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• Watershed Restoration • Aquatic Science

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Slocan River Rainbow Trout Population Assessment - 2000

Prepared for

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EXECUTIVE SUMMARY

An underwater census of the rainbow trout population at five index sites was conducted on the Slocan River in August 2000 to compare abundance with previous surveys completed since 1985. An underwater census of rainbow trout was also conducted on the Little Slocan River in July. Water temperatures were monitored at five sites in the Slocan basin downstream of Slocan Lake from July through September 2000 to assess potential impacts on trout due to recent documentation of summer maxima exceeding the range of upper temperature optima. Over the last two years, mean juvenile trout numbers have shown continued improvement at three of the lower four index sites however, mean sub-adult and adult trout numbers have declined at all four lower sites. Population trends have remained stable at the upper river index site. A balanced size structure was evident in the upper reaches but highly skewed to juvenile sizes in the mid to lower reaches. The number of catchable (>30 cm) fish in the upper river since 1998 has remained stable at ~90 fish/km but has declined from an average of ~16 to 7 fish/km in the mid to lower river. Daily maximum water temperatures up to ~21 °C were recorded at four monitoring stations however, maximum temperatures above 20 °C were only observed over a period of four days in early August. Differences in habitat complexity and temperature regime between upper and lower sites are suggested to have a direct influence on population trends and size structure. Implications of rainbow trout population resiliency are discussed in regard to reinstatement of the fishery and the risks of implementing catch and release regulations are identified. Recommendations for future fisheries investigations and temperature monitoring as well as habitat restoration requirements are outlined.

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HABITAT
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TRUST FUND

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1.0 Introduction

The status of the rainbow trout population in the Slocan River has been under investigation for more than a decade. A variety of studies have been conducted since the early 1980's to describe the distribution of rainbow trout and identify critical habitats for individual life history stages throughout the watershed. Mainstem and tributary surveys were initially completed to distinguish habitat use while population assessments have been conducted since the mid-1980's to monitor trends in abundance. In the early 1990's a nutrient bio-assay was undertaken to experimentally assess optimum N:P ratios for potential stream-wide fertilization (Oliver 1998a). More recently a radio telemetry study documented critical spawning habitats throughout the drainage; these results have emphasized the importance of mainstem versus tributary habitats (Baxter and Roome 1998). Population monitoring efforts have been a priority since 1993 following implementation of a rainbow trout angling closure in response to previous assessments that demonstrated numbers of fish in serious decline. The population response after two years showed only marginal improvements in overall abundance and age structure, therefore, continuation of the angling closure was recommended in the interest of stock conservation (Oliver 1996). Catch and release options were outlined in a later study (Oliver 1998b). The present study summarizes the results of underwater counts conducted in 2000, compares rainbow trout population trends since the mid-1980's, provides recommendations for future habitat restoration and addresses options for future angling opportunities.

1.1 Study Area

The Slocan River is a fifth order stream located in the southeast interior of British Columbia between Nelson and Castlegar (Fig. 1). The Slocan River drains Slocan Lake and flows south to join the Kootenay River/Brilliant Reservoir at Shoreacres. It is a large meandering river with a mean annual discharge of 89 m^3/s. Mean summer (July1 - September 30) flow is 95 m^3/s (Anon. 1977) and historical mean summer temperature was reported at 15.4 C (Anon. 1977). More recently, mean summer temperatures from July 1 to September 15 have been measured between 18.4 and 20.2 C at various locations throughout the mid to upper reaches (Arndt 1998). The lower reaches of the river (30 km upstream of its confluence with the Kootenay River) are typical of repeated riffle/glide sequences with cobble/rubble/boulder dominated bed materials. Over this same distance, the channel is moderately incised and ranges in width from 40 to 50 m. The upper reaches of the river immediately downstream of Slocan Lake resemble

Figure 1. Location of study area.

small shallow lakes in that the channel is exceptionally wide (up to 400 m) during spring freshet. Below Lemon Creek, the channel averages 50 m in width and is relatively unconfined for approximately 15 km.

From Perry Creek to Winlaw, the bed materials are comparatively smaller in size with sand and silts comprising the stream bottom. The river can be described as a relatively stable system, by virtue of its lake-headed nature, with an abundant water yield (low summer flows recorded at 64% of mean annual discharge). The river has 10 to 12 minor tributaries and one major tributary (Little Slocan River).

Water chemistry analyses indicate the river is oligotrophic. Ambient phosphorus levels are extremely low; always below detection limit (<0.003 $mg \cdot L^{-1}$) by standard wet chemical techniques. Nitrate + nitrite nitrogen levels can exceed 0.080 $mg \cdot L^{-1}$ during winter, however its availability is largely controlled by nutrient dynamics in Slocan Lake in late summer. Levels generally range between 0.020 and 0.030 $mg \cdot L^{-1}$ in early summer and fall below 0.005 $mg \cdot L^{-1}$ by August. Total alkalinity is approximately 42 $mg \cdot L^{-1}$ and total dissolved solids are approximately 50 $mg \cdot L^{-1}$.(BC Environment, file data, Nelson, B.C.).

1.2 Background

The Slocan River supports a wide variety of fish species: rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), mountain whitefish (*Prosopium williamsoni*), northern pikeminnow (*Ptychocheilus oregonensis*), as well as catostomids, cottids and cyprinids. Steelhead (anadromous rainbow), sockeye (*O. nerka*) coho (*O. kisutch*) and chinook (*O. tshawytscha*) can no longer access this system. The annual return of anadromous spawners was eliminated in 1936 with the completion of the Grand Coulee Dam in Washington State.

In 1986, the Fisheries Program of BC Environment (Kootenay Region) began studies to document the status of the rainbow trout population and fish habitat in the Slocan River drainage. To date, specific activities have included population estimates, habitat assessments, special regulations, stocking, tributary access improvement, gravel placement in spawning tributaries, a nutrient bio-assay and an assessment of mainstem spawning areas. Despite these efforts, angler catch did not improve. The lack of success was attributed to several factors, however, habitat limitations and low angler compliance with regulations were likely the most important. The continual decline in numbers during the early 1990's forced the closure of the river to rainbow trout angling in 1994 in the interest of stock conservation and as an initial step in population recovery.

The results of an underwater census in 1996 suggested a modest improvement in juvenile numbers without any improvement in adult numbers. The recommendation to continue the closure for an additional two years was suggested to improve the overall age structure, facilitate further recruitment and improve the number of catchable fish over the minimum size restriction (30 cm). A second assessment was conducted in 1998 to compare population trends with the 1996 survey; a fifth index site was included in the upper reaches in 1998 to provide an evaluation of the current population size and size structure associated with areas known to support extensive mainstem spawning. Overall, significant improvements in mean juvenile numbers were observed between years at the four original index sites however, marginal improvements in mean sub-adult and adult numbers were only evident between years at each of the four sites. A balanced age structure was evident in the upper reaches but highly skewed to juvenile sizes in the mid to lower reaches. The number of catchable fish (>30 cm) in the upper river approached 84 fish/km but did not exceed 25 fish/km in the mid to lower river. The low abundance of catchable fish did not warrant re-opening of the fishery to harvest and the recommendation to maintain the present closure was promoted. GG Oliver and Associates, Environmental Science was retained by Columbia Kootenay Fisheries Renewal Partnership with support from the Slocan River Wilderness Association and the Fish in the River Group in 2000 to provide an assessment of the rainbow population following a further two years of fishery closure and to recommend future management options.

