A FIVE-YEAR POST-IMPOUNDMENT STUDY OF FISH BIOLOGY IN ALBERTA'S OLDMAN RIVER RESERVOIR AND ADJOINING STREAMS

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A five-year post-impoundment study of fish biology in Alberta's Oldman River Reservoir and adjoining streams

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ABSTRACT

This report presents biological data gathered on fish populations in southern Alberta's Oldman River Reservoir during the first five years (1991 - 1995) of reservoir operation. The study involved the collection of fish each fall from the reservoir with gill nets and from upstream and downstream river habitats by electrofishing.

All of the predominant large fish species inhabiting the river system before impoundment (mountain whitefish - *Prosopium williamsoni*, rainbow trout - *Oncorhynchus mykiss*, bull trout - *Salvelinus confluentus*, longnose sucker - *Catostomus catostomus*, and white sucker - *Catostomus commersoni*) were present in significant abundance in the reservoir four years after its construction. Overall fish abundance in the Oldman River Reservoir was relatively high, compared to the abundance levels obtained in a similar 1983-87 study of the Dickson Dam Reservoir, another recently constructed reservoir located in central Alberta, on the Red Deer River. Both studies employed similar sampling techniques and strategies. Yearly catch rates for all species combined, ranged from 3.5 to 10.7 $fish{\cdot}h^{-1}{\cdot}100\ m^{-1}$ net at the Oldman River Reservoir, while catch rates obtained at the Dickson Dam Reservoir ranged from 0.12 to 0.47 $fish{\cdot}h^{-1}{\cdot}100\ m^{-1}$ net.

Catch rates at the Oldman River Reservoir were high right from the start of reservoir operation in 1991. Therefore, the abundance of fish in the reservoir is probably attributable to pre-existing fish populations in the parent rivers rather than to a trophic upsurge phenomenon which is commonly believed to drive reservoir productivity during the initial years of operation. Based on catch per unit of gill-netting effort (CPUE), the abundance of longnose sucker in shallow waters (< 10 m depth) of the reservoir declined from 1991 to 1993, then returned to previous levels in 1994 and 1995. None of the other fish species in the reservoir exhibited significant changes in abundance (i.e. CPUE) over the study period, although it should be noted that the experimental protocol used was not intended to detect changes in fish abundance.

Catch rates for bull trout at the Oldman River Reservoir ranged from 0.27 to 0.94 $fish{\cdot}h^{-1}{\cdot}100\ m^{-1}$ net. Hence, significant numbers of bull trout continue to exist upstream of the Oldman River Dam. Bull trout in both reservoir and stream habitats were highly piscivorus; fish comprised from 64 % to nearly 100 % of the diet by weight.

During the first two years of life, rainbow trout grew much faster in the Oldman River

Reservoir than in streams above and below the reservoir. Faster growth in the reservoir may reflect less energy expenditure for swimming due to lower water velocities in the reservoir compared to stream habitats and to consumption of poorly digestible material (algae) by rainbow trout in the streams. Whereas algae comprised 23 - 90 % by weight of rainbow trout stomach contents in the streams, the dominant prey of rainbow trout in the reservoir were *Daphnia* spp. which have been shown to sustain good growth rates of juvenile rainbow trout in other western North American reservoirs.

Unlike rainbow trout, mountain whitefish grew much more slowly in the reservoir than in the rivers. Moreover, habitat-related growth differences in mountain whitefish developed primarily after fish had reached two years of age. The slow growth of mountain whitefish in the reservoir may be related to a scarcity of benthic insect prey in the reservoir, a small subterminal mouth which may make feeding on small pelagic prey (i.e. *Daphnia*) inefficient, and a significantly higher percentage of empty stomachs compared to river populations.

In streams above and below the Oldman River Reservoir, most mountain whitefish matured reproductively at the usual ages of three or four years. However, mountain whitefish in the reservoir did not attain 50 % maturity rates until 6 or more years of age. The fecundity of mountain whitefish in the Oldman River system was similar to literature values for other mountain whitefish populations in western North America.

In summary, populations of the major sport-fish species in the Oldman River Reservoir appear to have remained relatively abundant during the first five years of reservoir operation. Continued monitoring of fish populations in the Oldman River Reservoir is recommended because limnological and biological conditions within reservoirs commonly require longer than five years to stabilize.

1.0 INTRODUCTION

Southern Alberta's Oldman River Reservoir was filled in 1991 following construction of an earth and rock filled irrigation storage dam on the Oldman River approximately 10 km below its confluence with the Crowsnest and Castle rivers. At full supply level, the reservoir inundates approximately 9.1 km of the Crowsnest River, 12.2 km of the Castle River, and 6.4 and 15.5 km of the north fork and main stem of the Oldman River, respectively. These rivers, especially the Crowsnest, are popular with sport-fishers (McLennan 1996; Dawson 1996) seeking rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), brown trout (*Salmo trutta*), bull trout (*Salvelinus confluentus*), and mountain whitefish (*Prosopium williamsoni*).

Construction of the dam raised human health concerns about the possibility of mercury accumulation in reservoir fish. Flooding of soil generally enhances the microbial conversion of ubiquitous inorganic mercury to methyl mercury which is highly toxic and readily accumulates in aquatic food chains (Jackson 1988). Elevated mercury concentrations in fish have been reported in several reservoirs in Canada (Bodaly et al. 1984, Jackson 1988), and elsewhere (Potter et al. 1975, Lodenius et al. 1983).

The reservoir is also expected to influence the biology of locally important fish species, notably rainbow trout (the most popular sport fish in the area), mountain whitefish, and bull trout. The bull trout is currently considered a species of special concern in Alberta because the abundance of this species has declined markedly in recent times (Berry 1994).

To address the above concerns, the Alberta Government implemented an extensive fisheries mitigation and monitoring program for the reservoir. As part of this program, the Alberta Research Council[1] (ARC) has, since 1991, conducted annual fall surveys of mercury concentrations in fish from the Oldman River Reservoir and adjoining streams. Although the primary purpose of this program is to monitor mercury concentrations, biological data are also gathered from fish collected for mercury analysis to provide supplementary information on fish stocks in the area.

This report presents a summary of the biological information gathered on fish populations in the upper Oldman River system during the initial five years (1991-95) of reservoir operation. The information presented includes species composition, catch-per-unit-effort, size and age

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[1] The work reported here was conducted by the Alberta Environmental Centre which joined with the Alberta Research Council on July 10, 1996.

distribution, growth rates, diet composition, and reproductive characteristics of mountain whitefish.

2.0 METHODS

2.1 Characteristics of the Oldman River Reservoir and Adjoining Streams

At full supply level (water elevation 1,118.6 m above sea level), the Oldman River Reservoir is approximately 2,400 ha in size, has a mean length of 24 km, and a mean depth of 21 m (Golder Associates 1995). Prior to reservoir filling, an estimated 150,000 m^3 of top soil and 440 ha of riparian vegetation were removed from the area to be flooded. Although the reservoir began filling in the spring of 1991, full supply level was not reached until the early summer of 1993 due to water draw-downs (Wu et al. 1996).

The principle streams entering the Oldman River Reservoir are the north fork of the Oldman River, the Crowsnest River, and the Castle River. All of these streams originate in the eastern slopes of the Rocky Mountains. The Oldman, Castle, and Crowsnest Rivers have mean annual discharges of 405,000, 503,000, and 152,000 dam^3 and mean annual flow rates of 12.8, 15.9, and 4.8 $m^3 \cdot s^{-1}$, respectively (Golder Associates 1995). Because water flow to the Oldman River Reservoir is primarily dependent on snow melt from the mountains, approximately 60 % of yearly inflow to the reservoir occurs during spring runoff between mid-May and mid-July. Reservoir flushing rate is estimated at approximately 2.7 times per year .

Moderate thermal stratification develops within the reservoir during summer. For example, in July and August water temperatures typically range from 9 to 12°C at the bottom to between 15 and 17°C at the surface (Golder Associates 1995). Oxygen concentrations are above 7 $mg \cdot L^{-1}$ at all depths and hypolimnetic oxygen depletion in summer is minimal (Golder Associates 1995; winter oxygen depletion has not been studied). On the basis of summer total phosphorus concentrations of 0.010 - 0.015 $mg \cdot L^{-1}$ (Golder Associates 1995) the reservoir would be classified as oligo-mesotrophic (Wetzel 1975).

Electroshocking surveys conducted in 1985 in the river reaches to be impounded showed that mountain whitefish and rainbow trout were the primary sport-fish species present (R.L. & L. 1986). Mountain whitefish were approximately five times as abundant as rainbow trout. Both species were common in all three rivers, but abundance and growth rates were considerably higher in the Crowsnest River than in the Oldman or Castle rivers. Brown trout were common only in the lower Crowsnest River below Lundbreck Falls where they exhibited good growth rates. Bull trout comprised only 0.4 % of the total catch of sport fish and occurred primarily in the Castle River. Cutthroat trout were the rarest sport fish, being represented by one individual from the Crowsnest River among a total of 4151 sport fish captured from the three rivers (R.L. & L. 1986).

Of the three rivers entering the Oldman River Reservoir, the Crowsnest River has been most highly impacted by land use practices which include coal mining, timber harvesting, cattle grazing, and urban development. The Crowsnest River has also become widely known for its productive recreational trout fishery. Factors contributing to the high productivity of the Crowsnest River include nutrient additions from communities in the Crowsnest Pass and the extensive enhancement work that has created additional habitat, allowing fish to take advantage of the productive fertile river environment. This work has included the placement of 250 large boulders and 5 rock ledges in the Blairmore area (R.L. & L. 1987), and the construction of 164 in-stream structures (e.g. v-wiers), 9 bank stabilization structures, and 31 run/pool excavations as part of the fisheries mitigation plan for the Oldman River Reservoir (Council 1995).

2.2 Fish Collection Methods and Sampling Schedule

Fish were collected from six sites (Fig. 1) once each year from 1991 to 1995, inclusive. Sampling was always done in the fall, between September 19 and October 23. The selection of sampling locations was based primarily on requirements for assessing the reservoir's impact on fish mercury concentrations (see Wu et al. 1996 for rationale). Site 1 on the Crowsnest River approximately 15 km above Lundbreck Falls (a natural barrier to the upstream movement of fish) was chosen as a control with which to evaluate variability in mercury concentrations independently of river impoundment. Sampling on the Oldman River above the reservoir (site 2) was conducted near the Olin Creek bridge (Fig. 1). Sampling sites on the reservoir were located in the west basin (site 3) and the central basin (site 4). An additional sampling site, near the mouth of the Crowsnest River (site 3A), was added in 1995 for collection of additional rainbow trout by electrofishing (see below). Because access to the Oldman River within the Piegan

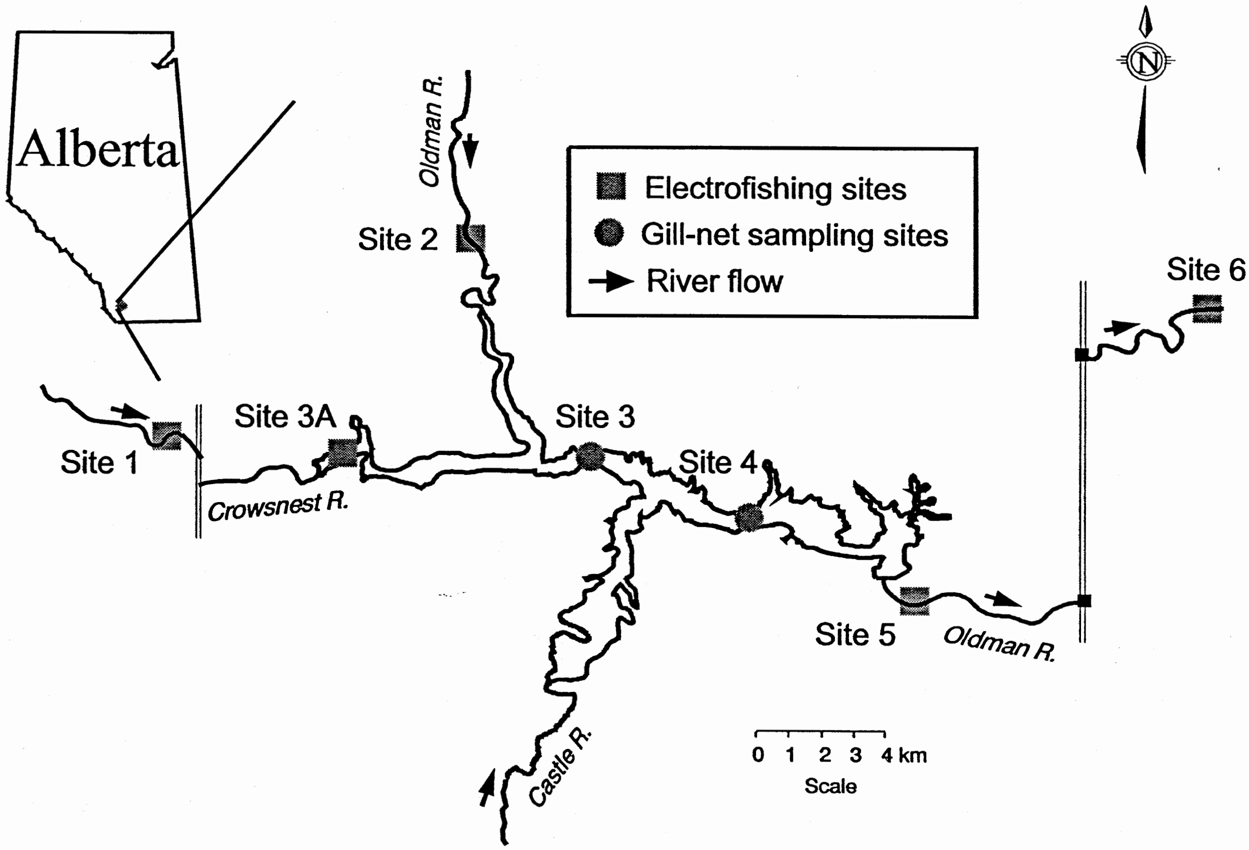

Figure 1. Fish collection sites on the Oldman River Reservoir and adjoining streams. Site 1 - Crowsnest River above Lundbreck Falls; Site 2 - Oldman River upstream of reservoir; Site 3 - west basin; Site 3A - mouth of the Crowsnest River; Site 4 - central basin; Site 5 - immediately below dam; Site 6 - Oldman River near Fort Macleod.

Indian Reservation is restricted, the only feasible sampling sites below the reservoir were located immediately below the dam (site 5) and near Fort Macleod (site 6), approximately 65 river km downstream of the reservoir (Fig. 1).

Fish were collected from the reservoir sites with 100 m by 1.8 m multi-mesh monofilament gill nets consisting of two 50 m sections. Section A consisted of four equal-length panels having mesh sizes of 25, 38, 51, and 64 mm and section B consisted of five equal-length panels of 76, 89, 102, 114, and 127 mm mesh sizes. By using a range of mesh sizes, the inherent size selectivity of gill nets is minimized, and the resulting fish catch more accurately reflects the size structure of the population (Hubert 1996). The locations and methods of gill-net sampling were held as constant as possible from year to year to ensure data continuity (Moore et al. 1993). Standardized gill-net fishing consisted of setting two nets simultaneously; one in shallow (2 -

10 m) and one in deeper (10 - 30 m) water. Both nets were suspended immediately above the bottom and set perpendicular to the shoreline. In 1991, gill nets were set overnight to make the sampling consistent with a previous study at the Dickson Dam Reservoir (Moore 1989a,b). However, this practice was stopped in 1992 after catch rates at the Oldman River Reservoir proved to be higher than expected. Beginning in 1992, gill nets were set for only 3 to 8 h to avoid catching excessive numbers of fish, particularly bull trout.

After standardized gill-net fishing had been completed, it was usually (1992 to 1995 inclusive) necessary to conduct additional sampling to fill in gaps in desired sample sizes for certain fish species. Supplemental sampling with gill nets was usually conducted in shallow water and often with only the B section of net. In 1995, some additional sampling by electrofishing was done at site 3A (Fig. 1) to obtain sufficient numbers of rainbow trout from the reservoir. In all years, collection of fish from sites upstream and downstream of the reservoir was done by electrofishing from boats. During in-stream electrofishing operations, fish were often visually screened by species. Once sufficient numbers of a given species had been collected, additional fish of that species were not necessarily collected or counted. Fish were collected and kept according to the numbers and conditions set out in yearly collection permits obtained from Alberta Fisheries Management Division. A schedule of standardized and supplemental sampling operations conducted at the reservoir is given in Table 1. Fish were placed into plastic bags to prevent dessication and stored in a commercial walk-in freezer in Pincher Creek within a few hours after capture. Once frozen, the fish were transported to ARC in Vegreville for dissection and processing.

2.3 Fish Dissections

Fish were dissected after having been warmed at room temperature to a frozen yet pliable state. Dissection of fish while still frozen prevented loss of liquid water from the tissues. After removing samples of epaxial white muscle for mercury determination (Moore et al. 1993), the visceral cavity was exposed for examination of the gonads and stomach. Gonads were assigned a maturity stage based on size and appearance. Ovaries in mature or ripe condition were excised, weighed, and preserved in 10 % formalin solution for fecundity determinations. Stomachs containing food were also excised, slit open (to facilitate fixation of prey), and preserved in 10 % formalin for later dietary analysis. Otoliths, scales, and pectoral or pelvic fin rays were removed

Table 1. Schedule of gill-net sampling and electrofishing at the Oldman River Reservoir. Abbreviations: S denotes sampling in shallow water (2 - 10 m), D denotes sampling in deep water (10 - 30 m), AB denotes sampling with both A and B gill nets, B denotes sampling with the B net only.

