	408
Num Anglers	17636	1745	8972	1157	7640	910	3202	585	10460	1060
Num Rods	18974	1856	9202	1179	8449	965	3499	623	11512	1119
Other Species Kept	35	16	20	13	13	8	0	0	11	7
Other Released	135	37	112	36	0	0	28	16	31	17
Other Total	170	43	131	38	13	8	28	16	43	21
Rainbow Kept	4241	593	1579	313	2298	429	613	123	2708	372
Rainbow Released	2171	315	663	173	1475	285	225	58	1552	256
Rainbow Total	6412	772	2242	430	3773	602	837	147	4260	519
Rod hours	89272	8481	38683	4671	41889	4835	18085	3751	57646	5708

Year 2005	All Sites/Zones		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	76842	7476	33346	5372	34986	4680	16839	4319	49981	5534

Bull Kept	1933	251	302	75	1083	179	592	191	1614	231
Bull Released	1374	209	79	43	615	132	698	186	1301	217
Bull Total	3307	400	381	94	1698	283	1290	342	2916	395
Burbot Kept	369	99	0	0	356	94	0	0	345	95
Burbot Released	19	17	0	0	18	17	0	0	17	15
Burbot Total	388	103	0	0	375	99	0	0	362	98
Kokanee Kept	6761	1329	7160	1755	1144	467	110	56	1186	433
Kokanee Released	4601	1043	4396	1583	1277	402	260	144	1496	408
Kokanee Total	11362	2125	11556	3083	2421	793	371	162	2682	777
Num Anglers	15939	1445	7493	1070	6889	904	3413	806	9972	1068
Num Rods	17096	1553	7689	1098	7571	951	3708	906	10893	1135
Other Species Kept	0	0	0	0	0	0	0	0	0	0
Other Released	34	11	31	13	0	0	7	6	8	7
Other Total	34	11	31	13	0	0	7	6	8	7
Rainbow Kept	3271	564	1450	383	1620	385	693	186	2201	472
Rainbow Released	1822	235	569	147	997	202	486	112	1423	223
Rainbow Total	5094	738	2019	464	2617	524	1179	281	3623	644
Rod hours	81901	7995	34112	5527	37958	4931	18200	4723	54115	5857

Year 2006	All Sites/Zones		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	72574	7571	32408	5760	27668	2960	19987	4450	45325	4707
Bull Kept	1817	238	264	105	905	142	676	153	1518	200
Bull Released	1736	271	116	103	702	141	916	263	1567	248
Bull Total	3552	463	380	203	1607	216	1592	400	3086	400
Burbot Kept	515	188	7	6	596	282	0	0	513	208
Burbot Released	0	0	0	0	0	0	0	0	0	0
Burbot Total	515	188	7	6	596	282	0	0	513	208
Kokanee Kept	2308	472	2795	728	203	75	61	30	257	76
Kokanee Released	843	228	427	161	303	93	72	40	371	102
Kokanee Total	3151	629	3222	825	506	113	133	46	628	118
Num Anglers	14576	1524	6334	1204	6125	705	3591	703	9252	908
Num Rods	15110	1555	5682	1030	6878	789	3742	727	10106	991
Other Species Kept	90	52	30	17	81	60	0	0	76	56
Other Released	104	62	95	61	31	29	0	0	30	27
Other Total	195	103	125	65	112	88	0	0	105	83
Rainbow Kept	3635	576	1696	518	1521	322	877	194	2257	322
Rainbow Released	1786	262	160	61	690	136	841	126	1449	182
Rainbow Total	5421	757	1856	550	2211	386	1718	277	3705	434
Rod hours	74726	7774	29729	5294	30724	3288	20679	4515	48884	5075

Year 2007	All Sites/Zones		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	82059	8599	45789	7477	31719	4079	16848	3188	47157	5042
Bull Kept	1821	218	327	81	935	137	555	105	1446	181
Bull Released	1184	223	7	7	446	93	559	130	984	157
Bull Total	3005	366	334	82	1381	171	1114	217	2430	275
Burbot Kept	466	169	27	24	386	132	0	0	361	126
Burbot Released	17	15	0	0	16	15	0	0	14	13
Burbot Total	483	165	27	24	402	128	0	0	375	122