1.3 Objectives

The objectives of this study have been expanded beyond population trend monitoring, owing to recent documentation of water temperature maxima in summer (Arndt 1998; 1999). The intent of this study was to complete replicate counts by underwater observation at five index sites (Lemon Creek, Winlaw, Passmore, Slocan Park and Crescent Valley) in early July and late August. A comparison of counts prior to (July) and during (August) the period of temperature maxima was further intended to determine if temperature extremes were in fact responsible for within-season differences in fish distribution. A concern was raised that the low counts observed in late summer of 1996 and 1998 may have been an artifact of water temperature resulting from changes in rainbow trout distribution that forced individuals to seek out temperature refugia outside of established index sites; differences that would otherwise mask potential population recovery and under-estimate actual numbers. A second objective was to monitor summer water temperature at various locations throughout the basin to further document ambient conditions that could potentially induce rainbow trout re-distribution and affect long-term survival. The purpose of this study is to analyze index counts at selected sites and summarize population trends since the mid-1980's. The study will also evaluate temperature effects on current population trends. As a final objective, the report will outline habitat concerns that may also effect present adult numbers as well as consider the risks of re-opening the fishery.

2.0 Methods

2.1 Underwater counts

Snorkel counts were scheduled for the last week of July and August 2000 to evaluate differences in seasonal distribution. High turbidity associated with ambient flow during the July survey hampered visibility in the Slocan River and decreased the accuracy of underwater counts. Mainstem river counts were abandoned after an initial pass at one of the index sites. A 3 km section on the lower Little Slocan River (Varney property to lower bridge crossing) was substituted to provide an estimate of tributary abundance (refer to Fig. 1).

Population estimates were obtained by underwater census using 5 counting lanes stratified into shore, near-shore and mid-channel zones after Slaney and Martin (1987). Four long-term index sites were assessed including a 2.3 km section of river downstream from the Winlaw bridge, a 2.8 km section between the old Vallican bridge to the Passmore bridge, a 3.4 km section immediately above and downstream of the Slocan Park bridge, and a 2.7 km section immediately above and downstream of the Crescent Valley bridge (refer to Fig. 1). A fifth site extending 1.5 km downstream of the Lemon Creek confluence was added in 1998 to assess upper river rainbow trout status. Population assessments were completed during the last week of August 2000 under low summer flow conditions. All counts at individual sites were replicated twice. Rainbow trout were visually grouped in size categories from 0-99, 100-199, 200-299, 300-399, and 400 + mm. Counts were completed using a pool of seven observers, five at a time. River wetted widths were estimated with a Bushnell Compact 600 laser rangefinder. Precision of the instrument was evaluated against lineal distances measured with a 30 m tape.

Population estimates include expanded counts for the mid-channel lanes, however, total numbers are uncorrected; mark and recapture estimates have never been undertaken to calibrate underwater observation efficiencies in the Slocan basin. Expanded counts were obtained by applying mean mid-channel counts to unobserved lane widths relative to the wetted channel cross-section however, full expansion was avoided where 1) unsuitable habitat conditions in mid-channel areas would otherwise contribute to over-estimation of numbers (e.g. long slow, shallow glides devoid of cover or typical of fine sediment/silt deposition) or 2) narrow sections of the channel that resulted in complete coverage of the cross-sectional area. Habitat use interpretations based on repeated evaluations over several years may provide estimates that could be considered conservative but expansion procedures were consistent between yearly comparisons.

Data were analyzed using Systat Version 5 (Wilkinson et al 1992). Analysis of variance (ANOVA) was used to compare mean counts between sites. A factorial analysis of variance was used to compare means between years, index sites and fish size. A probability of $p<0.05$ was considered significant and a plot of residuals was inspected for homogeneity of variance. Post hoc tests employed Bonferroni pairwise comparisons for each site or size category. All data were initially log transformed to avoid departures from assumptions of anova (normality, additivity). A transformation of the type log(Y+1) was used to avoid difficulties associated with zero counts.

2.2 Temperature records

Onset Stowaway Tidbit™ data loggers were used to collect continuous water temperatures (hourly intervals) at four stations in the Slocan River (Slocan Lake outlet, Slocan River upstream of Lemon Creek, Slocan River at Winlaw, and Slocan River at Slocan Park) and one station in the Little Slocan River (0.5 km downstream of Koch Creek) from July 9 to September 30, 2000 (refer to Fig. 1). Two other stations on the Slocan River (Crescent Valley and downstream of Lemon Creek) and one station on the Little Slocan River (upstream of the Slocan River confluence) were monitored with Hobo Temp™ data loggers by the Columbia Basin Fish and Wildlife Compensation Program; continuous water temperatures were monitored from July 12 to September 5, 2000 to capture summer maxima. These data are also included in the present study. Each data logger was calibrated against a laboratory grade thermometer to account for individual logger accuracy; mean, minimum and maximum temperature records were adjusted accordingly.

Data loggers used in the present study became dewatered in early August owing to ambient river height in early July that prevented deployment of loggers to deeper portions of the channel. Under continuously declining water levels through August, each mainstem Slocan River data logger eventually became exposed to the atmosphere. Missing water temperature data for Slocan outlet, Winlaw and Slocan Park were predicted from ambient air temperatures using a simple method after Stoneman and Jones (1996). In this instance, the relationship between daily maximum air temperature and daily maximum water temperature at the Crescent Valley site was used to predict daily maximum water temperatures at the three other mainstem stations based on site-specific air temperature records collected over the period of atmospheric exposure. The most extensive air temperature records (August 9 to September 5, 2000) from the Winlaw site were initially used to establish the air/water relationship at Crescent Valley. Water temperatures collected at 16:30 hrs were used to estimate daily maxima in the Slocan River. The relationship is described by the equation WATER=0.337(AIR) + 10.258 (R^2=0.78). The regression was highly significant ($P \leq 0.001$) and a plot of residuals was homoscedastic.

3.0 Results

3.1 Little Slocan River fish abundance and size structure

Underwater counts of rainbow trout were estimated at 94 fish / km in the lower Little Slocan River during the late July census (Fig. 2; replicate counts are provided in Appendix 1). The highest numbers (~50%) of fish were enumerated in the juvenile (9-20 cm) size class. A much lower abundance of fry (18%) and sub-adult fish (21%) were encountered in the lower reach; the lowest abundance was observed for the adult component (~5%). The number of fish observed is lower than expected given the high degree of habitat complexity (deep pool, large woody debris cover) presently available.

In addition to rainbow trout, 2 adult bull trout ranging in size from 30-50+ cm were also observed in the Little Slocan River section (refer to Appendix 1).

3.2 Slocan River rainbow fish abundance and size structure at index sites

The largest numbers of rainbow trout were observed at the Lemon Creek (LC) site with 468 fish / km enumerated (Fig. 3; replicate counts are provided in Appendix 1). Less than half that number (n=176/km) were observed at Winlaw (WIN) with about one quarter as many fish observed at Slocan Park (SP; 133/km). The lowest numbers of fish were enumerated at Passmore (PAS; n=106/km) and Crescent Valley (CV; n=59/km). A high degree of variation between replicate counts was evident for yearling and under-yearling fish at Lemon Creek, Winlaw, Passmore and Slocan Park sites and may be related to differences in observer experience or differences in fish distribution relative to time of day (i.e. a.m. vs p.m.). The lowest variation between replicate counts was evident at Crescent Valley; low overall fish abundance likely affected this outcome. The size structure of the population was highly contrasted at index sites; representative fish at the Lemon Creek site displayed a more balanced size structure than the other four sites. The largest mean number of yearling fish was also observed at this site. With the exception of the Crescent Valley site, under-yearling numbers were the highest of all size classes of fish encountered at Winlaw, Passmore and Slocan Park. The lowest size classes at the lower four index sites were represented by the adult component (30-39, 40+). Overall, mean numbers of fish at the Lemon Creek site were significantly different than the Passmore site (Bonferroni; $p \leq 0.029$) and the Crescent Valley site (Bonferroni; $p \leq 0.008$).