	Reservoir site 3					Reservoir site 4				
Year	Standardized Sets (AB)		Extra Sets		Electro-shocking	Standardized Sets (AB)		Extra Sets		Electro-shocking
	S	D	AB	B		S	D	AB	B	
1991	25.75[a]	24.15	--	--	No	23	25.7	--	--	No
1992	3.9	7	8.9	3.6	No	7.7	7.9	--	7.85	No
1993	3.85	3.65	--	2.9	No	4.1	4.25	--	10.3	No
1994	4.5	4.75	--	8.65	No	3	3.25	--	8.2	No
1995	5.2	5.8	3.6	10.1	Yes - site3A	5.5	6.3	4.7	11.5	No
Total hours	43.2	45.35	12.5	25.3		43.3	47.4	4.7	37.85	

[a] Values represent the number of hours fished with the indicated nets at each site, year, and depth.

from each fish for age determination. Scales were taken from immediately above the lateral line on the left side of the fish, mid-way between the head and dorsal fin.

2.4 Fecundity

The seasonal timing of fish collection in this study was appropriate for fecundity determinations in several fall-spawning species, notably mountain whitefish, bull trout, and brown trout. Unfortunately, none of the ovaries from the 54 female bull trout or 6 female brown trout collected during the study were mature or ripe. Consequently, fecundity measurements could only be conducted for mountain whitefish, this being the one species for which sufficient numbers of mature or ripe ovaries were available.

The fecundity of mountain whitefish was determined by first rinsing the preserved ovaries in water to remove formalin, then cutting each ovary into three sections (head, middle, and tail) of approximately equal size. Duplicate lots of 100 or 250 eggs were counted from each of the three ovarian sections and placed into desiccated, pre-weighed foil pans for drying. Counted eggs, and all remaining uncounted eggs, were dried to constant weight in a laboratory oven at 60°C. The total number of eggs (N) in a given ovary was calculated as:

$$N = (W_t \div W_m) \cdot S$$

where W_t is the total dry weight of all eggs within the ovary, W_m is the mean dry weight of the egg subsample from the same ovary, and S is the number of eggs in the subsample (i.e. either 100 or 250).

2.5 Fish Ageing

All bull trout, rainbow trout, and mountain whitefish retained for dissection were aged. Assignment of ages to fish was based on interpretation of growth annuli on otoliths as recommended in Mackay et al. (1990). Scales and fin rays served primarily as additional reference material with which to corroborate otolith readings when the latter were in doubt. Fish ageing was done by Mr. W. English (Alberta Environmental Protection, Fisheries Management Division) who is experienced in interpreting fish ageing structures and familiar with the biology of fish populations in the Oldman River system. Growth rates for longnose and white sucker are not reported because too few individuals of these species were aged for accurate growth rate assessment.

2.6 Diet Identifications

Prior to dietary identifications, preserved stomach contents were rinsed thoroughly with water to remove formalin. Food items were classified to the lowest taxonomic category possible. Insects could usually be classified to order. The total wet weight of each prey type was recorded for each stomach.

3.0 RESULTS

3.1 Sample Sizes, Species Composition, and Catch Rates

A total of 2,064 fish were captured from among the six sampling sites during the five-year study (Table 2). Two-thirds of these fish were collected from the reservoir whereas 12.8 % and 20.9 % were collected from the upstream (sites 1 and 2) and downstream (sites 5 and 6) locations, respectively. To a large degree, this distribution of fish catch reflects the greater emphasis placed on the reservoir as the most appropriate site for mercury monitoring, and the greater ease and lower cost of gill-net sampling compared to electrofishing.

Mountain whitefish and rainbow trout were the only species observed and captured during electrofishing operations on the Crowsnest River. Other large fish species appear to be uncommon, or absent, at this site. A greater diversity of species was captured from the upper Oldman River, but mountain whitefish and rainbow trout were much less common at this location compared to the Crowsnest River (Table 2).

The greatest diversity of fish species was observed in catches from the reservoir and probably reflects the larger sampling effort expended there compared to the river sites. Brown trout, lake trout (*Salvelinus namaycush*), and cutthroat trout were caught only at the reservoir and only in small numbers (Table 2).

Longnose sucker, white sucker, and mountain whitefish were abundant and frequently caught at both sites below the dam (Table 2). Rainbow trout and bull trout were more common immediately below the dam (site 5) than at Fort Macleod (site 6). Two cool-water species, northern pike (*Esox lucius*) and burbot (*Lota lota*), were also caught in small numbers, mostly from the Fort Macleod site (Table 2).

The total number of fish collected during standardized gill-net sampling at the reservoir was 1,046 (Table 3), which compares with 1,367 fish if supplemental catches are included (Table 2). Analyses of species composition, catch-per-unit-effort (CPUE), and fish length, weight, and age distributions were performed only for the reservoir and only with data gathered during standardized gill-net sampling. Supplemental gill-net sampling and electrofishing (both in the reservoir and rivers) were not conducted in a consistent manner and may not give reliable estimations of the above parameters.

Table 2. Total numbers of each fish species captured during the five-year study.

Species	Sampling Site: Crowsnest River	Oldman River	Reservoir		Below Dam	Fort Mcleod	Row Total	Row Percentage
	1	2	3	4	5	6		
Longnose sucker	0	27	257	465	53	21	823	39.9
White sucker	0	8	102	82	36	34	262	12.7
Mountain whitefish	86	14	158	143	68	125	594	28.8
Rainbow trout	94	25	38	19	59	7	242	11.7
Bull trout	0	10	55	35	10	4	114	5.5
Brown trout	0	0	6	2	0	0	8	0.4
Lake trout	0	0	3	0	0	0	3	0.1
Cutthroat trout	0	0	1	1	0	0	2	0.1
Northern pike	0	0	0	0	1	5	6	0.3
Burbot	0	1	0	0	2	7	10	0.5
Column Total	180	85	620	747	229	203	2064	
Column Percentage	8.7	4.1	30.0	36.2	11.1	9.8		100

Longnose sucker comprised 54.6 % of all fish collected from the reservoir during standardized sampling over the five-year study (Table 3). Mountain whitefish was the second most common species, representing 25.9 % of the five-year catch. The remainder of the catch (19.5 %) was comprised of white sucker, bull trout, rainbow trout, and brown trout. Bull trout were the predominant trout species present in the standardized catches. No lake trout, cutthroat trout, northern pike, or burbot were captured at the reservoir during standardized sampling operations (Table 3).

The species composition of the catch varied considerably from year to year (Fig. 2). From 1991 to 1993, mountain whitefish and bull trout became increasingly prominent in the standardized catch from the reservoir whereas longnose sucker declined (Fig. 2). However, from 1993 to 1995 this trend reversed; the proportion of mountain whitefish and bull trout in the catch

Table 3. Total numbers of each fish species captured from the reservoir during standardized gill-net sampling.

Species	Reservoir site 3	Reservoir site 4	Row Total	Row Percentage
Longnose sucker	149	422	571	54.6
White sucker	56	40	96	9.2
Mountain whitefish	137	134	271	25.9
Rainbow trout	11	12	23	2.2
Bull trout	47	33	80	7.6
Brown trout	5	0	5	0.5
Lake trout	0	0	0	0.0
Cutthroat trout	0	0	0	0.0
Northern pike	0	0	0	0.0
Burbot	0	0	0	0.0
Column Total	405	641	1046	
Column Percentage	38.7	61.3		100

declined while that of longnose sucker (and white sucker) increased. Bull trout comprised from 4.7 to 23.4 % of the yearly catch, the highest value occurring in 1993 (Fig. 2; Appendix 1).

Catch-per-unit-effort was calculated from the standardized gill-net catches to provide an approximate index of fish abundance in the reservoir. For each year, a separate CPUE value was calculated for each reservoir site and depth. A single yearly CPUE value for the reservoir as a whole was calculated by taking the mean of individual CPUE values at each site and depth. Calculated in this way, reservoir CPUE would not be influenced by unequal or varying distributions of sampling effort among sites and depths. Note, however, that sampling effort was distributed approximately equally among reservoir sites and sampling depths (Table 1). Therefore, it makes relatively little difference whether yearly CPUE is calculated as above or as total reservoir catch divided by the sum of sampling effort at each site and depth.

Total CPUE (i.e. all species combined) ranged from a low of 3.5 fish$\cdot$h$^{-1}\cdot$100 m^{-1} net in 1992 to a high of 10.7 fish$\cdot$h$^{-1}\cdot$100 m^{-1} net in 1994 (Fig. 3). Catch rates for longnose sucker were

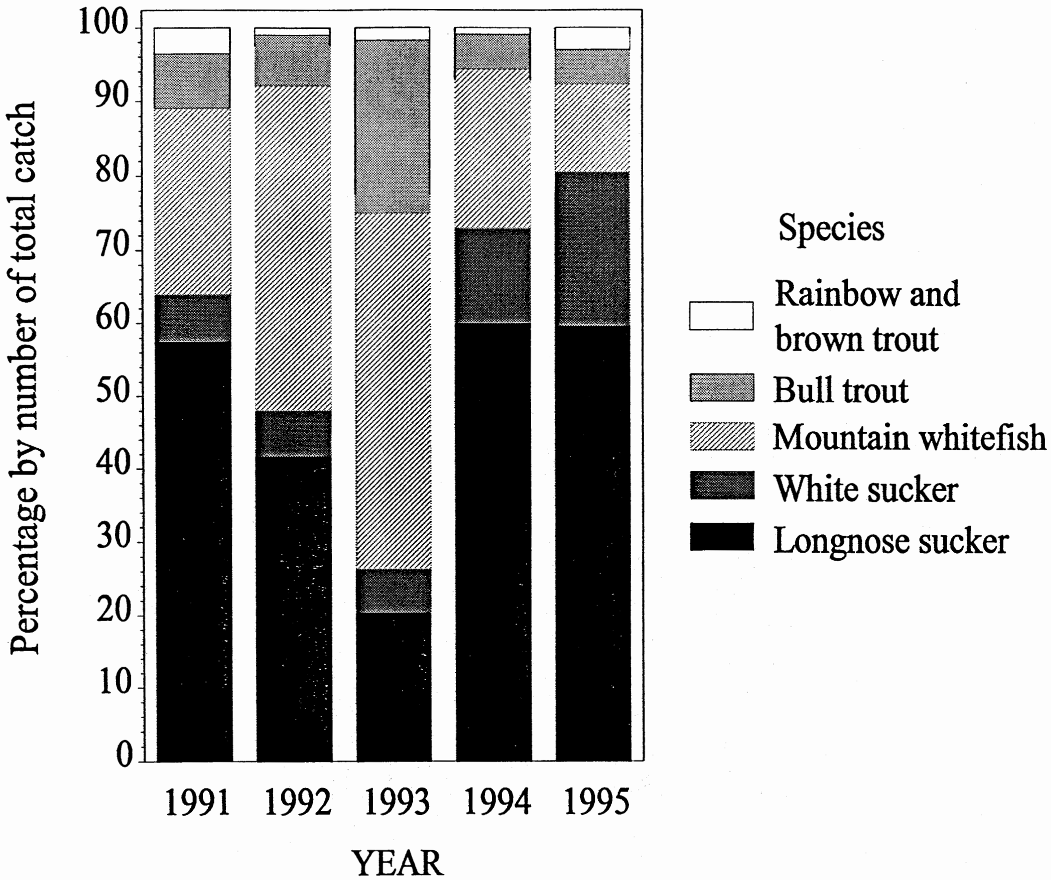

Figure 2. Species composition of fish collected from the Oldman River Reservoir during standardized gill-net sampling (data from all sampling sites and depths are combined).

low in 1992 and 1993, but much higher in 1994 and 1995. White sucker catch rates were also higher in 1994 and 1995 than in earlier years. From 1991 to 1994, catch rates for mountain whitefish were 1.47 to 2.47 fish·h^{-1}·100 m^{-1} net, but the 1995 catch rate was only 0.7 fish·h^{-1}·100 m^{-1} net. Catch rates for bull trout ranged from 0.27 fish·h^{-1}·100 m^{-1} net in 1992 to 0.94 fish·h^{-1}·100 m^{-1} net in 1993 (Fig 3).

The significance of variability in CPUE due to year, sampling site, and depth was tested using three-way ANOVA on log (Y + 1) transformed CPUE values. Log transformation of CPUE was necessary because counts of rare events (such as the capture of fish in nets) are not distributed normally and variances tend be heterogeneous (Sokal and Rohlf 1995; Fabrizio and Richards 1996). All first-order interaction effects were always examined and non-significant (p = 0.05) interaction effects were removed from the ANOVA model before the main effects were

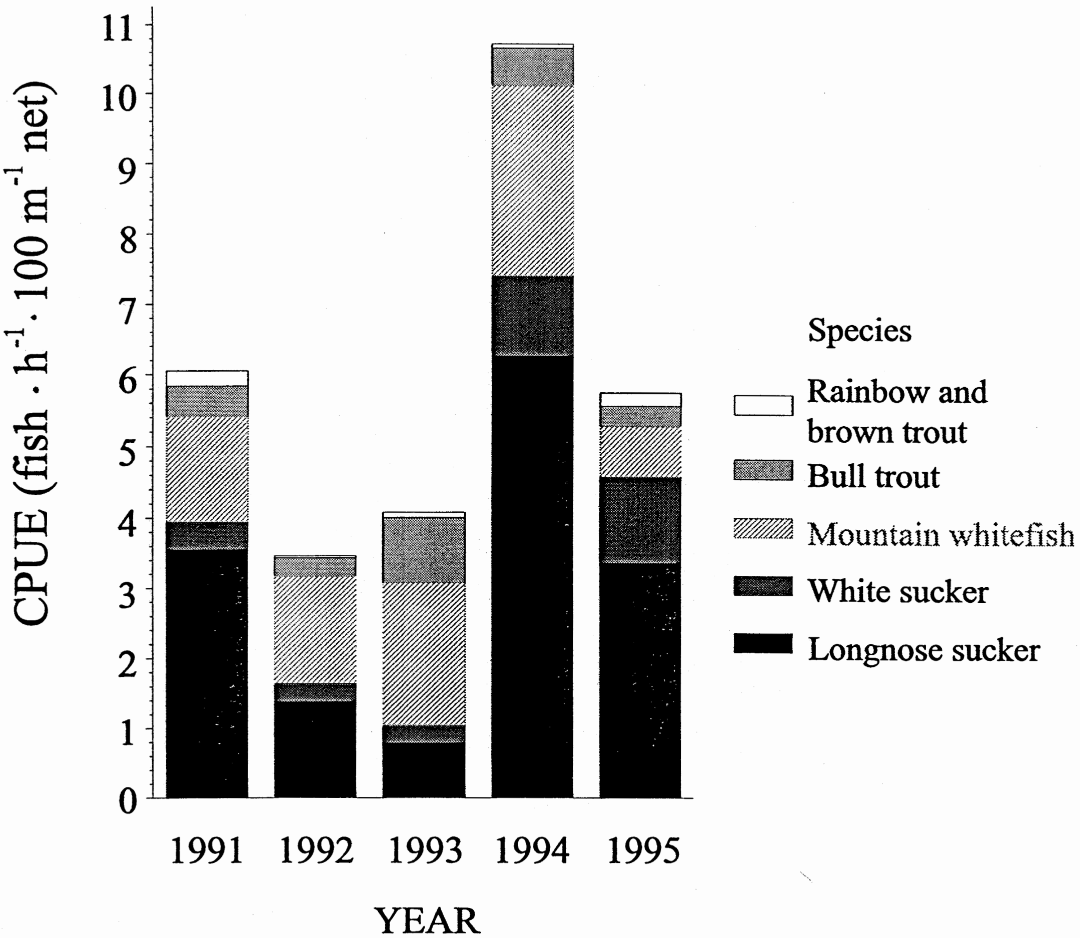

Figure 3. Catch-per-unit-effort for standardized gill-net sampling at the Oldman River Reservoir (data from all sampling sites and depths are combined).

tested. It was not possible to test for second order interaction (i.e. year×site×depth) because replication was insufficient (i.e. each combination of site and depth was sampled only once per year).

Significant site×year and depth×year interactions occurred in the CPUE values for longnose sucker. Therefore, year effects on CPUE should be tested separately for each combination of site and depth. However, to achieve adequate sample size, data from the two depths had to be combined to test for year effects at each of the two sampling sites, and data from the two sites had to be combined to test for year effects at shallow and deep depths. When tested in this way, catch rates for longnose sucker in shallow water varied significantly ($p = 0.05$) among years (Table 4). There were no statistically significant differences in CPUE among years in any species other than longnose sucker (Table 5).

Table 4. Catch-per-unit-effort for longnose sucker collected from the Oldman River Reservoir during standardized gill-net sampling.

Site	Depth	Year				
		1991	1992	1993	1994	1995
3	S	1.86[a]	0.00	0.00	4.22	2.70
	D	0.46	3.14	0.82	4.84	1.55
4	S	7.39	0.13	0.00	5.67	4.73
	D	4.59	2.28	2.35	10.46	4.44
p value for site effect[b]		0.07	0.81	0.50	0.28	0.17
p value for depth effect[b]		0.16	0.09	0.21	0.37	0.41

		Year				
Site or Depth	*p* value for year effect[c]	1991	1992	1993	1994	1995
3[d]	0.25	1.16	1.57	0.41	4.53	2.12
4[d]	0.10	5.99	1.20	1.18	8.06	4.59
S[e]	0.01	4.63	0.06	0.00	4.94	3.71
D[e]	0.38	2.52	2.71	1.59	7.65	3.00

[a] CPUE defined as fish · h^{-1} · 100 m^{-1} net.

[b] Tested using two-way ANOVA (site and depth as treatments) on log (Y+1) transformed CPUE values. Separate two-way ANOVAs were done for each year because three-way ANOVA revealed significant site × year and depth × year interactions ($p = 0.05$).

[c] Tested using one-way ANOVA on log (Y+1) transformed CPUE values. See text for additional details.

[d] Data for shallow and deep depths were combined to achieve sufficient sample size for one-way ANOVA.

[e] Data for sites 3 and 4 were combined to achieve sufficient sample size for one-way ANOVA.