Kokanee Kept	9009	1323	10706	2332	1733	495	280	116	1879	511
Kokanee Released	2816	459	3644	865	224	114	172	64	417	136
Kokanee Total	11826	1703	14350	3068	1957	531	452	145	2296	554
Num Anglers	16809	1628	9230	1430	6833	861	3227	392	9731	922
Num Rods	16939	1584	7978	1173	7523	925	3392	404	10550	975
Other Species Kept	23	16	0	0	0	0	17	12	24	18
Other Released	24	17	0	0	0	0	25	18	22	15
Other Total	48	24	0	0	0	0	42	21	46	23
Rainbow Kept	3787	496	2164	468	1605	304	798	192	2248	309
Rainbow Released	1568	259	504	120	840	232	390	70	1186	237
Rainbow Total	5355	561	2668	529	2445	379	1188	214	3434	403
Rod hours	82616	8311	40146	6210	34660	4307	17642	3216	50767	5219

Year 2008	All Sites/Zones		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	69743	6743	33347	5598	31459	3574	14338	2007	43900	3967
Bull Kept	1437	185	403	124	702	116	440	91	1077	147
Bull Released	1180	205	0	0	404	112	711	170	1081	185
Bull Total	2618	330	403	124	1106	187	1151	240	2158	283
Burbot Kept	454	139	0	0	449	142	0	0	427	133
Burbot Released	122	98	0	0	81	60	0	0	79	57
Burbot Total	576	189	0	0	530	165	0	0	506	157
Kokanee Kept	5249	917	7851	1774	189	61	80	43	261	84
Kokanee Released	767	271	479	238	342	142	102	51	433	159
Kokanee Total	6015	1090	8330	1879	532	168	182	90	694	215
Num Anglers	15190	1584	6886	1169	7380	847	2657	389	9607	931
Num Rods	15949	1619	6817	1181	8039	888	2773	401	10342	954
Other Species Kept	117	71	178	123	0	0	5	4	5	5
Other Released	22	5	0	0	0	0	16	2	23	7
Other Total	139	71	178	123	0	0	21	5	28	8
Rainbow Kept	3714	704	2413	893	1327	210	704	208	1923	297
Rainbow Released	1292	267	89	54	736	202	362	83	1081	212
Rainbow Total	5006	777	2502	903	2062	324	1066	269	3004	419
Rod hours	72789	6914	33059	5688	34029	3731	14946	2085	46937	4132

Year 2009	All Sites/Zones		Castlegar		Nakusp		Shelter Bay		Shelter Bay + Nakusp	
Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Angler Hours	76997	7229	35419	6004	33987	3644	16922	3099	48845	4250
Bull Kept	1621	195	470	134	722	121	567	139	1205	147
Bull Released	1267	229	79	24	418	104	773	322	1104	189
Bull Total	2888	355	549	145	1140	181	1340	434	2309	284
Burbot Kept	456	167	0	0	471	207	0	0	429	169
Burbot Released	126	87	0	0	146	112	0	0	130	92
Burbot Total	582	245	0	0	617	313	0	0	559	253
Kokanee Kept	5796	729	6957	1317	801	269	108	66	868	275
Kokanee Released	2385	611	1652	460	634	178	201	82	840	214
Kokanee Total	8182	1124	8609	1591	1435	374	309	79	1708	386
Num Anglers	15412	1378	7447	1122	6460	691	3389	570	9568	846
Num Rods	15588	1358	7057	1031	6702	709	3570	595	9992	874
Other Species Kept	29	21	53	41	0	0	0	0	0	0

Other Released	110	70	0	0	0	0	93	59	102	63
Other Total	139	74	53	41	0	0	93	59	102	63
Rainbow Kept	3215	408	2161	627	988	191	793	191	1754	235
Rainbow Released	1330	232	475	199	620	167	404	101	967	139
Rainbow Total	4545	542	2637	714	1608	328	1197	271	2721	324
Rod hours	77884	7131	34082	5676	35003	3707	17689	3203	50629	4358

APPENDIX 6a. Size statistics for bull trout in the Arrow Lakes Reservoir creel survey from 1998 to 2009. Data for 1998-2002 are from Arndt (2002a, 2004a).