The number of adult fish exceeding 30 cm in 2000 was highly contrasted between sites as well (Fig. 4). The highest number of adult fish (84/km) was observed at the Lemon Creek site, which comprised about 20% of the total number. The lower four index sites had considerably lower numbers of adult fish; the highest percentage was observed at Crescent Valley (12%) followed by Passmore (9%), Winlaw (4%) and Slocan Park (2%).

In addition to rainbow trout, bull trout were also observed at two mainstem index sites during the August census. The majority of bull trout (15) were observed in the Slocan River at the confluence of Lemon Creek and ranged in size from 30 – 60+ cm. A single individual was also observed in the Winlaw section and was estimated between 30-40 cm in length. Since 1998, bull trout have only been observed in the confluence pool at the mouth of Lemon Creek; snorkel investigations prior to 1998 have failed to observe any bull trout elsewhere in the Slocan River.

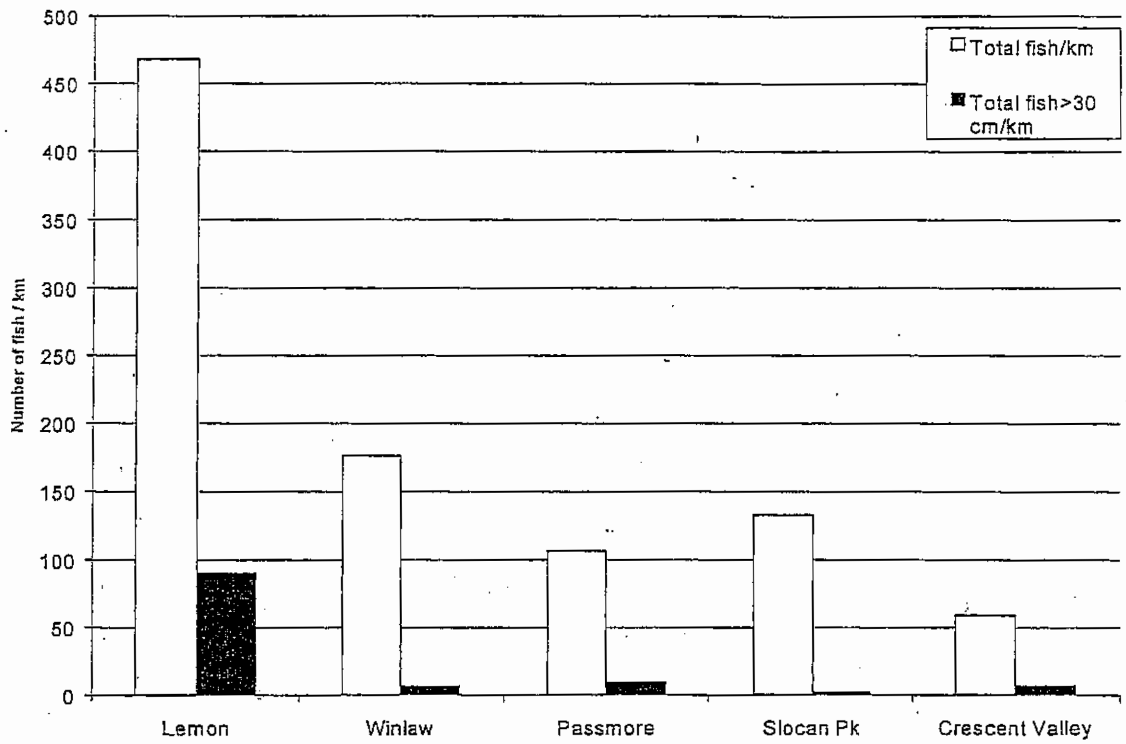

Figure 4. A comparison of total fish and total catchable fish at the five index sites.

3.2 Between and within year comparisons

A comparison of mean trout numbers and size at the five index sites between 1998 and 2000 indicates two important differences: with the exception of the Crescent Valley site, under-yearling and over-yearling numbers have increased while sub-adult and adult numbers have generally decreased (Fig. 5). Most notably, the 30-39 cm size class was significantly lower in number during 2000 (year by size interaction, $p \leq 0.001$; Bonferonni, $p \leq 0.047$). Numbers have continued to decline in 2000 for each size category at Crescent Valley.

Differences in number of fish between size categories and sites in 2000 were also evident. For the 0-9 cm size class, Lemon Creek had significantly higher numbers than Crescent Valley (site by size interaction, $p \leq 0.001$; Bonferonni, $p \leq 0.001$) whereas for the 10-19 cm category, Lemon Creek had significantly higher numbers than Slocan Park, Passmore and Crescent Valley sites (Bonferonni; $p \leq 0.012$). Significantly lower numbers between Lemon Creek and all other sites for the 20-29, 30-39 and 40+ cm size categories were also evident (Bonferonni; $p \leq 0.017$). Among the lower four index sites, significantly higher numbers of fry were only observed at Winlaw for comparisons between Winlaw and Crescent Valley sites (Bonferonni; $p \leq 0.001$).

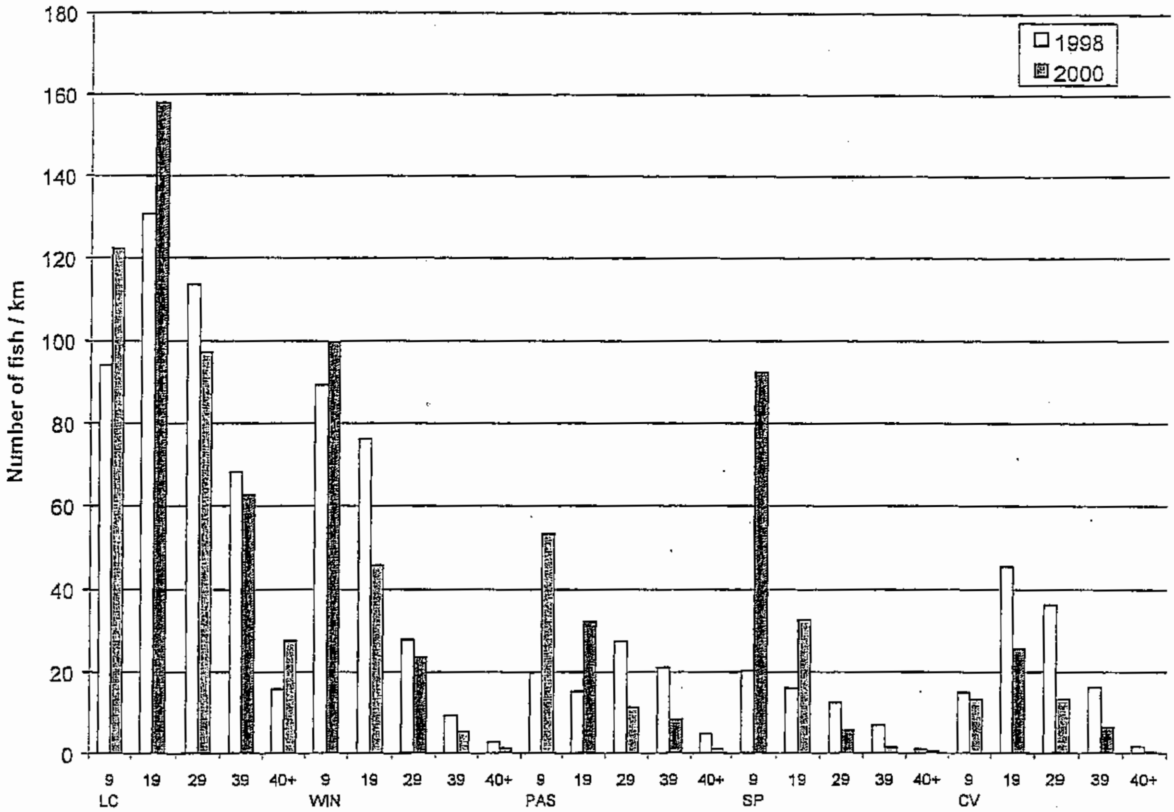

Figure 5. A comparison of mean rainbow trout number / km and size categories at five index sites on the Slocan River between 1998 and 2000.