Table 5. Catch-per-unit-effort for various fish species collected from the Oldman River Reservoir during standardized gill-net sampling.

Species	Site	Depth	Year					Main Effect	p value for main effect[b]
			1991	1992	1993	1994	1995		
White sucker	3	S	0.82[a]	0.51	0.26	2.00	2.50	Year	0.13
		D	0.04	0.00	0.00	1.90	0.00	Site	0.47
	4	S	0.17	0.52	0.49	0.67	2.00	Depth	0.02
		D	0.51	0.00	0.24	0.00	0.48		
Mountain whitefish	3	S	3.38	1.03	1.56	0.44	1.15	Year	0.88
		D	0.58	0.14	4.66	0.00	0.00	Site	0.77
	4	S	0.35	4.94	1.95	10.33	1.64	Depth	0.03
		D	1.56	0.00	0.00	0.00	0.00		
Bull trout	3	S	1.13	0.26	0.00	0.44	0.58	Year	0.42
		D	0.12	0.29	1.37	0.42	0.00	Site	0.80
	4	S	0.09	0.52	0.73	1.00	0.55	Depth	0.55
		D	0.39	0.00	1.65	0.31	0.00		
Rainbow trout	3	S	0.31	0.00	0.26	0.00	0.00	Year	0.32
		D	0.08	0.00	0.00	0.00	0.00	Site	0.59
	4	S	0.13	0.13	0.00	0.00	0.55	Depth	0.09
		D	0.20	0.00	0.00	0.00	0.00		

[a] CPUE defined as fish · h^{-1} · 100 m^{-1} net.

[b] Tested using three-way ANOVA on log (Y+1) transformed CPUE values. No significant ($p = 0.05$) first-order interaction effects occurred for any of the fish species listed. Therefore, interaction effects were removed from the ANOVA model prior to testing the main treatment effects.

White sucker and mountain whitefish were caught more frequently in shallow than in deep water (Table 5). Although there was a tendency for longnose sucker to be more frequent at site 4 than site 3, and for catch rates of rainbow trout to be higher in shallow than deep water, these trends were not statistically significant ($p = 0.05$; Tables 4,5).

3.2 Size and Age Distributions

Figures 4 - 8 show the length, weight, and (where possible) age distributions of the five predominant fish species collected from the reservoir. Bull trout collected from the reservoir ranged from 19.3 to 51.5 cm in fork length and from 73 to 1632 g in body weight. The upper portion of the bull trout length distribution appeared to be truncated; above 36 cm there was an abrupt decrease in the number of bull trout captured (Fig. 4). The ages of bull trout ranged from 1 to 7 years, but the majority were from 2 to 4 years old.

Rainbow trout age distribution was quite similar to that of bull trout, the most common ages again were 2 to 4 years (Fig. 5). Ranges for the fork length and body weight of rainbow trout collected from the reservoir during standardized sampling were 16.5 - 56.4 cm and 52 - 2467 g, respectively.

Mountain whitefish exhibited a bimodal, or possibly trimodal, length distribution (Fig. 6). The majority of mountain whitefish collected from the reservoir were 1 to 5 years old and weighed less than 200 grams. However, whitefish up to 18 years of age and up to 1378 g in weight were present in the catch (Fig. 6). The length distribution of longnose sucker appears to have three modes (Fig. 7) and white sucker length distributions appear to have at least two modes (Fig. 8). White sucker collected from the reservoir tended to be larger (i.e. longer and heavier) than longnose sucker (Figs. 7,8).

3.3 Growth Rate (Rainbow Trout, Mountain Whitefish, and Bull Trout)

The collected data are insufficient for a meaningful analysis of year to year changes in fish growth rates within the study period. However, reliable comparisons of growth rate between sampling locations are possible for rainbow trout and mountain whitefish if size at age data are combined from some, or all, of the five years. Growth curves generated after combining data over five years indicate that mountain whitefish grew much faster in river habitats than in the

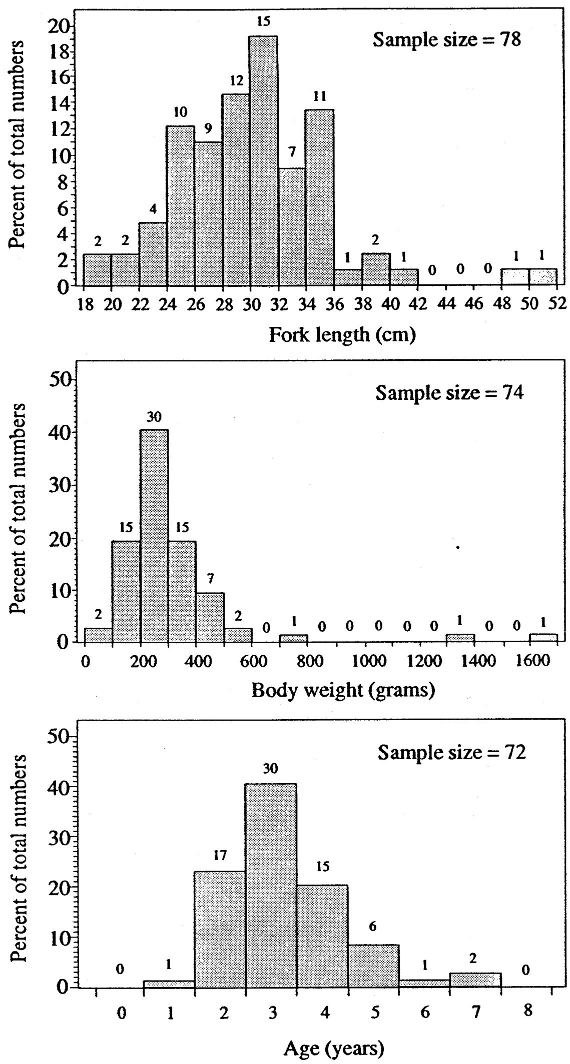

Figure 4. Size and age distributions of bull trout collected from the Oldman River Reservoir during standardized gill-net sampling. Sample sizes are indicated above each bar.

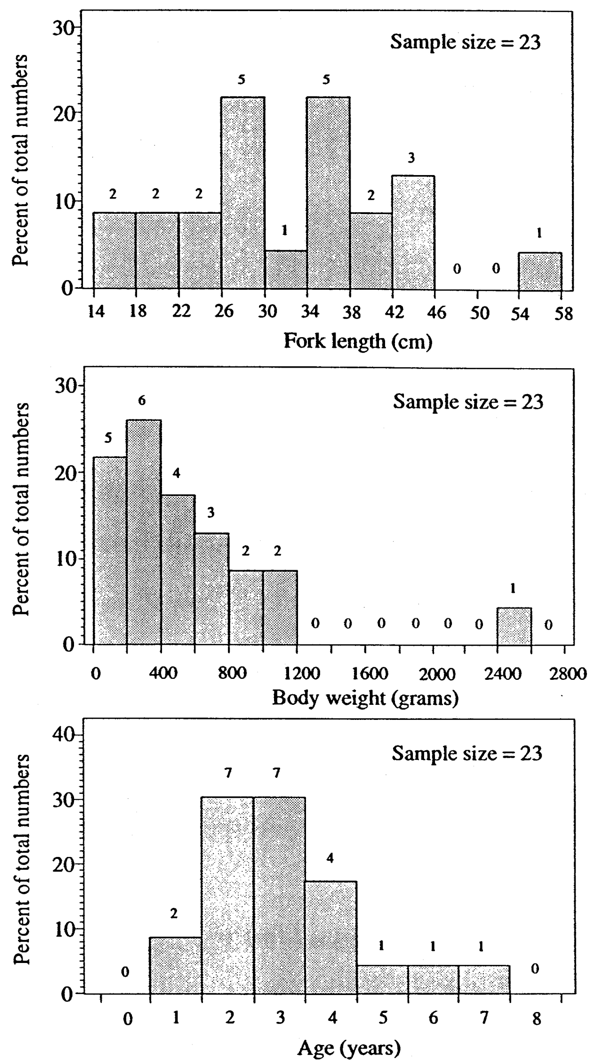

Figure 5. Size and age distributions of rainbow trout collected from the Oldman River Reservoir during standardized gill-net sampling. Sample sizes are indicated above each bar.

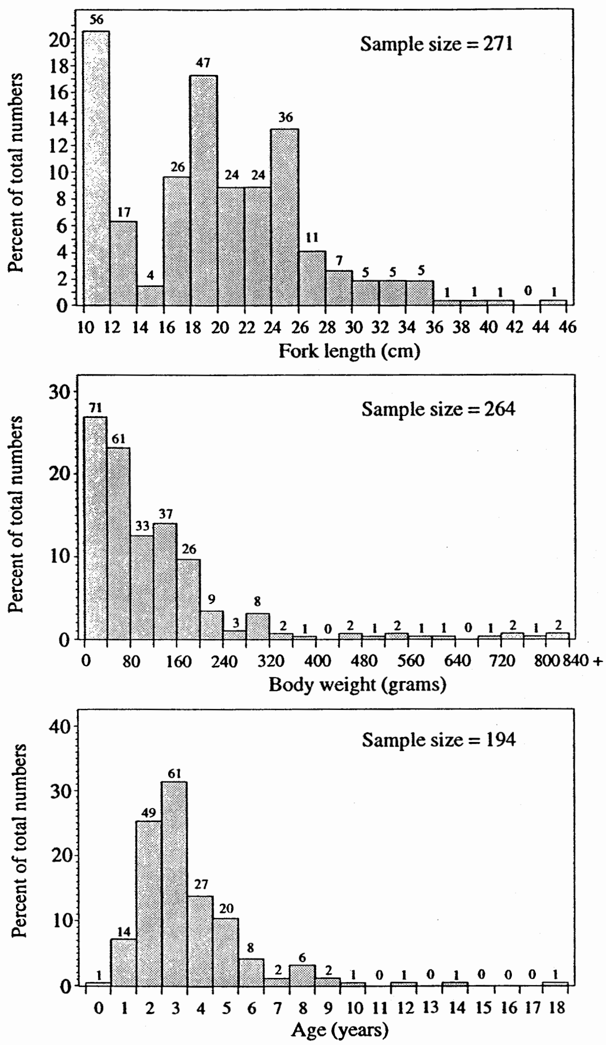

Figure 6. Size and age distributions of mountain whitefish collected from the Oldman River Reservoir during standardized gill-net sampling. Sample sizes are indicated above each bar.

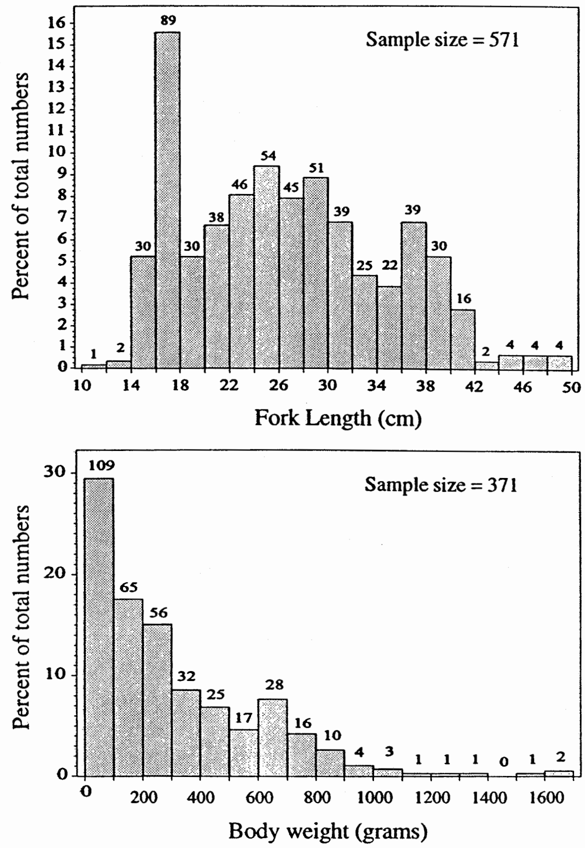

Figure 7. Size distributions of longnose sucker collected from the Oldman River Reservoir during standardized gill-net sampling. Sample sizes are indicated above each bar.

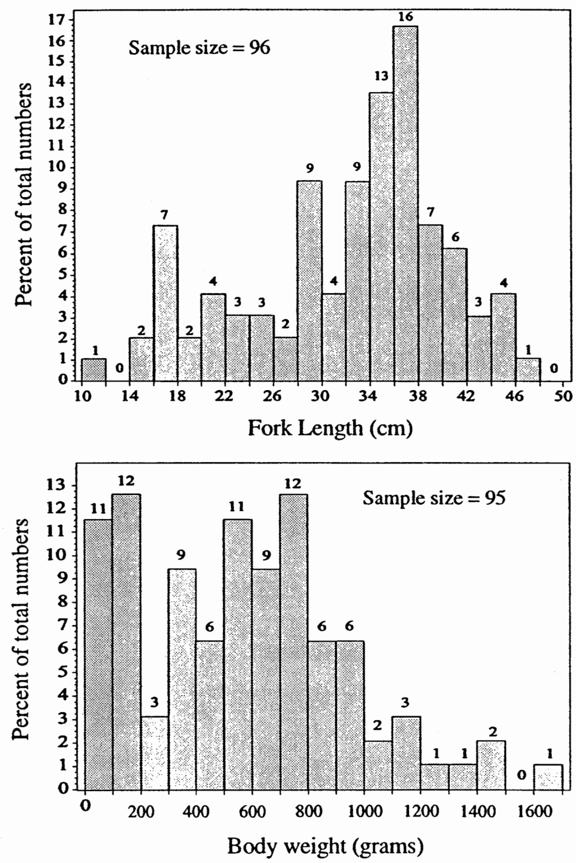

Figure 8. Size distributions of white sucker collected from the Oldman River Reservoir during standardized gill-net sampling. Sample sizes are indicated above each bar.

reservoir (Fig. 9). Body weights of 3 to 6 year old river fish were twice as large as those of mountain whitefish from the reservoir. Rainbow trout, in contrast, exhibited faster growth in the reservoir than in river habitats (Fig. 10).

It is also apparent that growth differentials between reservoir and river habitats developed after two years of age in mountain whitefish, but were already well established by two years of age in rainbow trout (Figs. 9, 10). The growth rates of mountain whitefish and rainbow trout did not differ significantly between river habitats upstream and downstream of the reservoir (Figs. 9,10).

To assess whether growth differentials between reservoir and river habitats might have been a spurious result of combining data for a five year period, additional analyses were done

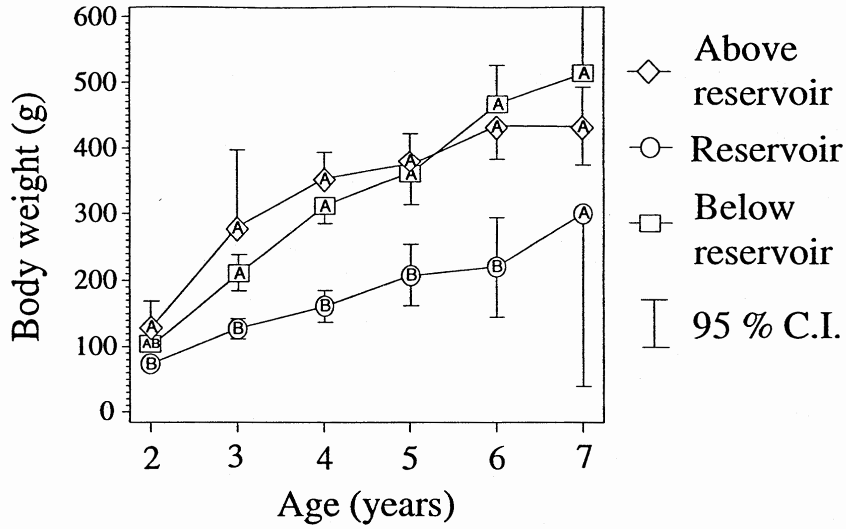

Figure 9. Growth trajectories of mountain whitefish in the Oldman River system. Statistical comparisons of body weight among sampling sites were done separately for each age of fish. Weights-at-age designated with the same letter are not significantly different (one-way ANOVA followed, if significant, by Tukey's studentized range test, $p = 0.01$). C.I. denotes confidence interval. Sample sizes are in Appendix 3.

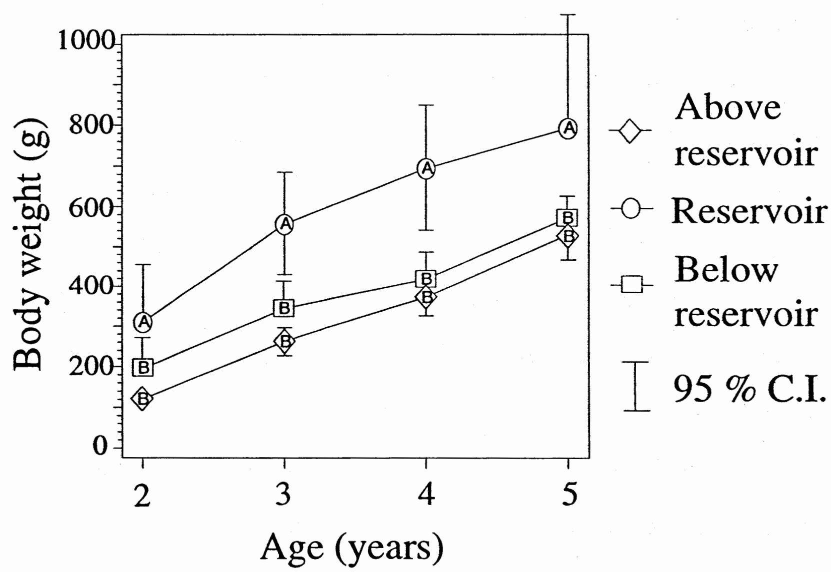

Figure 10. Growth trajectories of rainbow trout in the Oldman River system. Statistical comparisons of body weight among sampling sites were done separately for each age of fish. Weights-at-age designated with the same letter are not significantly different (one-way ANOVA followed, if significant, by Tukey's studentized range test, $p = 0.01$). C.I. denotes confidence interval. Sample sizes are in Appendix 4.

after grouping data into two shorter periods; 1991-92 (early) and 1993-95 (late). Although precision was reduced due to smaller sample sizes, 3 to 6 year old mountain whitefish were larger in the rivers than in the reservoir during both periods (Appendix 3), while 2 to 5 year-old rainbow trout were larger at the reservoir during both periods (Appendix 4). Therefore, growth differentials between reservoir and river habitats were present throughout the study and were not limited to a restricted period of time.