		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
2003	248	55.8 ± 1.2	32 – 88		2,252 ± 170	370 – 9,500
2004	263	59.2 ± 1.1	37 – 88		2,710 ± 168	600 – 10,517
2005	269	59.7 ± 1.1	35 – 83		2,570 ± 140	420 – 7,040
2006	240	59.2 ± 1.2	38 – 83		2,396 ± 158	405 – 6,123
2007	235	58.0 ± 1.5	34 – 90		2,320 ± 177	396 – 8,731
2008	181	58.4 ± 1.4	30 – 82		2,309 ± 182	340 – 6,350
2009	217	58.6 ± 1.6	23 – 87		2,543 ± 200	160 – 7,938

APPENDIX 6b. Size statistics for rainbow trout in the Arrow Lakes Reservoir creel survey from 1998 to 2009.

		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	150	35.8 ± 1.4	23 - 84		597 ± 105	100 – 5,942
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	316	42.1 ± 1.3	23 – 81		1,162 ± 141	170 - 8,000
2003	281	40.8 ± 1.4	20 - 85		1,144 ± 177	140 – 9412
2004	383	39.0 ± 1.4	17 - 92		1,034 ± 167	70 – 12,247
2005	315	38.6 ± 1.3	20 – 83		971 ± 853	85 – 8,620
2006	362	37.0 ± 1.0	18 - 82		679 ± 78	85 – 7,065
2007	364	37.3 ± 0.8	17 - 81		694 ± 74	56 – 7,700
2008	313	39.8 ± 1.1	19 - 76		885 ± 104	91 – 6,237
2009	323	40.1 ± 1.2	17 - 80		924 ± 112	50 – 7,800

APPENDIX 6c. Size statistics for kokanee in the Arrow Lakes Reservoir creel survey from 1998 to 2009.

		Fork Length (cm)		Weight (g)		
Year	**N**	**Mean ± 95% c.l.**	**Range**	**N**	**Mean ± 95% c.l.**	**Range**
1998	104	25.2 ± 0.9	18-34	59	172 ± 13	75-400
1999	1	21.0	na	1	136	na
2000	2	28.5	na	2	275	na
2001	666	25.8 ± 0.2	17-42	629	215 ± 8	56-963
2002	123	22.5 ± 0.7	16-41	109	138 ± 19	28-708
2003	199	21.2 ± 0.4	15-39	190	113 ± 11	28-680
2004	349	22.6 ± 0.5	13-50	340	155 ± 13	28-1,417
2005	295	23.1 ± 0.7	15-60	291	179 ± 25	28-2,353
2006	158	24.0 ± 0.7	16-47	148	203 ± 23	56-1,275
2007	576	24.6 ± 0.3	15-53	571	197 ± 12	56-2,041
2008	343	24.5 ± 0.4	17-55	338	207 ± 15	50-1,650
2009	412	24.0 ± 0.4	12-62	371	184 ± 23	28-3,260

APPENDIX 6d. Size statistics for burbot in the Arrow Lakes Reservoir creel survey from 1998 to 2009.

		Fork Length (cm)			Weight (g)	
Year	**N**	**Mean ± 95% c.l.**	**Range**		**Mean ± 95% c.l.**	**Range**
1998	5	73.2 ± 19.8	60-90		2019 ± 1588	900-4130
1999	18	59.1 ± 4.7	41-76		1264 ± 239	454-2223
2000	6	60.0 ± 4.8	52-65		1196 ± 419	700-1700
2001	39	63.1 ± 2.3	50-86		1596 ± 190	737-3345
2002	78	63.8 ± 1.8	45-84		1608 ± 133	737-3685
2003	73	63.0 ± 1.5	50-79		1601 ± 105	680-3175
2004	47	64.6 ± 2.3	51-98		1781 ± 281	737-6690
2005	55	66.1 ± 1.9	53-84		1944 ± 187	1020-4365
2006	64	65.9 ± 1.8	46-86		1685 ± 142	963-3628
2007	60	66.8 ± 1.6	52-88		1684 ± 117	822-3912
2008	55	64.2 ± 1.9	51.5-87		1569 ± 145	878-3515
2009	50	64.4 ± 2.3	41.5-89		1564 ± 187	652-4309

APPENDIX 7. Locations of fishing boats on Arrow Lakes Reservoir for 48 flights made between April 2003 and March 2005.