3.3 Rainbow trout population trends

The most extensive trend information exists for the lower four index sites that date back as early as 1985 (Fig. 6); total numbers of fish have more-less stabilized at Winlaw and Passmore sites whereas total numbers at Slocan Park demonstrate an increasing trend and total numbers at Crescent valley show a decreasing trend. Total numbers of fish at the Lemon Creek site are similarly stable over the last two years. The number of catchable-size trout (i.e. >30 cm) at each of the lower four sites, however, display a decreasing trend over the last two years (Fig. 7). With the exception of the Winlaw site, the lowermost three sites have shown a >50% reduction in the adult population in comparison to the 1998 counts that previously included the highest numbers over the recent period of record. The reduction in number at Passmore, Slocan Park and Crescent Valley certainly contrasts with the stable number of fish observed at the Lemon Creek site.

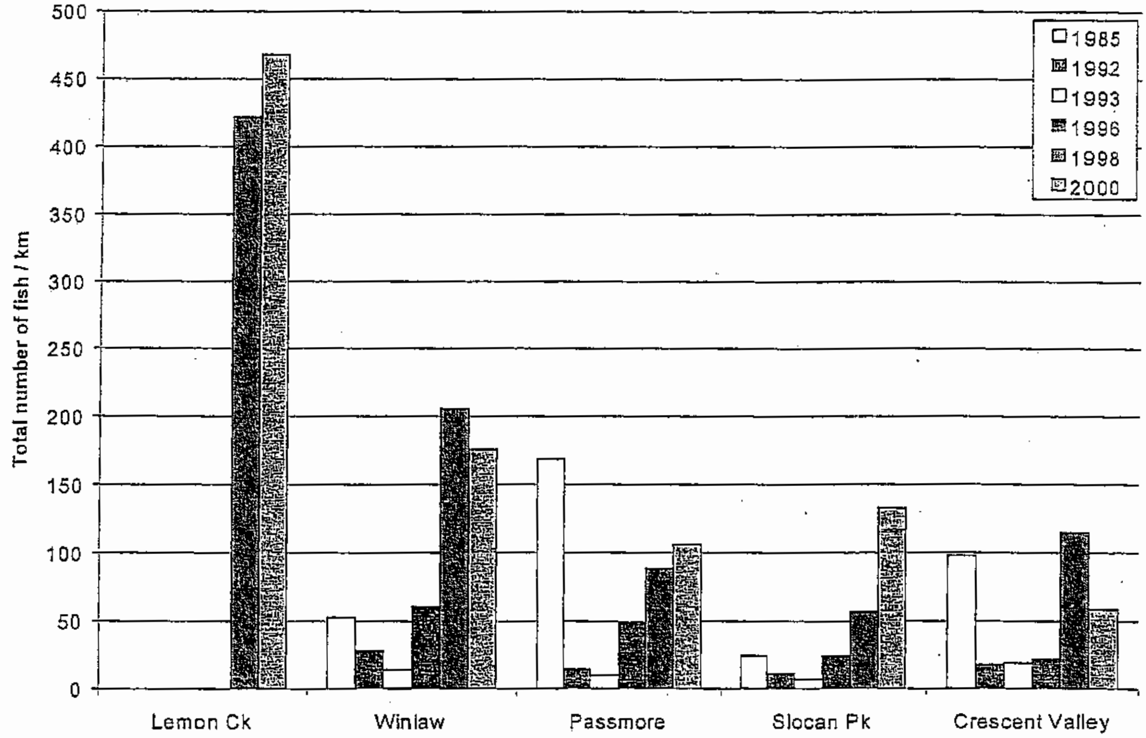

Figure 6. Slocan River rainbow trout total population trends at selected sites from 1985 to present.

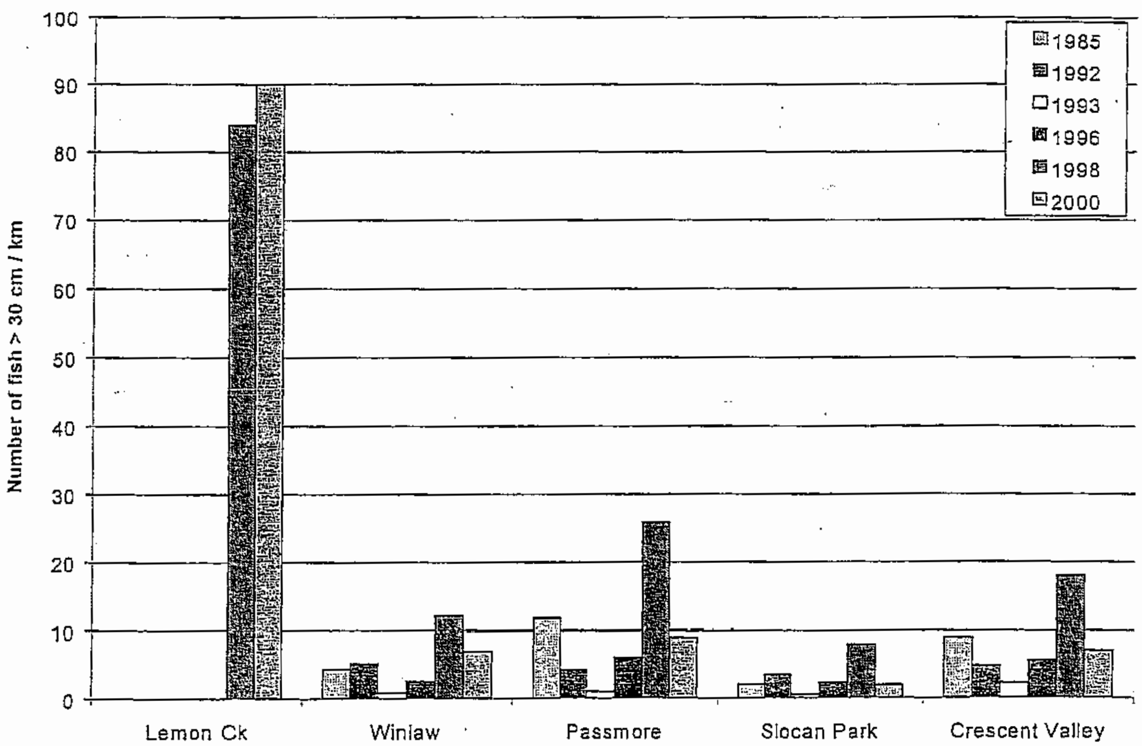

Figure 7. Slocan River adult rainbow trout (>30 cm) population trends at selected sites from 1985 to present.