A comparison of bull trout growth rates between sampling locations could not be done because of small samples sizes from the river habitats (Table 2). However, when data from the reservoir are pooled across years, reasonable growth curves can be constructed. Such growth curves show that lengths at age of bull trout in the Oldman River Reservoir are comparable, or higher, than published values for other bull trout populations in Alberta, especially at two and three years of age (Fig. 11).

3.4 Diet Composition

Three methods are commonly used to describe the prey composition of fish diets: frequency of occurrence, percent by diet weight, and percent by number. In this study, only the former two methods are used. Of the three methods, percent of diet weight indicates most accurately the nutritional contribution of each food type to the diet. Frequency of occurrence provides information on the degree of similarity among diets of individual fish. Percentage of diet by number was not used because accurate counts of prey items were often difficult to obtain and because this method greatly exaggerates the importance of small prey which may be very numerous yet contribute little mass to the diet. Two additional parameters, the percentage of empty stomachs and stomach fullness index (weight of stomach contents expressed as a percentage of body weight), were used as indicators of total food consumption.

Food preferences of fish are known to change considerably with fish age and size. Therefore, dietary analyses were done after grouping fish of each species into length categories. Unfortunately, because the size distribution of fish varied between the reservoir and river sampling locations, it was not possible to devise length categories which would all contain adequate sample sizes at all sampling locations. Length categories were chosen so that each category contained an approximately equal proportion of the fish collected from the reservoir.

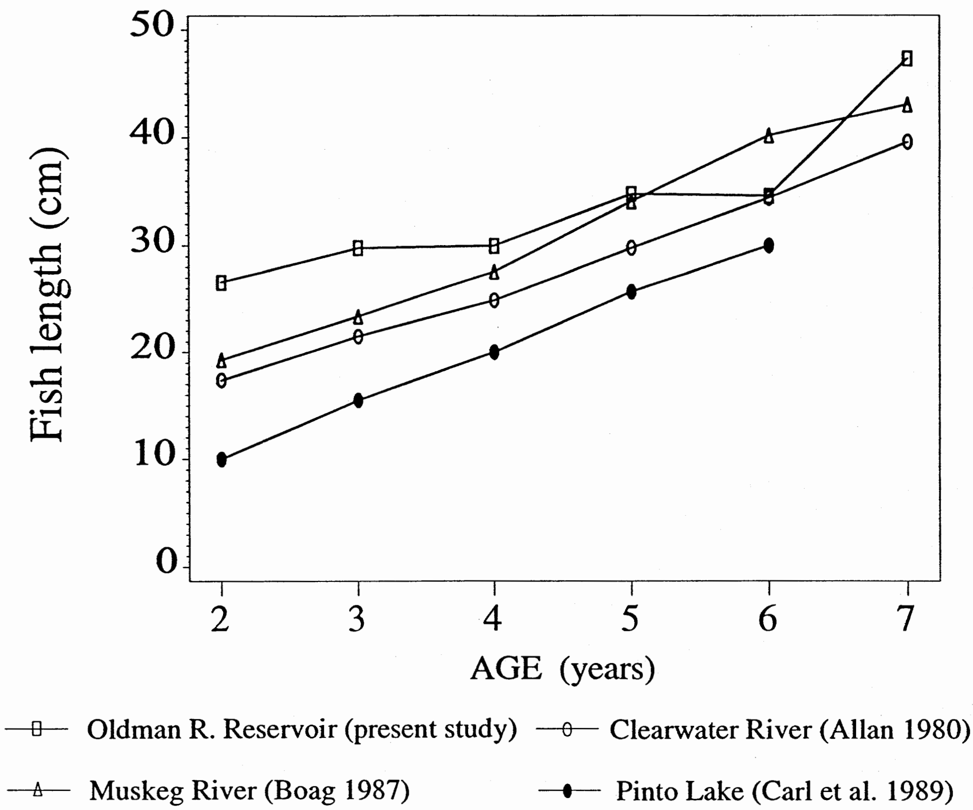

Figure 11. Comparison of growth trajectories of bull trout from the Oldman River Reservoir and other bull trout populations in Alberta. Fish length refers to total length for the Pinto Lake population and to fork length for other populations.

Thus, dietary information was sometimes sparse, or absent, for some size categories at locations above or below the reservoir (e.g. Table 6).

Bull trout were highly piscivorus in both reservoir and river habitats. Fish comprised from 64 % to nearly 100 % of diet weight in all size categories of bull trout except those containing less than two non-empty stomachs (Table 6). The frequency of occurrence of fish prey was also high: 28 of 38 non-empty stomachs from reservoir bull trout contained fish and 14 of 16 non-empty stomachs from bull trout caught in river habitats contained fish. Both sucker and salmonid species were identified as fish prey items in several of the bull trout stomach samples. However, in most cases, the partially digested fish prey items could not be accurately identified as to family or species.

Significant quantities of non-fish prey occurred only in the reservoir where *Daphnia* spp. comprised 13 - 34 % of diet weight in bull trout less than 33.4 cm in length (Table 6). Empty stomachs were somewhat more frequent in bull trout from the reservoir (42 empty, 38 non-empty) than in those from river habitats (8 empty, 16 non-empty) but these differences were not significant (chi-square test, $p = 0.05$). Too few bull trout were collected above and below the reservoir to assess differences in stomach fullness index between sites. However, at all sites, stomach fullness was considerably greater in bull trout longer than 33.4 cm than in smaller fish (Table 6).

Aquatic vegetation, mostly algae, comprised from 23 % to over 90 % of the material found in stomachs of rainbow trout from above and below the reservoir (Table 7). In contrast, rainbow trout from the reservoir contained only minor quantities (max. 3.5 %) of algae in their stomachs. Because algae has very little nutritional value to rainbow trout (Steffens 1989), the inclusion of algae in dietary analyses would obscure the importance of more nutritionally important foods such as fish, insects, and crustaceans. Therefore, dietary composition for non-algal foods was calculated as a proportion by weight of non-vegetative matter (Table 7). Among the non-algae components, insects and fish were dominant in the diet of rainbow trout above and below the reservoir. Nearly all non-empty stomachs of trout at these locations contained insects, and insects usually comprised the greatest portion by weight of non-vegetative matter as well. Fish occurred in only a few rainbow trout stomachs, but their contribution to diet weight was often greater than their low frequency of occurrence might suggest. Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, and Diptera were all common insect orders eaten by rainbow trout in river habitats, but their relative importance in the diet varied with trout size and method of quantification (weight or frequency; Table 7).

The dominant prey consumed by rainbow trout in the reservoir were *Daphnia* spp. which comprised 77 - 83 % of diet weight in all but the largest trout (Table 7). Stomachs from the latter fish (i.e. > 41.8 cm in length) contained primarily other fish and molluscs. Note, however, that molluscs occurred in only 2 of the 10 non-empty stomachs among the largest trout. Insects, primarily Hemiptera and Diptera, were also a small but significant dietary component in the smaller rainbow trout (< 41.8 cm) collected from the reservoir (Table 7).

When algae is included in calculation of stomach fullness, the latter is considerably higher in rainbow trout from river habitats than in those from the reservoir (Table 7). However, when only the nutritionally important food items are included, there is no consistent difference in stomach fullness between river and reservoir locations. Stomach fullness in reservoir rainbow

Table 6. Diet composition of bull trout in the Oldman River system. All years combined.

Oldman River Reservoir

	Fork Length (cm)				Fork length (cm)			
	< 26.6	26.6 - 30.0	30.1 - 33.4	> 33.4	< 26.6	26.6 - 30.0	30.1 - 33.4	> 33.4
Number of stomachs examined	20	20	20	20	20	20	20	20
Number of stomachs with food	13	9	9	7	13	9	9	7
% empty	35	55	55	65				
Fullness index[a]	1.28 ±0.27	0.95 ± 0.15	0.63 ± 0.16	2.36 ± 0.67				
	Percent of diet weight				Frequency of occurrence (number of stomachs containing indicated food)			
Fish	64.0	80.1	72.2	99.3	10	6	6	6
Daphnia spp.	33.9	13.0	27.8	0.7	3	1	5	1
Insecta	1.5	4.7	0.0	0.0	2	2	0	0
Other invertebrates[b]	0.6	2.1	0.0	0.0	1	1	0	0

Upstream of Oldman River Reservoir

	Fork Length (cm)				Fork length (cm)			
	< 26.6	26.6 - 30.0	30.1 - 33.4	> 33.4	< 26.6	26.6 - 30.0	30.1 - 33.4	> 33.4
Number of stomachs examined	2	0	0	8	2	0	0	8
Number of stomachs with food	1			6	1			6
% empty	50			25				
Fullness index[a]	0.09			3.47 ± 1.50				
	Percent of diet weight				Frequency of occurrence (number of stomachs containing indicated food)			
Fish	0.0			99.7	0			6
Daphnia spp.	0.0			0.0	0			0
Insecta	100.0			0.3	1			2
Other invertebrates	0.0			0.0	0			0

Table 6... Diet composition of bull trout in the Oldman River system. All years combined.

Downstream of Oldman River Reservoir

	Fork Length (cm)				Fork length (cm)			
	< 26.6	26.6 - 30.0	30.1 - 33.4	> 33.4	< 26.6	26.6 - 30.0	30.1 - 33.4	> 33.4
Number of stomachs examined	0	2	2	10	0	2	2	10
Number of stomachs with food		0	2	7		0	2	7
% empty		100.0	0.0	30.0				
Fullness index[a]		--	0.41 ± 0.39	1.84 ± 0.81				
	Percent of diet weight				Frequency of occurrence (number of stomachs containing indicated food)			
Fish			97.8	99.8			1	7
Daphnia spp.			0.0	0.0			0	0
Insecta			2.2	0.2			1	2
Other invertebrates			0.0	0.0			0	0

[a] - Weight of stomach contents expressed as a percentage of body weight. Empty stomachs were not included in calculation of mean fullness index.

[b] - Nematomorpha and Oligochaeta

Table 7. Diet composition of rainbow trout in the Oldman River system. All years combined.

Parameter	Oldman River Reservoir							
	Fork Length (cm)				Fork Length (cm)			
	< 32.6	32.6 - 36.7	36.8 - 41.8	> 41.8	< 32.6	32.6 - 36.7	36.8 - 41.8	> 41.8
Number of stomachs examined	14	14	14	13	14	14	14	13
Number of stomachs with food	6	12	11	10	6	12	11	10
% empty	57.1	14.3	21.4	23.1				
Fullness index (without vegetation)	0.36±0.11	0.20±0.06	0.20±0.06	0.53±0.24				
Fullness index[a] (with vegetation)	0.36±0.11	0.20±0.06	0.21±0.06	0.53±0.24				
	Percent by weight of total stomach contents				Frequency of occurrence (number of stomachs containing indicated food)			
Aquatic vegetation	0.0	2.7	3.5	< 0.1	0	3	3	1
	Percent by weight of non-vegetative matter				Frequency of occurrence (number of stomachs containing indicated food)			
Fish	0.0	9.2	0.0	36.4	0	2	0	4
Total Insecta	22.2	6.4	22.8	0.6	4	8	9	6
Unclassifiable Insects	4.7	0.7	<0.1	0.0	2	3	1	0
Diptera	0.5	0.6	9.4	<0.1	3	8	4	1
Plecoptera	0.0	0.0	0.0	0.0	0	0	0	0
Trichoptera	0.4	0.6	0.0	0.0	1	1	0	0
Ephemeroptera	0.0	0.0	< 0.1	<0.1	0	0	1	1
Hemiptera	12.6	2.2	12.5	0.6	1	5	6	4
Other Insecta	4.1	2.3	0.7	0.0	2	2	6	0
Crustacea (*Daphnia* spp.)	77.8	82.6	77.2	5.6	4	12	9	2
Mollusca (Gastropoda)	0.0	1.8	0.0	57.4	0	1	0	2
Other Invertebrates	0.0	<0.1	<0.1	0.0	0	3	1	0
Fish eggs	0.0	0.0	0.0	0.0	0	0	0	0

Table 7... Diet composition of rainbow trout in the Oldman River system. All years combined.

Parameter	Upstream of Oldman River Reservoir							
	Fork Length (cm)				Fork Length (cm)			
	< 32.6	32.6 - 36.7	36.8 - 41.8	> 41.8	< 32.6	32.6 - 36.7	36.8 - 41.8	> 41.8
Number of stomachs examined	85	19	12	2	85	19	12	2
Number of stomachs with food	73	15	10	2	73	15	10	2
% empty	14.1	21.1	16.7	0.0				
Fullness index[a] (without vegetation)	0.40±0.06	0.71±0.39	0.60±0.17	0.21±0.01				
Fullness index[a] (with vegetation)	0.69±0.07	0.95±0.37	0.65±0.17	0.41±0.14				
	Percent by weight of total stomach contents				Frequency of occurrence (number of stomachs with indicated food)			
Aquatic vegetation	52.9	23.5	76.8	48.4	36	9	2	2
	Percent by weight of non-vegetative matter				Frequency of occurrence (number of stomachs with indicated food)			
Fish	<0.1	75.5	15.7	0.0	1	3	2	0
Total Insecta	87.4	24.1	83.5	84.4	71	14	10	2
Unclassifiable Insects	25.0	6.0	42.9	21.6	34	11	6	1
Diptera	6.1	0.7	0.4	4.1	42	10	5	2
Plecoptera	20.9	3.6	1.8	7.6	24	6	2	2
Trichoptera	15.1	3.9	7.1	29.8	38	5	5	2
Ephemeroptera	2.1	0.6	< 0.1	1.4	18	4	2	1
Hemiptera	8.4	6.4	24.3	4.0	24	3	7	1
Other Insecta	9.9	3.0	6.9	15.9	19	3	5	1
Crustacea (*Daphnia* spp.)	7.0	0.0	0.1	0.0	7	0	2	0
Mollusca (Gastropoda)	0.2	0.0	0.6	0.0	2	0	1	0
Other Invertebrates	5.2	0.4	<0.1	15.6	6	2	1	1
Fish eggs	0.2	0.0	0.0	0.0	2	0	0	0

Table 7... Diet composition of rainbow trout in the Oldman River system. All years combined.

Parameter	Downstream of Oldman River Reservoir							
	Fork Length (cm)				Fork Length (cm)			
	< 32.6	32.6 - 36.7	36.8 - 41.8	> 41.8	< 32.6	32.6 - 36.7	36.8 - 41.8	> 41.8
Number of stomachs examined	35	20	11	0	35	20	11	0
Number of stomachs with food	30	19	8		30	19	8	
% empty	14.3	5.0	27.3					
Fullness index[a] (without vegetation)	0.65±0.17	0.22±0.09	0.07±0.03					
Fullness index[a] (with vegetation)	0.92±0.17	0.95±0.18	0.54±0.23					
	Percent by weight of total stomach contents				Frequency of occurrence (number of stomachs with indicated food)			
Aquatic vegetation	38.1	80.0	91.3		13	15	5	
	Percent by weight of non-vegetative matter				Frequency of occurrence (number of stomachs with indicated food)			
Fish	40.5	0.9	55.5		6	1	1	
Total Insecta	50.8	99.1	44.4		28	15	6	
Unclassifiable Insects	10.9	11.7	2.7		15	10	2	
Diptera	1.8	2.3	27.4		12	9	3	
Plecoptera	2.3	5.7	0.0		9	4	0	
Trichoptera	0.9	0.9	5.5		5	2	1	
Ephemeroptera	26.8	45.8	0.5		11	5	1	
Hemiptera	3.9	29.0	6.8		8	9	2	
Other Insecta	4.2	3.7	1.5		9	7	2	
Crustacea (*Daphnia* spp.)	8.6	0.0	0.0		2	0	0	
Mollusca (Gastropoda)	0.0	0.0	0.0		0	0	0	
Other Invertebrates	< 0.1	0.0	0.1		3	0	1	
Fish eggs	< 0.1	0.0	0.0		1	0	0	

[a] - Weight of stomach contents expressed as a percentage of body weight. Empty stomachs were not included in calculation of mean fullness index.

Table 8. Diet composition of mountain whitefish in the Oldman River system. All years combined.

Parameter	Oldman River Reservoir							
	Fork Length (cm)				Fork Length (cm)			
	< 18.9	18.9 - 22.5	22.6 - 25.4	>25.4	< 18.9	18.9 - 22.5	22.6 - 25.4	> 25.4
Number of stomachs examined	57	55	55	56	57	55	55	56
Number of stomachs with food	18	22	24	21	18	22	24	21
% empty	68.4	60.0	56.4	62.5				
Fullness index[a]	0.43±0.10	0.37±0.06	0.33±0.08	0.28±0.06				
	Percent of diet weight				Frequency of occurrence (number of stomachs containing indicated food)			
Fish	0.0	< 0.1	0.0	0.0	0	1	0	0
Total Insecta	73.6	28.7	16.3	16.7	11	9	14	6
Unclassifiable Insects	11.2	0.0	0.4	1.3	2	0	4	2
Diptera	61.5	28.3	15.9	9.6	11	9	14	4
Plecoptera	0.0	0.0	0.0	0.0	0	0	0	0
Trichoptera	0.9	0.1	0.0	0.0	1	1	0	0
Ephemeroptera	0.0	0.0	0.0	5.8	0	0	0	1
Other Insecta	0.0	0.2	0.0	0.0	0	1	0	0
Crustacea (*Daphnia* spp.)	25.9	71.2	81.4	82.1	7	9	15	15
Other Invertebrates	< 0.1	0.0	2.3	0.0	1	0	2	0
Fish eggs	0.0	0.0	0.0	1.2	0	0	0	1
Vegetation	0.5	< 0.1	< 0.1	0.0	1	1	1	0

Table 8... Diet composition of mountain whitefish in the Oldman River system. All years combined.

Parameter	Upstream of Oldman River Reservoir							
	Fork Length (cm)				Fork Length (cm)			
	< 18.9	18.9 - 22.5	22.6 - 25.4	>25.4	< 18.9	18.9 - 22.5	22.6 - 25.4	> 25.4
Number of stomachs examined	0	5	3	87	0	5	3	87
Number of stomachs with food		3	2	63		3	2	63
% empty		40.0	33.3	27.6				
Fullness index[a]		0.18±0.06	0.45±0.10	0.26±0.03				
	Percent of diet weight				Frequency of occurrence (number of stomachs containing indicated food)			
Fish		0.0	0.0	0.0		0	0	0
Total Insecta		100.0	99.9	91.6		3	2	63
Unclassifiable Insects		0.0	3.3	0.6		0	1	13
Diptera		66.2	70.1	66.1		2	2	54
Plecoptera		0.0	0.0	2.9		0	0	14
Trichoptera		3.4	22.0	21.0		2	2	40
Ephemeroptera		30.3	4.5	0.8		1	1	13
Other Insecta		0.0	0.0	0.3		0	0	12
Crustacea (*Daphnia* spp.)		0.0	0.0	0.0		0	0	0
Other Invertebrates		0.0	0.1	5.6		0	1	11
Fish eggs		0.0	0.0	0.5		0	0	6
Vegetation		0.0	0.0	2.4		0	0	2

Table 8... Diet composition of mountain whitefish in the Oldman River system. All years combined.

Parameter	Downstream of Oldman Reservoir							
	Fork Length (cm)				Fork Length (cm)			
	< 18.9	18.9 - 22.5	22.6 - 25.4	>25.4	< 18.9	18.9 - 22.5	22.6 - 25.4	> 25.4
Number of stomachs examined	15	13	24	138	15	13	24	138
Number of stomachs with food	10	10	14	74	10	10	14	74
% empty	33.3	23.1	41.7	46.4				
Fullness index[a]	0.31±0.07	0.28±0.08	0.29±0.07	0.21±0.03				
	Percent of diet weight				Frequency of occurrence (number of stomachs containing indicated food)			
Fish	0.0	< 0.1	0.0	7.2	0	1	0	2
Total Insecta	99.6	85.1	60.9	83.9	10	10	14	69
Unclassifiable Insects	36.2	20.5	6.2	18.6	9	8	8	40
Diptera	1.5	53.2	25.1	6.7	5	6	8	29
Plecoptera	3.5	2.5	0.4	10.6	1	1	1	24
Trichoptera	52.4	8.0	29.2	46.4	8	5	8	43
Ephemeroptera	1.5	0.5	0.0	0.2	2	1	0	8
Other Insecta	4.4	0.6	0.0	1.4	3	1	0	4
Crustacea (*Daphnia* spp.)	0.0	0.0	20.2	0.0	0	0	2	0
Other Invertebrates	0.0	< 0.1	0.1	0.3	0	1	1	3
Fish eggs	0.0	14.9	16.1	7.2	0	1	2	13
Vegetation	0.4	0.0	2.7	1.4	2	0	3	14

[a] - Weight of stomach contents expressed as a percentage of body weight. Empty stomachs were not included in calculation of mean fullness index.

trout was highest in the largest fish (> 41.8 cm) whereas below the dam stomach fullness was highest in small trout (< 32.6 cm) and above the reservoir intermediate sized fish (32.6 - 41.8 cm) had the fullest stomachs. The percentage of empty stomachs in small rainbow trout (< 32.6 cm) length category at the reservoir. The proportion of empty stomachs in other size categories of rainbow trout ranged from 14 to 27 % with no clear differences between reservoir and river sites (Table 7).

Empty stomachs were considerably more frequent in mountain whitefish than in rainbow trout. Additionally, empty stomachs were significantly (chi-square test, $p = 0.05$) more frequent in mountain whitefish at the reservoir (56 - 68 %) than above the reservoir (27 - 40 %) or below it (23 - 43 %; Table 8). Non-empty stomachs were slightly fuller in mountain whitefish from the reservoir than in those collected from river habitats. Within the reservoir and below it, smaller mountain whitefish tended to have fuller stomachs than larger fish (Table 8).

In river habitats, the diet of mountain whitefish consisted predominantly of insects, mainly Diptera and Trichoptera, plus some Plecoptera below the reservoir and Ephemeroptera above the reservoir. Unlike rainbow trout, very little aquatic vegetation was present in stomachs of mountain whitefish from these locations (Table 8). Stomachs of mountain whitefish collected below the reservoir also contained small quantities of fish eggs which could not be identified to species.

The diet composition of mountain whitefish in the reservoir differed considerably from that in river habitats. In the reservoir, the smallest size category (< 18.9 cm) consumed primarily Diptera, with *Daphnia* spp. being of secondary importance. However, in mountain whitefish longer than 18.9 cm, *Daphnia* spp. became the dominant dietary constituent comprising 71 - 82 % of diet weight. Dipterans remained the primary insect prey eaten by larger mountain whitefish, but became increasingly less important in the diet as the size of mountain whitefish increased (Table 8).

3.5 Mountain Whitefish Reproductive Biology

The size and age at which mountain whitefish mature sexually were determined after pooling data over the five-year study period to achieve adequate sample size. In general, the majority of male and female mountain whitefish attained sexual maturity at between 25 and 35 cm in fork length (Fig. 12), and between 200 and 400 g in body weight (Fig. 13). Irrespective of

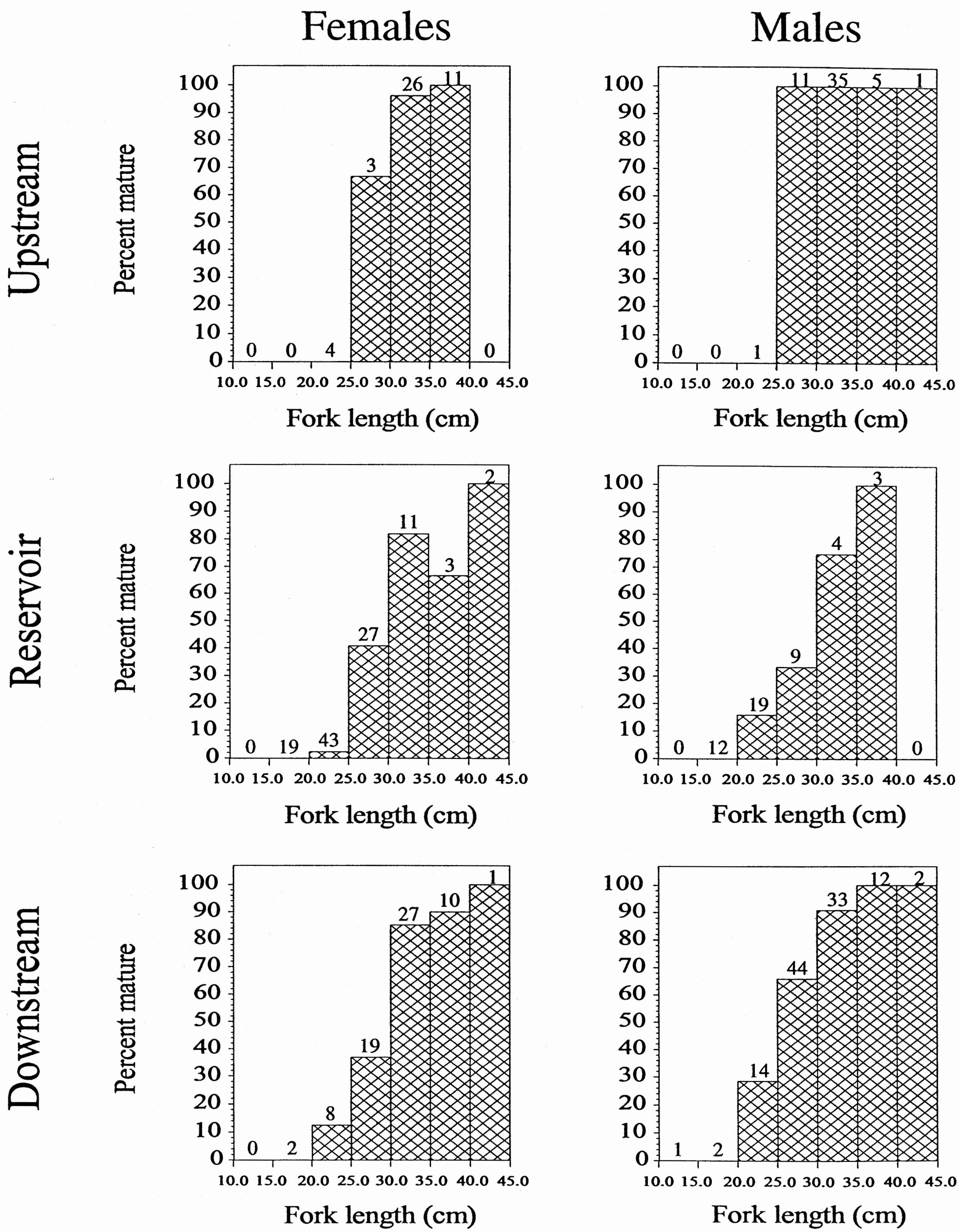

Figure 12. Percentage of reproductively mature fish among various length classes of mountain whitefish from the Oldman River system. The number of fish in each length category is indicated above the bars.

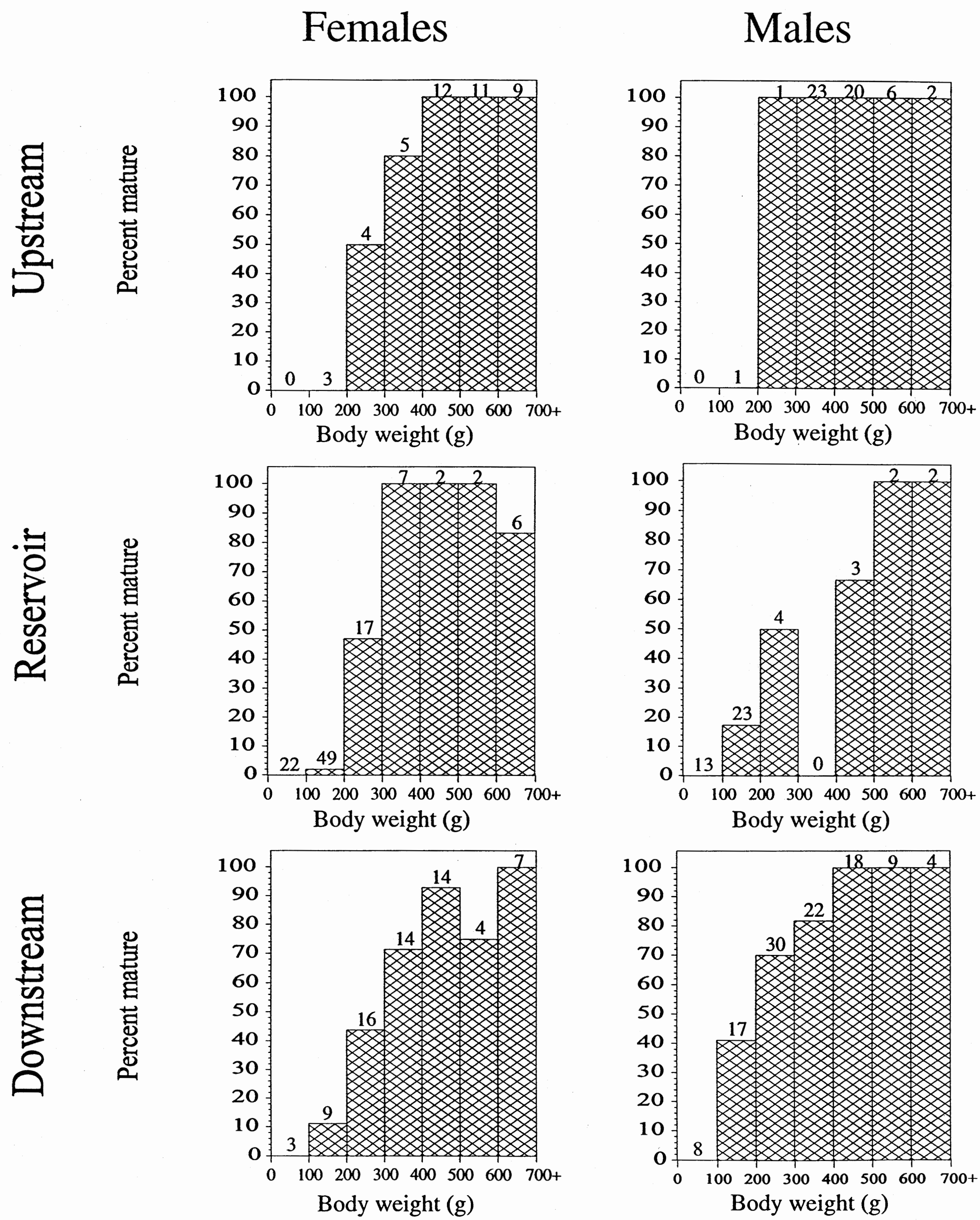

Figure 13. Percentage of reproductively mature fish among various weight classes of mountain whitefish from the Oldman River system. The number of fish in each weight category is indicated above the bars.

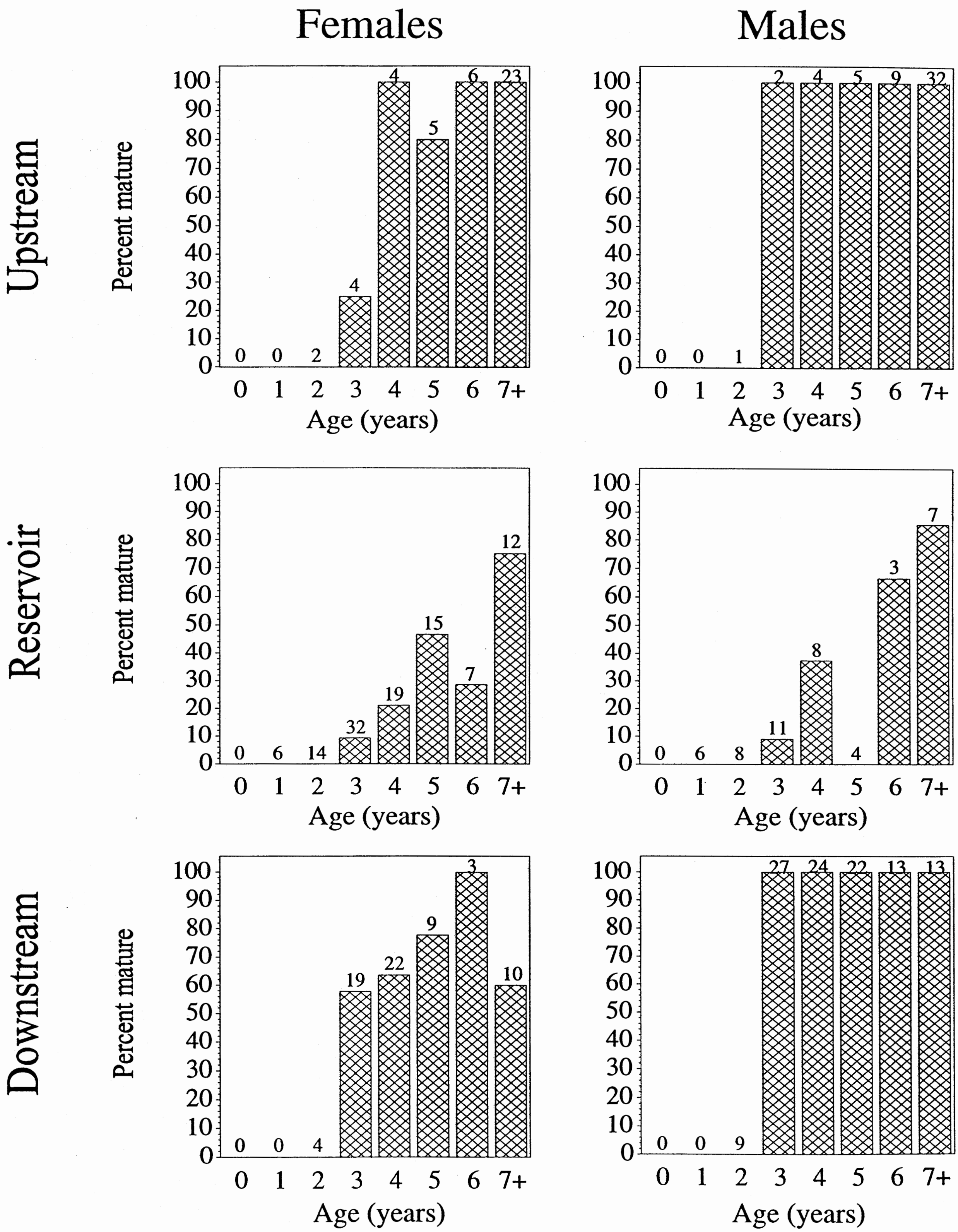

Figure 14. Percentage of reproductively mature fish among various age classes of mountain whitefish from the Oldman River system. The number of fish in each age class is indicated above the bars.