3.3 Continuous water temperature records

3.3.1 Slocan River

Daily mean and maximum water temperatures at designated sites in the Slocan River were highly variable over the period of monitoring from July to September 2000 (Figs. 8 and 9; mean, minimum and maximum daily values for individual sites are provided in Appendix 2). Daily mean temperatures increased from a low of ~10.4 to 12.6 °C on July 14 to a high of ~18.5 to 19.9 °C on August 7. Daily mean temperatures varied from ~1.5 to 2.2 °C between the six sites. Up until the middle of August, daily mean temperatures at the outlet of Slocan Lake were generally the warmest and the station downstream of Lemon Creek was generally the coolest. Examples of exceptionally cool temperatures during a cooling trend are reflected by the lowest mean daily temperatures at the lake outlet. A cooler outflow may have occurred in combination with prevailing meteorological conditions affecting lake surface temperatures (e.g. cloud cover, strong wind activity). Over the balance of the monitoring period, mean daily temperatures

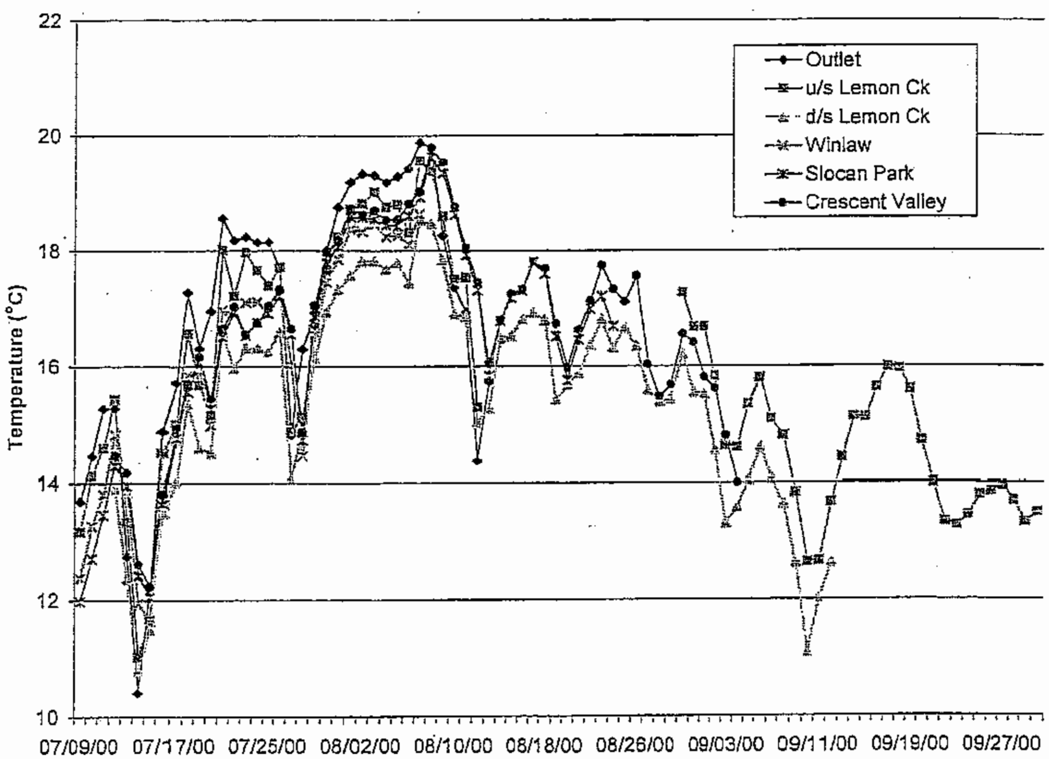

Figure 8. Daily mean water temperature at six sites in the Slocan River basin from July through September 2000.

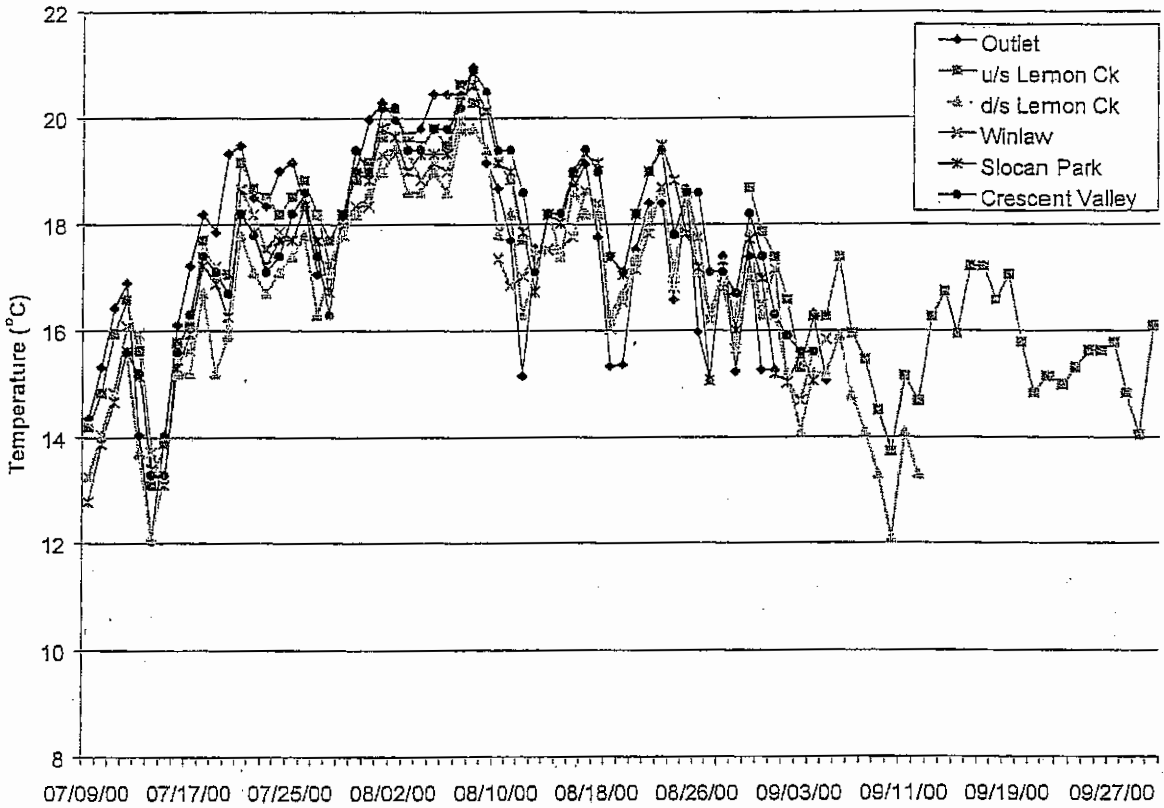

Figure 9. Daily maximum water temperature at six sites in the Slocan River basin from July through September 2000.

continued to oscillate with the warmest temperatures reported for the Slocan Park and Crescent Valley sites; the lower Lemon Creek station followed the same pattern but remained up to 1 °C cooler. By September 10, daily mean water temperature at the lower Lemon Creek site declined to ~11.1 °C while the upper Lemon Creek station declined to ~ 12.6 °C. Oscillations leading to a warming trend were again evident until the end of September at the upper Lemon Creek station where mean daily temperature increased to ~13.5 °C.

Daily maximum water temperatures at the six stations followed the same pattern of warming and cooling as illustrated for daily mean temperatures; daily maxima were highest at the lake outlet and coolest at the lower Lemon Creek site. Daily maximum temperature peaked near the end of the first week of August, reaching a high of ~21 °C at the lake outlet. The remainder of the downstream stations ranged ~ 0.5 to 1 °C cooler during the initial warming trend. Maximum temperatures exceeding 20 °C however, only extended over a period of 4 d during the first week of August. Beyond the timing of summer maxima (after August 8), daily maximum temperatures continued to oscillate through periods of cooling and warming; Upper Lemon

Creek, Slocan Park and Crescent Valley sites represented the warmest daily maxima and the Lower Lemon Creek and Winlaw sites represented the coolest daily maxima. Over the remaining weeks of August, daily maxima never exceeded 19.3 °C and differences in maximum temperature between sites ranged from ~0.8 to 1.6 °C. By September 10, the daily maximum temperature at the Upper and Lower Lemon Creek sites declined to 13.7 and 12.1 °C, respectively. At the end of September, daily maxima at the Upper Lemon Creek site reached 16.1 °C during a final warming trend.