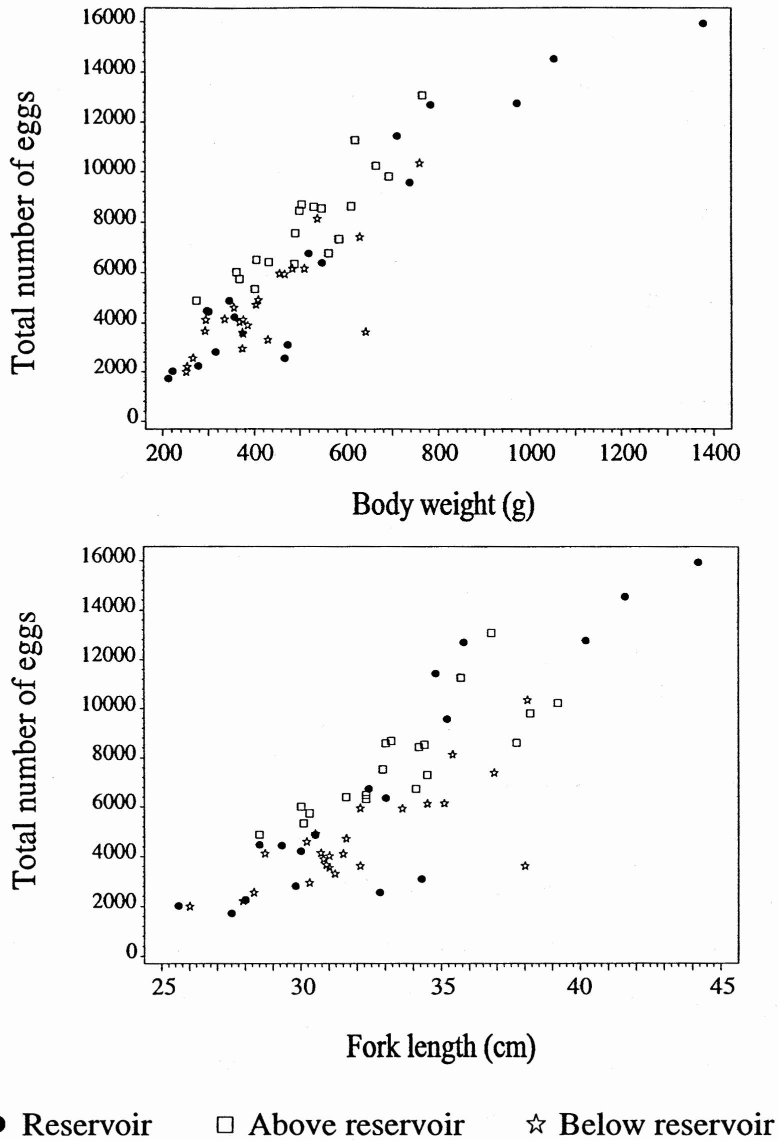

Figure 15. The fecundity - body size relationship in mountain whitefish from the Oldman River system.

sampling location, male and female mountain whitefish first matured at three years of age (Fig. 14). Upstream of the reservoir, nearly all fish four years of age and older were sexually mature. The same was true of male fish below the dam. Most female fish below the dam also matured at three years of age, but some immature females were present even among fish older than four years (Fig. 14).

Sexual maturation was considerably delayed in mountain whitefish from the reservoir compared to fish from the river habitats. Although some male and female fish were mature at age three, 50 % maturity in reservoir fish was not reached until age 6 in males and until at least age 7 in females (Fig. 14).

The fecundity - body size relationship in mountain whitefish from the Oldman River system is shown in Figure 15. Regression equations for the relationship between fecundity (Y) and body size are:

$$Y = -595 + 14.16 \cdot W \qquad r^2 = 0.79 \qquad p < 0.001$$

$$Y = -17485 + 725.4 \cdot L \qquad r^2 = 0.68 \qquad p < 0.001$$

where W is body weight in grams and L is fork length in cm. There is some indication that fecundity may have been slightly higher in mountain whitefish from above the reservoir than in fish from below the reservoir (Fig. 15). Small variations in fecundity among locations appear to be attributable to slightly greater gonadosomatic index (GSI) and slightly smaller egg size upstream of the reservoir compared to the other locations (Fig. 16).

4.0 DISCUSSION

4.1 Trophic Upsurge and Fish Abundance

One of the most widely accepted concepts in reservoir biology is that greatest biological productivity occurs shortly after impoundment of the water body (O'Brien 1990; Kimmel and Groeger 1986). New reservoirs often exhibit high fish biomass and support productive sport or commercial fisheries during the first few years after impoundment. However, the initially high fish production invariably declines after 5 to 20 years and remains at lower levels thereafter (O'Brien 1990; Kimmel and Groeger 1986). Factors believed to contribute to high levels of fish production during the early years of reservoir operation include stimulation of phytoplankton production by the release of nutrients from the flooded soil, proliferation of benthic invertebrates which derive nourishment from flooded terrestrial vegetation and in turn serve as food for fish, and the use of submerged vegetation as spawning and rearing habitat by fish (O'Brien 1990; Kimmel and Groeger 1986). Abatement of fish production after a number of years is believed to be a direct result of the decline and disintegration of submerged vegetation. Once the influence of submerged vegetation has subsided, fish production depends solely on primary productivity in the open water (O'Brien 1990). Because of its perceived dependence on nutrient release from flooded soil and vegetation, this boom and bust cycle in reservoir fisheries has become known as the "trophic upsurge" phenomenon.

During the first five years of operation, yearly mean CPUE for all species combined ranged from 3.5 to 10.7 fish$\cdot h^{-1} \cdot 100\ m^{-1}$ net (Fig. 3). The only other Alberta foothill reservoir for

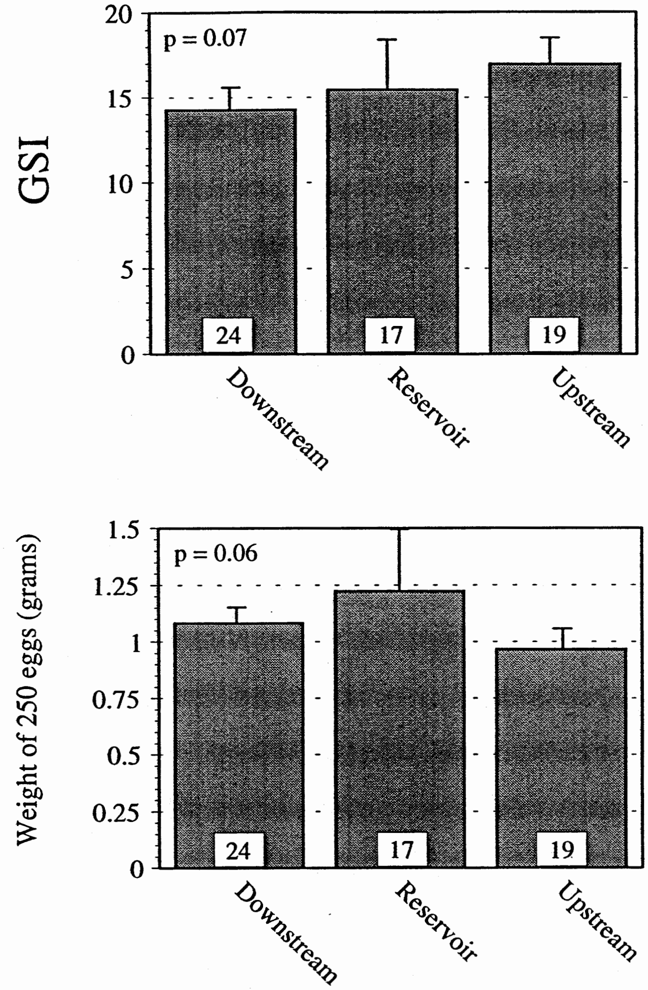

Figure 16. Gonadosomatic index (GSI) and egg weight in mountain whitefish from the Oldman River system. Mean and 95 % confidence intervals are shown. Sample sizes are indicated within each bar. GSI refers to ovary weight expressed as a percentage of body weight. Probability values for a one-way ANOVA comparison among sampling locations are given within each frame.

which comparable CPUE data are available is the Dickson Dam Reservoir where the Alberta Environmental Centre conducted fish inventories from 1983 to 1987 using similar types of gill nets and gill-net procedures to those used at the Oldman River Reservoir (Moore 1989a,b). The only difference in methodology was that gill nets at the Dickson Dam Reservoir were set overnight rather than for 3 to 8 h as in the present study. However, even allowing for lower catch rates at night, overall fish abundance in the Dickson Dam Reservoir was exceedingly low, as indicated by CPUE values of 0.12 to 0.47 fish$\cdot$ $h^{-1}\cdot 100\ m^{-1}$ net (Moore 1989b). Additional evidence for abundant fish populations in the Oldman River Reservoir is provided by creel surveys conducted by Alberta Fisheries Management Division which reveal that angler success at the reservoir was quite good in 1994 (Ripley 1995a).

Although it is tempting to attribute high fish abundance in the Oldman River Reservoir to the "trophic upsurge" phenomenon, several factors suggest that a trophic upsurge was either absent or had only a minor influence on reservoir fish populations. Most notably, catch rates of fish from the reservoir were high right from the start of reservoir operation in 1991 (Fig. 3), long before any effect due to enhanced recruitment could possibly occur. Therefore, the high abundance of fish in this reservoir is probably attributable to pre-existing fish populations in the parent rivers rather than to a trophic upsurge after impoundment.

The absence of a large trophic upsurge in the Oldman River Reservoir is also indicated by summer epilimnetic phosphorus concentrations which have been low (0.010 - 0.015 $mg{\cdot}L^{-1}$) and declining steadily since the reservoir first filled in 1991 (Golder Associates 1995). Hence, any release of nutrients from flooded soil probably occurred too quickly to have more than a small, temporary impact on the recruitment of sport-fish. Additionally, most of the riparian vegetation was removed prior to reservoir impoundment (Wu et al. 1996) which probably negated an otherwise important source of nutrients for benthic invertebrate production. The prominence of *Daphnia* in the diet of rainbow trout and mountain whitefish from the Oldman River Reservoir (Tables 7,8) indicates that fish production in the reservoir was always dependent on open-water primary production rather than on benthic invertebrate populations. On this basis, the invertebrate production phase of the trophic upsurge scenario appears to have been bypassed at the Oldman River Reservoir.

There is also no conclusive evidence for an increase in reservoir fish biomass during the first four years after impoundment. Although total CPUE was high in 1994 (Fig. 3), these catch rates are well within the rather wide limits of variability inherent in gill-net sampling. Furthermore, the total amount of sampling effort expended in 1994 (9.25 h at site 3 and 6.25 h at site 4; Table 1) raises doubt as to whether CPUE values are a reliable index of fish abundance. Accurate population assessment at the Oldman River Reservoir would require more extensive sampling effort, or more direct quantification of population size by means such as mark-recapture methods or hydroacoustic surveys, all of which were beyond the scope of this study.

4.2 Reservoir Species Assemblage

Gill-net catches showed that all of the large fish species present in the Oldman River system when the reservoir first filled in 1991 were still reasonably abundant (as indicated by catch rates) in the reservoir four years later (Fig. 3). The prominence of catostomid species (longnose sucker and white sucker) in the fish community of the Oldman River Reservoir is typical of reservoirs within the province. Other Alberta reservoirs with fish communities dominated by one or more species of sucker include the Dickson Dam Reservoir (Moore et al. 1989b), Chain Lakes reservoir (Walton 1980), Paine Lake Reservoir (Barton and Bidgood 1980; Barton 1980), and reservoirs along the Kananaskis River (Nelson 1965). Possible reasons for why catostomids do well in reservoirs include flexible spawning requirements and the ability to subsist on a diet of detritus.

Expansion of catostomid populations is generally viewed as undesirable in Alberta because these fish are not valued as game species and are often perceived as competing with game species, especially rainbow trout (Barton and Bidgood 1980). Observations cited as evidence for competition between catostomids and rainbow trout include several examples of dietary overlap (Barton and Bidgood 1980; Rawson and Elsey 1948; Hubert and Chamberlain 1996). Barton (1980) found that longnose and white suckers in Paine Lake Reservoir fed heavily on *Daphnia*, an important food of rainbow trout in many western reservoirs (present study, Tabor et al. 1996).

A study of 107 lakes and reservoirs in Wyoming (Hubert and Chamberlain 1996) found poor growth and productivity in rainbow trout was correlated with a high relative abundance of non-salmonid species (catostomids, cyprinids, and yellow perch). In an analysis of eight decades of trout stocking in Canadian mountain national parks, Donald (1987) observed that the presence of longnose sucker, mountain whitefish, or lake trout prevented colonization, or restricted the population size, of rainbow and cutthroat trout. Alberta waters in which small population size and poor angler harvest of rainbow trout has been attributed to pre-existing or expanding catostomid populations include Pyramid Lake (Rawson and Elsey 1948), Paine Lake Reservoir (Barton and Bidgood 1980), Chain Lakes Reservoir (Walton 1980), Upper Kananaskis Reservoir, and Barrier Reservoir (Nelson 1965).

Although several studies report an apparently negative influence of catostomids on rainbow trout, the issue remains open to debate. For example, attempts to improve the abundance and growth of rainbow trout in Pyramid Lake, Alberta through removal of longnose sucker and mountain whitefish were unsuccessful (Rawson and Elsey 1948). The relatively high growth rates observed for rainbow trout in the Oldman River Reservoir in this study (Fig. 10) also seems at odds with a negative impact of sucker populations on trout, at least for the time period observed. Furthermore, the potential exists for longnose and white sucker juveniles in the reservoir to serve as food for large rainbow trout and the piscivorus bull trout (Table 6). Hence, it is probably premature to regard catostomid populations in the Oldman River Reservoir as undesirable until more conclusive evidence becomes available on the question of sucker - trout interactions.

Creel surveys by Alberta Fisheries Management Division showed that rainbow trout comprised 95 % of all sport fish captured from the Oldman River Reservoir between April and October, 1994 (Ripley 1995a). In the winter sport fishery (January - March), rainbow trout comprised 59 % of the total catch (Ripley 1995b). An estimated 6,635±805 rainbow trout were caught by sport fishers at the Oldman River Reservoir during the 1994 summer fishery and an additional 202±63 were estimated to have been caught in the 1994 winter fishery (Ripley 1995a,b). Angler catch rates for rainbow trout in the Oldman River Reservoir were higher than for similar cold-water reservoirs in Wyoming and Montana (Ripley 1995a,b).

Prior to the 1994 creel survey, a sport-fish transport program was conducted as part of the fisheries mitigation program for the reservoir. The intent of this program was to collect sport fish trapped below the newly constructed dam and release them several kilometres above the dam where they would have access to upstream spawning areas. The program was conducted from 1989 to 1992, inclusive (Environmental Management Associates 1992, 1994). In comparison with the more than six thousand rainbow trout caught by anglers in 1994, only 1,995 rainbow trout from below the Oldman River Dam were transferred into the reservoir during the four-year transport program. Therefore, the sport-fish transport program was probably not an important factor in the high success rate of rainbow trout anglers in 1994.

The large number of rainbow trout taken in the sport fishery also suggests that species composition data (Table 3 and Figs. 2,3) may underestimate the actual abundance of rainbow trout in the reservoir. Whereas rainbow trout dominated the sport-fishing catch, the species comprised only 2.2 % of all fish captured during standardized gill-net sampling (Table 3). Reasons for the apparent under-representation of rainbow trout in gill-net catches are uncertain, but perhaps rainbow trout were more abundant at locations that were not sampled, such as the river mouths or the upper water column of the reservoir and perhaps they have a migratory tendency.

The rainbow trout collected from the reservoir (standardized and non-standardized sampling) were predominantly 30 to 45 cm in fork length (Fig. 5), the same slot-size range that anglers are required to release in the Crowsnest River (Alberta Guide to Sport Fishing 1994, 1995, 1996). These observations concur with those of Ripley (1995a,b) who found that 53 - 67 % of rainbow trout caught in the reservoir sport fishery were also of this size range. Furthermore, the proportion of slot-size rainbow trout in the angler catch from the Crowsnest River in 1994 declined appreciably as the season progressed from May to August (Ripley 1995a). This decline was attributed to a post-spawning or temperature-induced movement of larger rainbow trout from the Crowsnest River into the reservoir (Ripley 1995a). Results of the present study suggest that large intrinsic differences in growth rate (Fig.10) may be an additional explanation for why rainbow trout captured from the reservoir tend to be larger than those from the river habitats.

The impact of reservoirs on mountain whitefish populations is currently unresolved. Mountain whitefish were never abundant in the Dickson Dam Reservoir, and all but disappeared from that reservoir within two years after its construction in 1983 (Moore 1989b). Possible reasons for the decline of mountain whitefish populations in the Dickson Dam Reservoir include inadequate food, lack of suitable spawning areas, and predation by northern pike and burbot. In contrast, populations of mountain whitefish in the Kananaskis River were apparently unaffected by the construction of several storage and hydroelectric reservoirs between 1913 and 1955 (Nelson 1965).

Mountain whitefish have also fared reasonably well in the Oldman River Reservoir; populations there were abundant four years after river impoundment (Fig. 3). This may be explained by the fact that mountain whitefish were already abundant in the parent rivers before impoundment. It is unlikely that the number of mountain whitefish resident in the reservoir during those four years was artificially elevated by the sport-fish transport program. Mountain whitefish from below the dam were transferred into the reservoir during the first three years of the program (1989-1991). The number of mountain whitefish transferred during that time was 8,512 (Environmental Management Associates 1992,1994). If these transplanted fish comprised a substantial portion of the reservoir population, then gill-net catch rates for mountain whitefish from the reservoir may give an overly optimistic impression of the suitability of the reservoir environment for this species. However, in 1989, when the majority of mountain whitefish (5,266 fish) were transported, the transported fish apparently suffered high mortalities from handling stress (Environmental Management Associates 1992). Hence, there is probably little need to invoke transplanted fish to explain the catch rates reported for mountain whitefish in this study.

Irrespective of whether the abundance of mountain whitefish in the Oldman River Reservoir during the 1991-95 period was a natural phenomenon or a reflection of the fish transport program, data collected in this study cast doubt on the future success of this species in the reservoir. The slow growth (Fig. 9) and delayed maturation (Fig. 14) of mountain whitefish in the reservoir suggest that environmental conditions are sub-optimal for this species. Continued monitoring of reservoir fish populations is necessary to determine the ultimate success or failure of mountain whitefish populations in this environment.