Predicted water temperature estimates from air temperature records for Winlaw (after August 8) and Slocan Park (after August 24) sites follow the patterns established from continuous records for both Crescent Valley and Lower Lemon Creek sites and generally fall within the range of expected values. Predicted values for Slocan outlet (after August 12) suggest that water temperatures were among the coolest during cooling trends observed throughout August. Daily maximum lows from August 19 - 31 are consistent with the water temperature measured at the outlet station on August 12. These data provide some insight as to the importance of low elevation, large headwater lakes and air/water temperature dynamics at the lake surface that strongly influence the downstream temperature regime of the attendant drainage.

3.3.2 Little Slocan River

Daily mean and maximum temperatures in the Little Slocan River displayed a similar pattern of temperature oscillation as demonstrated in the Slocan River, however, the degree of fluctuation during warming and cooling trends was less dramatic (Figs. 10 and 11; mean, minimum and maximum daily temperatures of individual stations are provided in Appendix 2). Daily mean temperatures at the lower station rose from a low of ~11 °C on July 12 to a high of ~17 °C on August 8 and declined to ~13 °C at the end of the month. Differences in daily mean temperature between the upper and lower stations on the Little Slocan River generally varied from ~0.5 to 1.0 °C over the period of record. The upper station remained consistently cooler than the lower station owing to the cold influx of Koch Creek located immediately upstream of the monitoring site. Of particular interest, the lower station warmed more quickly and cooled more rapidly than the upper station. As a consequence, temperature oscillations during warming and cooling trends at the upper station generally lagged about 1 d behind temperature change at the lower station. A warming trend during the middle two weeks of September was followed by a sharp decline in daily mean temperature during the third week; mean temperature stabilized at ~9.5 °C by months end.

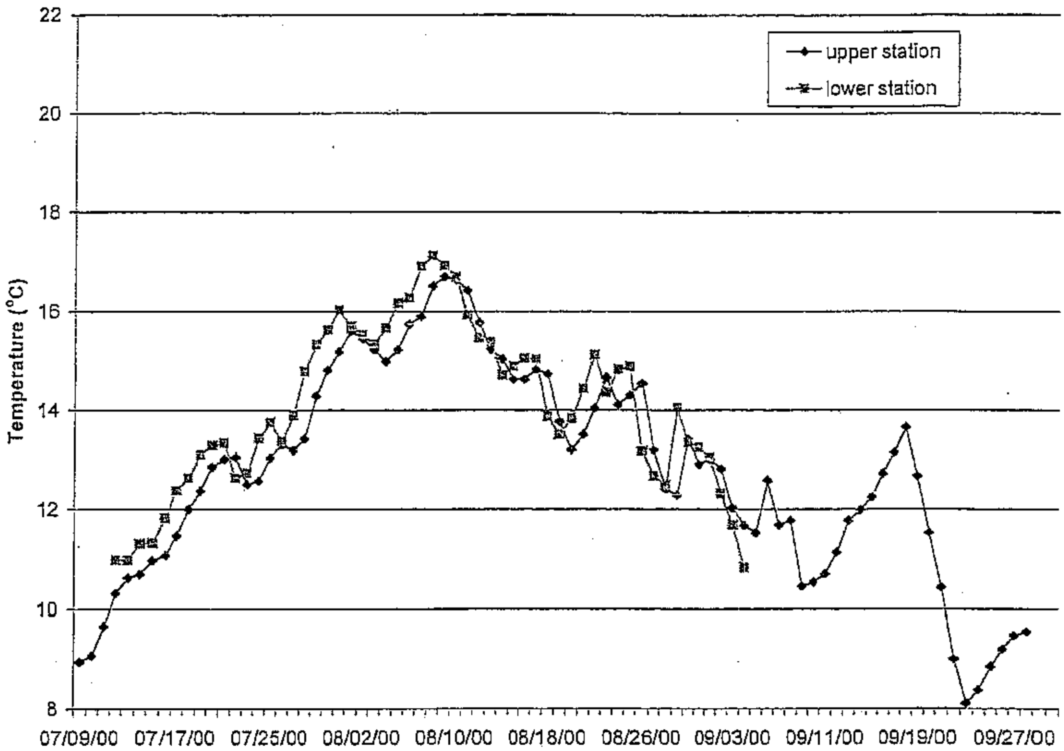

Figure 10. Daily mean water temperature at two sites in the Little Slocan River from July through September 2000.

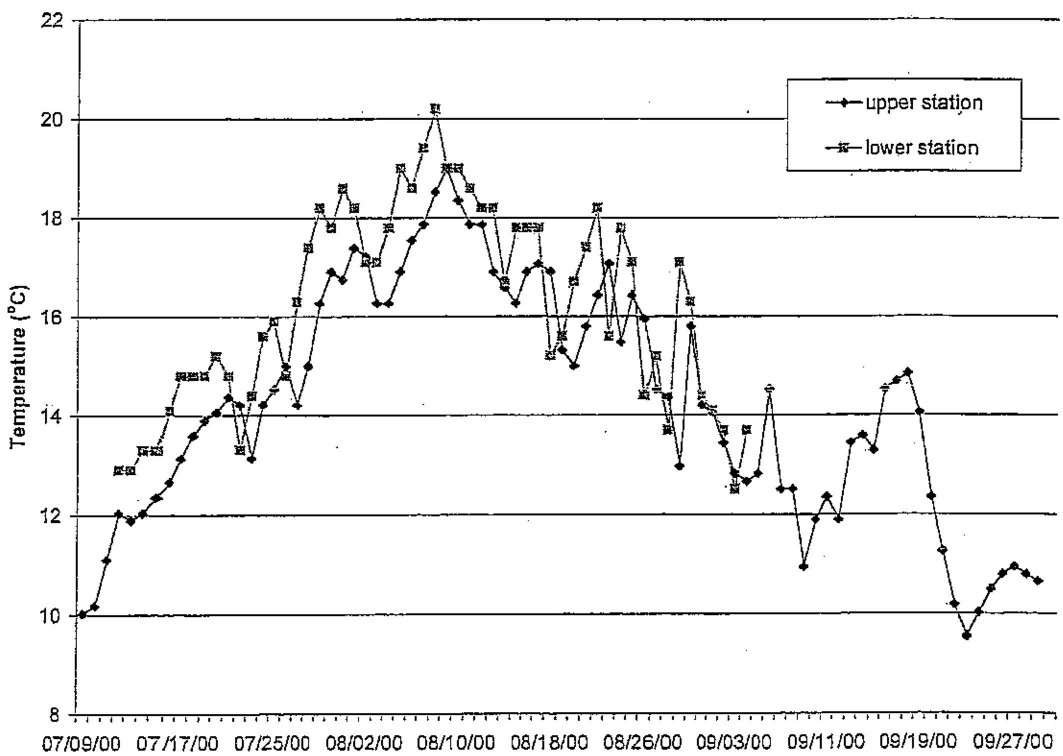

Figure 11. Daily maximum water temperature at two sites in the Little Slocan River from July through September 2000.

Daily maximum temperatures at the lower station increased from ~13 °C on July 12 to ~20 °C on August 8 and decreased to ~14.5 °C at the end of the month. Daily maximum temperatures at the upper station varied 1-2 °C cooler than the lower station and reached its summer maxima at ~19 °C on August 9; an extreme temperature difference of ~4 °C between stations was observed on August 29. Differences in temperature response between the two stations during warming and cooling trends followed the same pattern observed for daily mean temperature with a similar lag period of about 1 d. The period exceeding 20 °C in August at the lower station totaled one day.