Incidental catches of lake trout from the Oldman River Reservoir were reported in the 1994 creel survey but the authenticity of this observation was in doubt (Ripley 1995a). However, the positive identification of three lake trout in the present study (Table 2) confirms that this species is present in the Oldman River Reservoir. Lake trout in the reservoir were probably migrants that had travelled downstream from Crowsnest Lake (source of the Crowsnest River) which has been stocked with lake trout in the past (Alberta Fishing Guide 1996). The presence of lake trout in the Oldman River Reservoir is significant because this species is suspected of competing with bull trout. Donald and Alger (1993) presented evidence from 34 mountain lakes in southwest Alberta, Montana, and British Columbia suggesting that lake trout tend to displace bull trout from mountain lakes or prevent bull trout from becoming established. The mechanism of displacement is not definitely known, but competition reflected in diet overlap, similar mouth morphology, and similar growth rates was suspected (Donald and Alger 1993).

Although the number of lake trout currently inhabiting the Oldman River Reservoir appears to be quite small, the population size at which lake trout begin to negatively impact bull trout is not known. Suitable spawning areas for lake trout are probably scarce within the Oldman River Reservoir. However, the species has been known to spawn in streams in certain areas (McPhail and Lindsey 1970). Because of the potential impact on bull trout, incidental reports of lake trout in the reservoir should probably be monitored and any appreciable increase in their frequency merits further investigation.

4.3 Bull Trout Biology

The relatively high catch rates for bull trout reported in this study (Fig. 3; Table 5) suggest that significant numbers of this species continue to exist upstream of the Oldman River Dam. Furthermore, the relative abundance of bull trout in gill-net catches from the reservoir was substantially higher than would be expected from surveys conducted on the parent rivers prior to impoundment. During electrofishing surveys conducted from August to October 1985, bull trout comprised only 0.4 % of all sport fish collected from portions of the Oldman, Crowsnest, and Castle rivers lying within, and several km upstream, of the projected reservoir FSL (R.L. & L. 1986). In the present study, bull trout comprised 7.6 % of the total fish catch and 21.1 % of all sport fish (mountain whitefish plus all trout species) collected during standardized gill-net sampling at the reservoir (Table 3).

Unfortunately, the reliability of gill-net sampling as an indication of bull trout abundance is unclear. One important issue is whether bull trout, being piscivorus, are attracted to gill nets by the presence of entangled fish. If such behavior occurred, catch rates reported in this study would over-estimate bull trout abundance. To some extent, the relative abundance of bull trout in the present study is also inflated by the under representation of rainbow trout in the gill-net catch. On the other hand, because the Oldman River Reservoir was sampled in fall, when mature bull trout are spawning in the upper tributaries, catch rates from the reservoir may underestimate the species' abundance. This consideration is particularly applicable to ages older than five years; the latter being the youngest age at which bull trout commonly reach sexual maturity (Fraley and Shepard 1989; Nelson and Paetz 1992). More definitive studies, such as the operation of a counting fence on the Castle River, are needed to accurately determine the current abundance of bull trout upstream of the Oldman River Dam. Fisheries Management Division staff of Alberta Environmental Protection routinely monitor the number of redds in the tributary streams as an index of bull trout numbers.

Truncation of the bull trout length distribution above 36 cm (Fig. 4), and the absence of mature or ripe bull trout in the reservoir catch, is evidence that reproductively mature bull trout may have migrated out of the reservoir prior to the fall sampling operations. Although the body weight and age distributions of bull trout were not obviously truncated, this is not at odds with a truncated length distribution. In this study, the mean body weight of a 36 cm bull trout was approximately 500 grams. Because few bull trout heavier than 500 grams were collected from the reservoir (Fig. 4), the body weight distribution of bull trout is consistent with a truncated length distribution. Furthermore, since attainment of reproductive maturity in individual fish is more dependent on body size than on age (Diana 1995), there is no reason to expect truncation in the bull trout age distribution despite a truncated length distribution.

Although CPUE values for bull trout in the Oldman River Reservoir seem high, these values were not influenced by the provincial sport-fish transport program. From 1989 to 1992, 161 bull trout from below the dam were transferred into the reservoir and 138 of these bull trout were marked with Floy® tags (Environmental Management Associates 1992, 1994). If gill-net catches from the reservoir consisted predominantly of transported bull trout, it could mean that few adult bull trout were present above the dam when it was being built. However, of the 80 bull trout collected from the Oldman River Reservoir during this study (Table 3) only one fish (captured in 1991) bore a Floy® tag. Therefore, catch rates from the reservoir are indicative of bull trout populations of that existed upstream of the dam when the dam was being built, plus contributions through reproduction and recruitment. In the present study, small bull trout (< 25 cm in fork length) were captured above the dam up to and including 1995, which suggests that at least some recruitment has occurred after construction of the dam.

Bull trout are difficult to age reliably. Some authors recommend using otoliths (Mackay et al. 1990), whereas others recommend scales (Goetz 1989). Agreement in age between scales and otoliths appears to be good up to age 3, but poor in older fish (Fraley and Shepard 1989; Goetz 1989). Because electroshocking may have selected larger fish of a given age, size-at-age data of bull trout collected from the reservoir by gill-net sampling probably offers the best basis for comparison with published growth rates. Alberta bull trout populations for which published growth rates are available include those in Pinto Lake (Carl et al. 1989), the Muskeg River (Boag 1987), Clearwater River (Allan 1980), and Bow River (Miller 1949). Based on these references, the growth rate of bull trout in the Oldman River Reservoir appears to be greater, up to age 4, than rates reported for other Alberta populations (Fig. 11).

Several factors could explain the apparent fast growth of bull trout in the Oldman River Reservoir, including failure to validate age (in the present study and in others). Underestimation of age by one year would bring growth rates of bull trout in the Oldman River Reservoir more in line with previous studies. Alternatively, fast growth could be a reflection of size dependent migrational behavior. If faster growing juvenile bull trout move to the reservoir earlier than slower growing fish, the apparent growth rate in the reservoir would be biased upwards. Validation of bull trout age and growth rate in the Oldman River system appears to be a useful area for future research and should include collection of 0 and 1 year old fish to verify the location of the first annulus.

4.4 Habitat-Related Growth Variations in Rainbow Trout and Mountain Whitefish

Before attributing differences in growth rates of fish from reservoir and river habitats to the effects of impoundment, it is important to consider the possible effects of size selective sampling. The larger size at age of mountain whitefish above and below the reservoir (Fig. 9) is consistent with the view that electrofishing preferentially selects the larger fish of a given age class (Reynolds 1996). However, several considerations strongly suggest that growth differences between reservoir and river habitats observed in this study are not due to size selectivity in sampling methods. First, considering that mountain whitefish as young as two years and weighing less than 100 g were collected by electrofishing (Fig. 9), it is unlikely that electrofishing was sufficiently size selective among the 3 to 7 year old fish to account for the large differences in growth rate observed between habitat types. To illustrate, if six-year old mountain whitefish from the river habitats really had the same mean weight of reservoir fish (220 grams), then fish of the latter size should have been capturable by electrofishing from the river locations. Furthermore, and perhaps most significantly, if electrofishing did preferentially select for large fish, this tendency should have been manifest in all species sampled. However, rainbow trout captured by electrofishing in river habitats were actually smaller at any given age than those collected by gill-net sampling from the reservoir (Fig.10). Therefore, variations in the growth rate of rainbow trout and mountain whitefish between reservoir and river habitats are real and not an artifact of the sampling methods used.

Plausible hypotheses for habitat-related growth variations in rainbow trout and mountain whitefish can be proposed based on morphology, diet compositions, and energetic factors. The relatively slow growth of rainbow trout in streams above and below the Oldman River Reservoir may be related to their ingestion of large quantities of algae (Table 7). Algae have little nutritional value to rainbow trout because, being carnivores, rainbow trout lack the enzymes necessary to digest cellulose (Steffens 1989). Algae could slow growth by diluting the nutritional content of digestible food, and also through a direct impact on the digestive process. Because it is resistant to digestion, algae likely pass from the gut slowly, or may even accumulate, thereby impeding the contact of digestive secretions with other food and slowing its digestion. Ingestion of algae, despite its poor nutritional value, can probably be attributed to the rainbow trout's large, terminal mouth which seems poorly suited to pick invertebrate prey cleanly from amongst algae growing on the stream substrate. Significant ingestion of algae by rainbow trout has been reported elsewhere in western North America (Laakso 1950; Tabor et al. 1996), but the previous authors did not comment on its relationship to morphology or nutrition.

In contrast to the river habitats, rainbow trout in the Oldman River Reservoir had access to good quality food (*Daphnia* spp.) which could be consumed without the concomitant ingestion of large amounts of algae. Although the present study was conducted in the fall, well after the main feeding period of most north-temperate fish, creel sampling at the Oldman River Reservoir during summer also showed that cladocerans occurred in a greater percentage of rainbow trout stomachs than any other food item (Ripley 1995a). *Daphnia*, especially the larger sizes (> 1.5 mm in length), have been shown to support good growth rates in juvenile rainbow trout in many western lakes and reservoirs (Galbraith 1975; Schneidervin and Hubert 1987; Hubert et al. 1994; Tabor et al. 1996; Wurtsbaugh et al. 1996). Tabor et al. (1996) proposed daphnid biomass as a useful index of potential growth rates in rainbow trout inhabiting lakes and reservoirs. Because of their small size, *Daphnia* may not seem like a good forage base for rainbow trout. However, the trout's large, terminal mouth may allow it to efficiently inhale *Daphnia* in large numbers, especially if the latter are present as dense swarms.

Another reason for the relatively fast growth of rainbow trout in the Oldman River Reservoir could be lower energy costs associated with swimming, since current velocities are less in the reservoir than in the streams. Other things being equal, less energy spent on locomotion leaves more energy available for growth. Note that both the energetic advantages associated with lower current velocity and the value of *Daphnia* as food would be greater in younger, smaller rainbow trout than in older, larger individuals. As rainbow trout grow older and larger they probably expend progressively less of their total energy budget on swimming and prefer to consume progressively larger prey, eventually becoming piscivorus. Such dietary and energetic consequences of changing body size could explain why habitat-related growth differences in rainbow trout were limited primarily to fish two years of age and younger (Fig. 10).

The preceding arguments imply that trout collected from the reservoir and rivers remain in these habitats most of the time. Clear differences in the diet composition of reservoir and river trout suggest that this assumption is correct for the fall period. However, even trout with an affinity for the reservoir must enter the rivers in spring to spawn. Collection of data on diet composition and movements of trout in spring and early summer is necessary to determine whether fall data are representative of the annual food budget and provide adequate explanations for growth differences between reservoir and river trout.

It seems paradoxical that mountain whitefish should grow more slowly in the reservoir than in the rivers even though their diet in the reservoir is similar to that of the fast-growing rainbow trout (Fig. 9 and Table 8). However, a plausible hypothesis for this can be proposed, based again on mouth morphology, feeding habits, and prey availability. Mountain whitefish have small, sub-terminal mouths which are well suited to feeding on benthic invertebrates. In streams, mountain whitefish feed predominantly on larval and pupal stages of Chironomidae, larval Trichoptera, and nymphs of Plecoptera and Ephemeroptera, the relative proportions of which vary with location, season, and fish size (McHugh 1940; Laasko 1950; Pontius and Parker 1973; Thompson and Davies 1976; present study). These insects appear to be taken both directly from the substrate and from the drift (Pontius and Parker 1973; Thompson and Davies 1976). Although mountain whitefish will feed on pelagic organisms and even take food from the water surface when benthic prey are not available (Laasko 1950; Pontius and Parker 1973), their small, subterminal mouths may make these feeding modes inefficient. In the Oldman River Reservoir, where pelagic prey (*Daphnia*) form the dominant food of mountain whitefish, one can envisage the capture of these small prey one at a time by a small-mouthed predator to be an inefficient process. The high proportion of empty stomachs among mountain whitefish in the reservoir (Table 8) suggests that these fish may have had difficulty in finding *Daphnia* and consuming them efficiently. Rainbow trout, in contrast, may be more efficient at feeding on *Daphnia* if the trout's larger mouth allows capture of many *Daphnia* in a single bite.

Mountain whitefish are much more abundant than rainbow trout in the Oldman River Reservoir and in adjoining rivers. Therefore, greater intra-specific competition may be another reason for the relatively slow growth of whitefish in the reservoir. It is also significant that habitat-related growth variations in mountain whitefish developed largely after the age of two years (Fig. 9). Diet studies show that as mountain whitefish become larger they prefer to feed on progressively larger sizes of insect prey (McHugh 1940; Pontius and Parker 1973). However, the small mouth of mountain whitefish prevents them from becoming piscivorus as adults. It is possible that a lack of benthic insect fauna in the Oldman River Reservoir obligates mountain whitefish to consume a diet of small prey (*Daphnia*) which becomes more and more sub-optimal as the fish grow older and larger. As a consequence, growth rate in the reservoir declines progressively below that of stream populations.

In conclusion, the slow growth of mountain whitefish in the Oldman River Reservoir appears attributable to three factors: pelagic food in the reservoir (*Daphnia*) which is unsuited to the mouth morphology and benthic feeding habits of mountain whitefish; a paucity of benthic insect fauna in the reservoir; and intra-specific competition. The energetic advantage over river populations gained by mountain whitefish in the reservoir due to slower water velocities must presumably be out-weighed by sub-optimal feeding.

Although only a few studies have examined the biology of mountain whitefish in lakes, they show some important similarities with characteristics of mountain whitefish in the Oldman River Reservoir. In Phelps lake, Wyoming, mountain whitefish fed almost exclusively on zooplankton, grew more slowly than in adjacent streams, and there was no evidence of mixing between lake and stream populations (Hagen 1970). Mountain whitefish in Okanagan Lake also fed chiefly on cladocera during the summer, presumably because of a scarcity of bottom fauna (McHugh 1940). A study of lakes in the Skeena River system of British Columbia found mountain whitefish to be abundant in the shallow and more eutrophic lakes, but scarce in one lake (Morrison Lake) which had a very low abundance of benthic invertebrates (Godfrey 1955). The similarity in mountain whitefish biology between these lakes (especially Phelps Lake) and the Oldman River Reservoir provides further evidence that the responses to impoundment observed at the latter reservoir were not artifacts arising from sampling methodology or a limited sampling schedule.

Nevertheless, the hypotheses offered above for observed growth variations in rainbow trout and mountain whitefish are based mainly on dietary data collected in late September or early October, well after the main summer feeding period. Additional data on the diet of rainbow trout and mountain whitefish during summer (July or early August) are needed to confirm the interpretations offered in the present study.

4.5 Mountain Whitefish Reproductive Biology

In streams above and below the Oldman River Reservoir, the majority of mountain whitefish became reproductively mature by three or four years of age, males tending to mature slightly earlier and at slightly smaller sizes than females (Figs. 12-14). This pattern appears to be typical of the species. Mountain whitefish in Phelps Lake, Wyoming, and in the Sheep River, Alberta, matured at three or four years of age (Hagen 1970; Thompson and Davies 1976). In the Yellowstone, Gallatin, and Madison rivers of Montana and the Kananaskis River system of Alberta the majority of mountain whitefish also mature at three years of age, but some males attain maturity at age two (Brown 1952; Nelson 1965). The only published size at maturity data for mountain whitefish is for Phelps Lake where the length of the smallest mature fish (18.1 to 24.5 cm; Hagen 1970) corresponds approximately to that in the Oldman River system (Fig. 12). In contrast, most mountain whitefish in the reservoir did not mature until 6 or 7 years of age (Fig. 14) when they attained a similar size to mature fish in the river habitats (Fig. 9).

Most published fecundity values for mountain whitefish range from 1,000 to 10,000 eggs per fish (Brown 1952; Hagen 1970; Thompson and Davies 1976) which corresponds closely to values observed in this study (Fig. 15). The largest fecundity previously published for a mountain whitefish is a value of 24,143 eggs for a 49.5 cm specimen weighing 1,493 g (Brown 1952). This value is somewhat greater than values predicted from regression equations for the Oldman River Reservoir.

Fecundity and egg size in mountain whitefish appears to vary somewhat depending on environmental conditions. Hagen (1970) observed two rates of ova development in the mountain whitefish population of Phelps Lake. Fish with slow maturing ova spawned later in the season, but within the same year, as fish with faster maturing ova. McPhail and Lindsey (1970) report that Kootenay Lake, British Columbia, contains two races of mountain whitefish which may differ in morphology and time of spawning. Mountain whitefish from Phelps Lake produced more eggs on average (17,101 eggs·kg^{-1}; Hagen 1970) than did stream populations in Montana (11,779 eggs·kg^{-1}; Brown 1952) and Alberta (11,598·kg^{-1}; Thompson and Davies 1976). Mountain whitefish in the upper Oldman River system have a weight-specific fecundity of 13,565 eggs·kg^{-1} (calculated from regression equations on page 36), which falls within the range of literature values reported for other populations.

Variations in egg size and fecundity also exist between different species of whitefish. Booke (1970) found that variation in mean egg size among eight species of North American whitefishes (genus' *Prosopium* and *Coregonus*) was related to water depth and time of spawning. Species spawning at greater depths and later in the season produced smaller eggs than those spawning earlier and at shallower depths. Although fecundity and egg size in mountain whitefish exhibited some variability among different locations within in the Oldman River system (Figs. 15,16), whether such variations are related to construction of the reservoir cannot be determined from these data.

4.6 Conclusions

Four years after the Oldman River Reservoir first filled, significant populations of all predominant large fish species are still present in the reservoir. Longnose sucker may have become more abundant in the reservoir since 1993. However, it would be premature to regard increasing catostomid populations as undesirable because they may serve as food for bull trout, a species of special concern in Alberta.