4.0 Discussion

The contrast in rainbow trout abundance between the upper and the mid to lower reaches of the Slocan River after seven years of angling closure indicates a continued failure of survival of older age classes in the lower basin. Using the upper river as a benchmark for fish capability, the mid to lower river remains from 13 to 38% of potential capacity and the age structure of the population remains highly skewed to juvenile age classes. Present environmental conditions (habitat quality, temperature) appear more suitable in the upper river below Lemon Creek than other downstream areas. It is important to recognize that a major slump in the spring of 2000 at Passmore, B.C. caused a large volume of sediment to enter the river. Fine sediment deposition in interstitial areas of the streambed was most evident at Crescent Valley during the late summer snorkel survey. It remains uncertain whether the effects of elevated suspended sediment during its downstream displacement impacted fish survival, or the deposition of fine sediment on bed materials has since impacted benthic production, that may otherwise explain the lower abundance/absence of fish in the lower basin.

A review of mainstem fry abundance over the last two years has clearly shown that late summer fry numbers in the middle reaches (e.g., Winlaw during 1998 and 2000; Slocan Park during 2000) of the Slocan River are comparable to late summer fry numbers observed in the upper reaches (e.g., Lemon Creek during 1998 and 2000). Notwithstanding these similarities, stock recruitment leading to a balanced age structure in the rainbow trout population is only typical of the upper river and characteristically lacking in the mid to lower river. Differences in habitat quality between these areas have been discussed in an earlier report (Oliver 1998b). The lower habitat quality in downstream reaches likely contributes to a lower survival of juvenile fish seeking limited lateral habitat during the transition from juvenile to adult life stage. In regard to short-term trends since the mid-1980's, the successful recruitment to older age-classes remains a nagging bottleneck to stock recovery in the mid to lower reaches.

Differences in trout cover attributes aside, the prevailing temperature regime in the Slocan River may be equally problematic to stock recruitment, if not more. Salmonids have evolved to complete certain life history functions within the range of ambient temperatures provided in nature. Individual species occupy aquatic environments with thermal regimes that vary daily, seasonally, annually and spatially; each species has demonstrated well-defined temperature preferences and tolerances (Bjornn and Reiser 1991). The majority of juvenile salmonids display an optimum growth zone between 10 and 15 °C while positive growth is maintained from ~4-19 °C (Armour 1990). Temperature extremes as high as 22-24 °C and as low as 0 °C have been considered life-threatening or shown to alter growth due to differences in metabolic efficiencies at high or low temperatures (McCullough 1999). The upper incipient lethal temperature for rainbow trout occurs at ~26 °C (examples cited in Oliver 2000).

In nature, diurnal temperature fluctuations are generally greatest under hot summer, low flow conditions. Temperature shifts of 15 °C have been reported in small streams of low volume and limited riparian cover without high juvenile mortality, if maximum daily temperatures approaching upper incipient lethal levels are short-lived and temperatures are restored within the optimal range for growth (Bjornn and Reiser 1991). Under high temperature extremes however, juvenile salmonids become lethargic, are unable to defend individual territories and become more vulnerable to predation (McCullough 1999). Similarly, experimental evidence also suggests that temperature shifts of 15-18 °C can be tolerated by most fish provided that exposure temperatures fall within the tolerance range of individual species (Hokanson et al. 1977).

In general, adult salmonids show a preference for lower water temperature than juveniles of the same species and adult fish are generally much more sensitive to high temperature extremes than juveniles (McCauley and Higgins cited in Spigarelli et al. 1983). The results of ten rainbow trout temperature preference studies have demonstrated that preferenda for adults and juveniles is 13.5 and 19 °C, respectively (Reynolds and Casterlin 1979). Temperature preferentia may be related to the heat exchange/body size relationship wherein a slower rate of heat transfer occurs in larger fish owing to their larger body volume. Therefore, when ambient temperatures exceed those for optimum growth, the period of exposure during a diurnal cycle is lengthened due to a longer period of equilibration.

With respect to water temperatures observed in the Slocan River during 2000, the summer regime cannot be considered as an extreme event. Prevailing water temperatures up to ~20 °C in 2000 were likely related to a cooling atmospheric trend during the last three weeks of August and above average run-off during July and August (Environment Canada website; weather and flow level records (STN 08NJ013), July and August 2000). Much less favourable water temperatures for rainbow trout have been reported in previous studies however, where daily maxima have ranged from 22 – 24 °C during late July, August and early September 1998 (Arndt 1999). The prevailing summer water temperature regime in the middle reaches of the Slocan River in 1998 provides an example of temperature extremes possible during a hot summer typical of below average streamflow. The most relevant concern however, is the fact that the daily maximum temperature exceeded 20 °C on 58 occasions (Arndt 1999). Moreover, the daily mean temperature exceeded 20 °C on 27 occasions keeping water temperature consistently high. While variable rates of temperature change together with high endpoint values have demonstrated both sub-lethal and lethal effects, it is important to recognize the potential effects of a cyclic regime of diel fluctuations that extend beyond temperature tolerance ranges over a period of weeks. To this end, the thermal exposure history may induce a cumulative response that ends in mortality where fish are subjected to unusual stress loading (DeHart 1975 and Golden 1976 cited in McCullough 1999). The higher metabolic costs that preclude growth rates from achieving 80% of maximum growth can induce conditions that reduce disease resistance and increase mortality (Armour 1990). Similarly, where body fat in winter declines to <2.2%, winter energy demands may cause mortality or seriously effect future reproductive performance (McCullough 1999). The decline in the number of sub-adult and adult rainbow trout in the middle and lower reaches between 1998 and 2000 may therefore, be related to the effects of extreme temperature as well as the duration of extremes witnessed in 1998. The observation of kelted fish in poor condition at the end of the summer growing season in 1998 is further testimony to the suspected interaction between high temperature and metabolic requirements of fish under extreme conditions (Oliver 1998b). Future investigations should compare growth rates and condition factor for individual age classes to test potential temperature effects on growth inhibition between upstream and downstream index sites. Growth rate has been used as an index of environmental condition and can be used as a tool to predict later fish survival (Rodgers and Griffiths 1983). A comparison of growth increments between upstream and downstream locations by conventional methods (scales, fin rays) would be instructive to demonstrate potential differences in growth that may be attributed to differences in rearing environments (i.e. potential temperature effects). The direct comparison of condition factor (length, live weight) of rainbow trout between sites would similarly provide a measure of performance of individual age classes.

In addition to the growth study, future investigations should include an examination of a physiological stress response in representative age classes that may arise from sub-optimal environmental conditions. Examination of the blood chemistry of individual fish has been used previously to detect hormonal responses to stress that manifest in changes in corticosteroid, and blood glucose or ion levels (Barton et al. 1985; Adams 1990). Alternatively, changes in the number of circulating leucocytes can be dramatic in response to acute or chronic stress (Ainsworth 1991). An analysis of fish plasma may be instructive to discern if temperature-induced physiological stress may be responsible for potential growth inhibition or chronic sub-lethal factors that may lead to eventual mortality and explain the current lack of response in overall population recovery. The inclusion of inter-renal nuclear histology in kidney tissue is highly recommended as this analysis can show direct linkage to temperature-induced stress in fish (Tillman Benfey, Department of Biology, University of New Brunswick, Fredericton, N.B.; pers. comm.). The analysis, however, will require a representative number of fish from each age class to be sacrificed.

Future proactive measures to address current habitat and temperature issues will necessarily include the restoration of lateral cover to the channel. The installation of large woody debris structures is intended to fulfill present habitat limitations for juvenile and sub-adult age classes; treatments will also provide suitable shade to offset the lack of canopy cover and margin habitat. A test of the efficacy of restoration efforts will require large-scale treatments to ensure that the existing population is not simply re-distributed to a few treatment sites. The broad application (i.e., over 1-2 km of channel) of large woody debris to two index sites would provide an opportunity to evaluate the utility of habitat restoration structures to improve long-term survival and population recovery. Recommended areas include index sites at Winlaw and Slocan Park. Further habitat complexing would complement areas known to support mainstem spawning and facilitate stock recruitment (i.e., both an increase in the amount of available habitat and over-stream shading).

In consideration of the population response over the last seven years, the opportunity to re-open the fishery remains dismal. A number of factors seem imminent that have a large bearing on future fishery reinstatement. With the exception of the upper river, biomass remains low to moderate and the stock appears to be non-resilient in the mid to lower reaches. Juvenile survival is moderate to high but the high natural mortality for older age-groups prevents the development of a balanced age structure. Consequently, recruitment remains low to moderate despite a relatively young age of first maturity (age 3 for males, age 4 for females). To this end, the existing population would be highly vulnerable to exploitation given the current age structure. Open to catch and release only, individual fish would be placed at high risk owing to the high probability of post-release mortality associated with high ambient water temperature. From a wild stock management perspective, the low degree of resiliency after seven years of closure strongly suggests that density independent factors (i.e., temperature effects during hot summers combined with below average streamflow) may impose environmental conditions that directly (sub-lethal effects leading to mortality) or indirectly (juvenile mortality due to predation or lack of transitional habitat) impair the recruitment of older age classes of trout. If catch and release is considered, then, a summer closure from mid July to mid September would likely be required to minimize further losses due to anticipated temperature-induced angling mortality.

Temperature refugia in the basin are restricted to mainstem habitats downstream of coldwater tributaries or other groundwater sources. Tributary refugia provide alternate summer habitats but small tributary size for the majority of attendant streams may preclude their utilization for older fish. In the larger systems such as the Little Slocan River, individuals may be forced to ascend upstream locals that have cold headwater tributary inflows (e.g., Koch Ck). The apparent low to moderate rainbow trout biomass in the lower Little Slocan River suggests that the stream may be susceptible to similar temperature perturbations consistent with the mainstem river. In consideration of the anticipated low run-off in 2001, a monitoring program should resume at the previously designated sites to track background water temperature and complement the growth study. Unfortunately, efforts to determine whether late summer water temperature affects trout distribution (i.e., fish seeking thermal refugia) were compromised by turbidity levels that did not permit underwater censusing in July. In future, it would be desirable to time July counts during a period of below average run-off. Improved visibility under lower flow conditions might provide useful insights into mid summer distribution prior to the onset of maximum stream temperature.

As a final note, the recent increase in bull trout numbers in the main river is encouraging however, their distribution may be severely limited owing to their dependency on cool temperatures. The deep pool habitat at the confluence of Lemon Creek should be regarded as critical habitat in light of its current use as a staging area prior to entry into Lemon Creek for spawning purposes. Permanent closure of the pool should be considered if the fishery is re-opened.

5.0 Literature Cited

Adams, S.M. 1990. Status and use of biological indicators for evaluating the effects of stress on fish. American Fisheries Society Symposium 8:1-8.

Ainsworth, A.J., C. Dexiang and P.R. Waterstrat. 1991. Changes in peripheral leukocyte percentages and function of neutrophils in stressed channel catfish. Journal of Aquatic Animal Health 3:41-47.

Anonymous. 1977. Historical Streamflow Summary. British Columbia. Inland Waters Directorate. Water Survey of Canada. Vancouver, British Columbia.

Anonymous. 1977. Water temperatures. British Columbia and Yukon Territory. Inland Waters Directorate. Water Survey of Canada. Vancouver, British Columbia, Vol. 4.

Armour, C.L. 1990. Guidance for evaluating and recommending temperature regimes to protect fish. U.S. Fish and Wildlife Service. Fort Collins. Biological Report 90(22). 13 p.

Arndt, S.K.A. 1998. Slocan and Salmo rivers temperature monitoring-summer 1997. Columbia Basin Fish and Wildlife Compensation Program. Nelson, B.C. 19 p.

Arndt, S.K.A. 1999. Slocan River summer temperatures in 1997 and 1998: implications for rainbow trout distribution and production. Columbia Basin Fish and Wildlife Compensation Program. Nelson, B.C. 30 p + appnd.

Barton, B.A., C.B. Shreck and L.A. Sigismondi. 1986. Multiple acute disturbances evoke cumulative physiological stress responses in juvenile chinook salmon. Trans. Am. Fish. Soc.115:245-251.

Baxter, J.S. and R. Roome. 1998. Migratory, overwintering and spawning behaviour of rainbow trout (*Oncorhynchus mykiss*) in the Slocan River, British Columbia. Prepared for Ministry of Environment, Lands and Parks, Nelson, B.C. Prepared by James Baxter and Robyn Roome Fisheries Consultants, Nelson, B.C. 24 p + appnds.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

DeHart, D.A. 1975. Resistance of three freshwater fishes to fluctuating thermal environments. M.S. Thesis. Oregon State University, Corvallis, Oregon.

Golden, J.T. 1976. Lethal temperatures for coastal cutthroat trout under fluctuating temperature regimes. Federal Aid Progress Reports, Fisheries. Oregon Department of Fish and Wildlife. 14 p.

Hokanson, K.E.F., C.F. Kleiner and T.W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri*. J. Fish. Res. Bd. Can. 34(5):639-648.

McCullough, D.A. 1999. A review an synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. US Environmental Protection Agency. EPA 910-R-99-010, Region 10, Seattle, Washington.

Oliver, G.G. 1996. Slocan River rainbow trout population assessment - 1996. Prepared for Ministry of Environment, Lands and Parks, Nelson, B.C. Prepared by Interior Reforestation Co. Ltd., Cranbrook, B.C. 11 p + appnd.

Oliver, G.G. 1998a. Benthic algal and insect response to nutrient enrichment of an in-stream mesocosm. Master of Science Thesis. University of British Columbia, Vancouver, B.C. 127 pp.

Oliver, G.G. 1998b. Slocan River rainbow trout population assessment - 1998. Prepared for Ministry of Environment, Lands and Parks, Nelson, B.C. Prepared by G.G. Oliver and Associates, Cranbrook, B.C. 16 p + appnd.

Oliver, G.G. 2000. Towards a water quality guideline for temperature in the Province of British Columbia. Prepared for Ministry of Environment, Lands and Parks, Water Quality Branch, Victoria, B.C. Prepared by G.G. Oliver and Associates, Cranbrook, B.C. 45 p + appnd.

Reynolds, W.W. and M.E. Casterlin. 1979. The role of temperature in the environmental physiology of fishes. *In*: M.A. Ali (ed.) Environmental physiology of fishes. Plenum Press, New York.

Rodgers, D.W. and J.S. Grifiths. 1983. Effects of elevated thermal regimes on survival of rainbow trout (*Salmo gairdneri*) alevins. J. Great Lakes Res. 9(3):421-424.

Slaney, P.A. and A.D. Martin. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. N. Am. J. Fish. Mgmt. 7:91-105.

Spigarelli, S.A., M.M Thommes, W. Prepejchal, and R.M. Goldstein. 1983. Selected temperatures and thermal experience of brown trout, *Salmo trutta*, in a steep thermal gradient in nature. Environ. Biol. Fishes. 8(2):137-149.

Stoneman, C.L. and M.L. Jones. 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. N. Am. J. Fisheries Management 16:728-737.

Wilkinson, L., M. Hill, J.P. Welna and G.K. Birkenbeuel. 1992. SYSTAT for Windows, Version 5. SYSTAT Inc., Evanston, Illinois.

APPENDIX 1. Underwater counts at index sites