The relative abundance of bull trout in gill-net catches from the reservoir was much greater than expectations based on electrofishing surveys conducted in the same river reaches prior to reservoir construction. It is not known whether the apparent abundance of bull trout is a reliable observation or an artifact caused by selectivity of gill nets for piscivorus species. Operation of a counting fence on the Castle River during late summer and fall could be a non-lethal method of obtaining more reliable information on current population levels of bull trout upstream of the Oldman River Dam. Reports of lake trout in the reservoir should also be monitored because this species has the potential to negatively impact bull trout.

Rainbow trout collected from the reservoir exhibited good growth rates. However, consumption of large quantities of algae may be limiting the growth of rainbow trout in river habitats. Quantitative studies of diet composition in rainbow trout during the summer growth period would help resolve this issue.

Mountain whitefish populations in the Oldman River Reservoir appear to be at some risk based on slow growth rate, a high percentage of empty stomachs, and delayed age at reproductive maturation. Mountain whitefish populations are of concern for their own sake and also for the success of bull trout which may rely on mountain whitefish as a food base. Studies of the dietary consumption and prey preferences of mountain whitefish during summer would help clarify the suitability of the reservoir as habitat for mountain whitefish and may suggest ways of helping the population sustain itself.

Finally, continued monitoring of fish populations in the Oldman River Reservoir is recommended because limnological and biological conditions within newly formed reservoirs commonly require longer than five years to stabilize.

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Appendix 1. Total numbers and species composition of fish collected from the Oldman River Reservoir during standardized gill-net sampling.

1991

Species	Site 3		Site 4		Total	
	Shallow	Deep	Shallow	Deep	Numbers	Percent composition
Longnose sucker	48	11	170	118	347	57.8
White sucker	21	1	4	13	39	6.5
Mountain whitefish	87	14	8	40	149	24.8
Bull trout	29	3	2	10	44	7.3
Rainbow trout	8	2	3	5	18	3
Brown trout	3	0	0	0	3	0.5
Yearly total	196	31	187	186	600	100

1992

Species	Site 3		Site 4		Total	
	Shallow	Deep	Shallow	Deep	Numbers	Percent composition
Longnose sucker	0	22	1	18	41	41.8
White sucker	2	0	4	0	6	6.1
Mountain whitefish	4	1	38	0	43	43.9
Bull trout	1	2	4	0	7	7.1
Rainbow trout	0	0	1	0	1	1
Brown trout	0	0	0	0	0	0
Yearly total	7	25	48	18	98	100

Appendix 1... Total numbers and species composition of fish collected from the Oldman River Reservoir during standardized gill-net sampling.

1993

Species	Site 3		Site 4		Total	
	Shallow	Deep	Shallow	Deep	Numbers	Percent composition
Longnose sucker	0	3	0	10	13	20.3
White sucker	1	0	2	1	4	6.3
Mountain whitefish	6	17	8	0	31	48.4
Bull trout	0	5	3	7	15	23.4
Rainbow trout	1	0	0	0	1	1.6
Brown trout	0	0	0	0	0	0
Yearly total	8	25	13	18	64	100

1994

Species	Site 3		Site 4		Total	
	Shallow	Deep	Shallow	Deep	Numbers	Percent composition
Longnose sucker	19	23	17	34	93	60
White sucker	9	9	2	0	20	12.9
Mountain whitefish	2	0	31	0	33	21.3
Bull trout	2	2	3	1	8	5.2
Rainbow trout	0	0	0	0	0	0
Brown trout	1	0	0	0	1	0.6
Yearly total	33	34	53	35	155	100

Appendix 1... Total numbers and species composition of fish collected from the Oldman River Reservoir during standardized gill-net sampling.

1995						
Species	Site 3		Site 4		Total	
	Shallow	Deep	Shallow	Deep	Numbers	Percent composition
Longnose sucker	14	9	26	28	77	59.7
White sucker	13	0	11	3	27	20.9
Mountain whitefish	6	0	9	0	15	11.6
Bull trout	3	0	3	0	6	4.7
Rainbow trout	0	0	3	0	3	2.3
Brown trout	1	0	0	0	1	0.8
Yearly total	37	9	52	31	129	100
Five-year total	281	124	353	288	1046	

Appendix 2. Total numbers and catch-per-unit-effort (CPUE) for each species collected from the Oldman River Reservoir during standardized gill-net sampling.

1991					
Site	Depth	Species	Number Caught	Set Time (hours)	CPUE (fish · h^{-1} · 100 m^{-1} net)
3	1	Longnose sucker	48	25.75	1.864
3	1	White sucker	21	25.75	0.816
3	1	Mountain whitefish	87	25.75	3.379
3	1	Bull trout	29	25.75	1.126
3	1	Rainbow trout	8	25.75	0.311
3	1	Brown trout	3	25.75	0.117
3	2	Longnose sucker	11	24.15	0.455
3	2	White sucker	1	24.15	0.041
3	2	Mountain whitefish	14	24.15	0.58
3	2	Bull trout	3	24.15	0.124
3	2	Rainbow trout	2	24.15	0.083
3	2	Brown trout	0	24.15	0
4	1	Longnose sucker	170	23	7.391
4	1	White sucker	4	23	0.174
4	1	Mountain whitefish	8	23	0.348
4	1	Bull trout	2	23	0.087
4	1	Rainbow trout	3	23	0.13
4	1	Brown trout	0	23	0
4	2	Longnose sucker	118	25.7	4.591
4	2	White sucker	13	25.7	0.506
4	2	Mountain whitefish	40	25.7	1.556
4	2	Bull trout	10	25.7	0.389
4	2	Rainbow trout	5	25.7	0.195
4	2	Brown trout	0	25.7	0
Year Total			600		

Appendix 2... Total numbers and catch-per-unit-effort (CPUE) for each species collected from the Oldman River Reservoir during standardized gill-net sampling.

1992

Site	Depth	Species	Number Caught	Set Time (hours)	CPUE (fish · h^{-1} · 100 m^{-1} net)
3	1	Longnose sucker	0	3.9	0
3	1	White sucker	2	3.9	0.513
3	1	Mountain whitefish	4	3.9	1.026
3	1	Bull trout	1	3.9	0.256
3	1	Rainbow trout	0	3.9	0
3	1	Brown trout	0	3.9	0
3	2	Longnose sucker	22	7	3.143
3	2	White sucker	0	7	0
3	2	Mountain whitefish	1	7	0.143
3	2	Bull trout	2	7	0.286
3	2	Rainbow trout	0	7	0
3	2	Brown trout	0	7	0
4	1	Longnose sucker	1	7.7	0.13
4	1	White sucker	4	7.7	0.519
4	1	Mountain whitefish	38	7.7	4.935
4	1	Bull trout	4	7.7	0.519
4	1	Rainbow trout	1	7.7	0.13
4	1	Brown trout	0	7.7	0
4	2	Longnose sucker	18	7.9	2.278
4	2	White sucker	0	7.9	0
4	2	Mountain whitefish	0	7.9	0
4	2	Bull trout	0	7.9	0
4	2	Rainbow trout	0	7.9	0
4	2	Brown trout	0	7.9	0
Year Total			98		

Appendix 2... Total numbers and catch-per-unit-effort (CPUE) for each species collected from the Oldman River Reservoir during standardized gill-net sampling.

1993

Site	Depth	Species	Number Caught	Set Time (hours)	CPUE (fish · h^{-1} · 100 m^{-1} net)
3	1	Longnose sucker	0	3.85	0
3	1	White sucker	1	3.85	0.26
3	1	Mountain whitefish	6	3.85	1.558
3	1	Bull trout	0	3.85	0
3	1	Rainbow trout	1	3.85	0.26
3	1	Brown trout	0	3.85	0
3	2	Longnose sucker	3	3.65	0.822
3	2	White sucker	0	3.65	0
3	2	Mountain whitefish	17	3.65	4.658
3	2	Bull trout	5	3.65	1.37
3	2	Rainbow trout	0	3.65	0
3	2	Brown trout	0	3.65	0
4	1	Longnose sucker	0	4.1	0
4	1	White sucker	2	4.1	0.488
4	1	Mountain whitefish	8	4.1	1.951
4	1	Bull trout	3	4.1	0.732
4	1	Rainbow trout	0	4.1	0
4	1	Brown trout	0	4.1	0
4	2	Longnose sucker	10	4.25	2.353
4	2	White sucker	1	4.25	0.235
4	2	Mountain whitefish	0	4.25	0
4	2	Bull trout	7	4.25	1.647
4	2	Rainbow trout	0	4.25	0
4	2	Brown trout	0	4.25	0
Year Total			64		

Appendix 2... Total numbers and catch-per-unit-effort (CPUE) for each species collected from the Oldman River Reservoir during standardized gill-net sampling.

1994

Site	Depth	Species	Number Caught	Set Time (hours)	CPUE (fish · h^{-1} · 100 m^{-1} net)
3	1	Longnose sucker	19	4.5	4.222
3	1	White sucker	9	4.5	2
3	1	Mountain whitefish	2	4.5	0.444
3	1	Bull trout	2	4.5	0.444
3	1	Rainbow trout	0	4.5	0
3	1	Brown trout	1	4.5	0.222
3	2	Longnose sucker	23	4.75	4.842
3	2	White sucker	9	4.75	1.895
3	2	Mountain whitefish	0	4.75	0
3	2	Bull trout	2	4.75	0.421
3	2	Rainbow trout	0	4.75	0
3	2	Brown trout	0	4.75	0
4	1	Longnose sucker	17	3	5.667
4	1	White sucker	2	3	0.667
4	1	Mountain whitefish	31	3	10.333
4	1	Bull trout	3	3	1
4	1	Rainbow trout	0	3	0
4	1	Brown trout	0	3	0
4	2	Longnose sucker	34	3.25	10.462
4	2	White sucker	0	3.25	0
4	2	Mountain whitefish	0	3.25	0
4	2	Bull trout	1	3.25	0.308
4	2	Rainbow trout	0	3.25	0
4	2	Brown trout	0	3.25	0
Year Total			155		

Appendix 2... Total numbers and catch-per-unit-effort (CPUE) for each species collected from the Oldman River Reservoir during standardized gill-net sampling.

1995

Site	Depth	Species	Number Caught	Set Time (hours)	CPUE (fish · h^{-1} · 100 m^{-1} net)
3	1	Longnose sucker	14	5.2	2.692
3	1	White sucker	13	5.2	2.5
3	1	Mountain whitefish	6	5.2	1.154
3	1	Bull trout	3	5.2	0.577
3	1	Rainbow trout	0	5.2	0
3	1	Brown trout	1	5.2	0.192
3	2	Longnose sucker	9	5.8	1.552
3	2	White sucker	0	5.8	0
3	2	Mountain whitefish	0	5.8	0
3	2	Bull trout	0	5.8	0
3	2	Rainbow trout	0	5.8	0
3	2	Brown trout	0	5.8	0
4	1	Longnose sucker	26	5.5	4.727
4	1	White sucker	11	5.5	2
4	1	Mountain whitefish	9	5.5	1.636
4	1	Bull trout	3	5.5	0.545
4	1	Rainbow trout	3	5.5	0.545
4	1	Brown trout	0	5.5	0
4	2	Longnose sucker	28	6.3	4.444
4	2	White sucker	3	6.3	0.476
4	2	Mountain whitefish	0	6.3	0
4	2	Bull trout	0	6.3	0
4	2	Rainbow trout	0	6.3	0
4	2	Brown trout	0	6.3	0
Year Total			129		
Five Year Total			1046		

Appendix 3. Size at age of mountain whitefish for early and late monitoring periods. Values reported as mean±SEM (n).

	1991 - 1992					
Age (years)	Body weight (g)			Fork length (cm)		
	Upstream	Reservoir	Downstream	Upstream	Reservoir	Downstream
0	--	18 (1)	--	--	11.7 (1)	--
1	--	--	--	--	--	--
2	64±33 (3)	69±3 (40)	101±13 (6)	19.1±0.0 (3)	18.4±0.2 (40)	21.5±0.9 (6)
3	224±48 (3)	131±7 (34)	178±14 (13)	25.3±2.2 (3)	22.8±0.5 (34)	25.7±0.6 (13)
4	363±15 (6)	171±23 (14)	259±18 (14)	30.2±0.3 (6)	23.9±1.0 (14)	27.8±0.4 (14)
5	372±22 (4)	227±47 (10)	291±29 (7)	31.1±1.2 (4)	25.7±1.7 (10)	29.5±1.1 (7)
6	434±42 (6)	245±92 (4)	417±22 (5)	31.4±0.8 (6)	26.0±2.2 (4)	34.4±0.9 (5)
7	406±24 (7)	525 (1)	388±45 (6)	31.6±0.6 (7)	34.6 (1)	31.8±1.5 (6)
8	539±17 (4)	518±112 (7)	355 (1)	33.6±0.5 (4)	32.7±2.6 (7)	30.2 (1)
9	496±42 (5)	521±79 (2)	503±138 (2)	33.2±1.2 (5)	34.6±1.2 (2)	34.9±3.1 (2)
10	463 (1)	662±48 (2)	--	34.3 (1)	37.0±2.2 (2)	--
11	666±50 (3)	--	--	36.0±0.5 (3)	--	--
12	481 (1)	738 (1)	--	33.4 (1)	35.2 (1)	--
13	--	--	842 (1)	--	--	41.1 (1)
14	--	742 (1)	--	--	38.0 (1)	--
15	--	--	--	--	--	--
16	--	--	--	--	--	--
17	--	--	--	--	--	--
18	--	1378 (1)	--	--	44.2 (1)	--

Appendix 3... Size at age of mountain whitefish for early and late monitoring periods. Values reported as mean±SEM (n).

	1993 - 1995					
Age (years)	Body weight (g)			Fork length (cm)		
	Upstream	Reservoir	Downstream	Upstream	Reservoir	Downstream
0	--	--	--	--	--	--
1	--	81±4 (14)	--	--	19.2±0.4 (14)	--
2	148±8 (3)	97±14 (10)	106±17 (19)	22.8±0.3 (3)	19.9±1.2 (10)	20.3±1.0 (19)
3	338±70 (3)	124±12 (34)	223±18 (39)	29.9±2.0 (3)	21.3±0.7 (34)	25.7±0.7 (39)
4	329±59 (2)	155±12 (21)	338±19 (32)	29.4±1.5 (2)	23.3±0.7 (21)	30.0±0.6 (32)
5	378±32 (6)	191±15 (13)	384±30 (24)	30.8±0.8 (6)	25.5±0.6 (13)	31.3±0.9 (24)
6	438±34 (9)	208±29 (8)	492±34 (11)	31.8±0.7 (9)	25.5±1.1 (8)	34.3±0.7 (11)
7	462±51 (6)	224±48 (3)	598±60 (9)	33.2±1.1 (6)	26.4±1.7 (3)	35.7±0.9 (9)
8	485±11 (12)	486±14 (2)	664±252 (2)	33.3±0.3 (12)	34.2±0.1 (2)	36.4±3.8 (2)
9	493±72 (3)	--	659±82 (2)	34.4±1.3 (3)	--	36.8±0.3 (2)
10	513±45 (5)	--	--	34.5±1.5 (5)	--	--
11	649±44 (2)	--	--	37.7±0.6 (2)	--	--
12	635±54 (2)	--	--	37.8±2.4 (2)	--	--
13	541±71 (2)	--	--	35.4±2.4 (2)	--	--
14	--	--	--	--	--	--
15	540 (1)	--	--	36.1 (1)	--	--
16	--	--	--	--	--	--
17	486 (1)	--	--	34.3 (1)	--	--
18	--	--	--	--	--	--

Appendix 4. Size at age of rainbow trout for early and late monitoring periods. Values reported as mean±SEM (n).

1991 - 1992

Age (years)	Body weight (g)			Fork length (cm)		
	Upstream	Reservoir	Downstream	Upstream	Reservoir	Downstream
0	--	--	--	--	--	--
1	73±21 (3)	52 (1)	197 (1)	18.4±1.8 (3)	16.5 (1)	25.0 (1)
2	107±13 (11)	332±67 (6)	189±53 (4)	20.9±0.9 (11)	28.1±1.9 (6)	26.3±1.5 (4)
3	246±24 (14)	566±123 (7)	297±46 (12)	27.1±1.0 (14)	33.1±2.7 (7)	29.2±1.1 (12)
4	374±23 (14)	1004±123 (2)	468±46 (10)	31.2±0.6 (14)	43.7±1.7 (2)	34.0±0.8 (10)
5	532±52 (10)	1062±120 (4)	591±35 (3)	35.1±0.9 (10)	44.0±1.5 (4)	36.6±0.6 (3)
6	619±133 (2)	992±106 (2)	694 (1)	36.7±2.4 (2)	43.4±1.5 (2)	37.9 (1)
7	312 (1)	2467 (1)	--	29.2 (1)	56.4 (1)	--
8	643 (1)	--	--	39.6 (1)	--	--

1993 - 1995

Age (years)	Body weight (g)			Fork length (cm)		
	Upstream	Reservoir	Downstream	Upstream	Reservoir	Downstream
0	--	--	--	--	--	--
1	69±9 (8)	107 (1)	122 (1)	17.9±0.8 (8)	21.3 (1)	21.8 (1)
2	132±11 (13)	242±173 (2)	198±47 (8)	22.4±0.8 (13)	25.1±7.6 (2)	25.1±1.6 (8)
3	277±20 (14)	548±45 (8)	400±32 (10)	28.4±0.6 (14)	36.6±1.3 (9)	33.2±0.6 (10)
4	370±48 (9)	658±77 (17)	357±38 (8)	31.5±1.5 (9)	39.1±1.4 (17)	31.9±1.2 (8)
5	530±38 (13)	523±85 (4)	562±20 (5)	35.2±0.9 (13)	36.4±2.4 (4)	37.9±0.5 (5)
6	425±105 (2)	2396 (1)	626±96 (2)	34.3±2.0 (2)	55.0 (1)	40.2±0.1 (2)
7	677±105 (4)	--	--	39.6±1.9 (4)	--	--