Juvenile Salmonid Utilization of Selected Habitat Restoration Projects in Southern Interior British Columbia

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JUVENILE SALMONID UTILIZATION OF SELECTED HABITAT RESTORATION PROJECTS IN SOUTHERN INTERIOR BRITISH COLUMBIA

by

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Abstract

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Many off-channel and mainstem riparian fish habitat restoration projects have been completed in the British Columbia Interior to restore endangered Interior Fraser coho salmon. However, there has been little assessment of the productivity and success of these projects. This study assessed the utilization by juvenile salmonids of various habitat restoration projects and techniques during the critical rearing periods of summer (early August to early September 2001), fall (late September to late October 2001) and winter (January and February 2002), with a focus on off-channel habitat utilization. Assessments were undertaken at 42 mainstem and 7 off-channel sites in the Shuswap, North Thompson and Thompson-Nicola sub-basins of the Thompson River drainage.

The structural integrity of some restoration components met performance expectations while others required maintenance, indicating a need to change some techniques. Rock-based (rip-rap) bank stabilization projects generally met stream bank stabilization objectives but did not provide the habitat quality and diversity required to support multiple salmonid species. Projects incorporating woody material with rock addressed both bank stabilization and fish habitat considerations. The success of riparian corridor re-vegetation has not met expectations at many sites, particularly in the Thompson-Nicola sub-region. Observations of successes and failures and recommendations pertaining to alternative techniques to re-establish riparian vegetation have been made.

Despite data and analysis limitations, some trends in juvenile salmonid utilization were evident. Catch per unit effort data suggested greater salmonid utilization of restored habitats than control sites. Salmonid abundance, particularly rearing coho, was in most cases greater in off-channel and tributary restoration sites than mainstem sites. This was most noticeable during winter when almost all coho and chinook were utilizing off-channel habitats. An essential recommendation was therefore to maintain the productivity of those habitats.

To better understand and maximize the success of restoration projects, it was also recommended that assessment studies be continued over the long-term.

Résumé

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Plusieurs projets de restauration de l'habitat piscicole riparien portant sur des artères principales et sur des cours d'eau secondaires du réseau hydrographique de l'Intérieur de la Colombie-Britannique ont été exécutés pour reconstruire les stocks de saumon coho en déclin dans ce secteur du Fraser. Mais très peu d'études ont été faites pour évaluer la productivité et le succès de ces sites de restauration. La présente étude avait pour objet d'établir à quel taux les salmonidés juvéniles fréquentent ces divers sites de restauration au moment des phases de croissance critiques de la période estivale (début août à début septembre 2001), automnale (fin septembre à fin octobre 2001) et hivernale (janvier et février 2002), l'accent étant mis sur la fréquentation des habitats du chevelu secondaire. Les travaux ont porté sur 42 sites en zone d'artère principale et sur 7 sites en zone de chevelu secondaire dans les sous-bassins de la Shuswap, de la Thompson Nord et de la Thompson-Nicola (réseau hydrographique de la Thompson).

L'intégrité structurale de certains équipements de restauration semblait répondre aux critères de performance établis tandis que pour d'autres, des travaux d'entretien devraient être effectués, signifiant que certaines techniques pourraient être améliorées. Les travaux de stabilisation des berges (perrés) répondaient généralement aux critères de consolidation qui avaient été établis, mais n'avaient pas procuré la qualité et la diversité d'habitat requises pour que plusieurs espèces de salmonidés soient supportées. Les solutions qui combinent le bois et la roche ont produit un bon rapport stabilisation des berges-considérations piscicoles. Toutefois, dans de nombreux sites le taux de succès remporté par le reverdissement de la zone riparienne n'a pas été à la hauteur des attentes, en particulier dans la zone Thompson-Nicola. Des observations ont été effectuées sur les succès et les échecs des diverses interventions effectuées et des recommandations ont été formulées concernant d'autres techniques de rétablissement de la ripisylve.

Malgré les limites des données et des analyses produites, certaines tendances ont pu être dégagées concernant la fréquentation de ces sites par les salmonidés juvéniles. Les données de densité (CPUE) indiquent que le taux de fréquentation de salmonidés est plus élevé dans les habitats restaurés que dans les sites témoins. L'abondance des salmonidés, en particulier des saumons cohos en phase de croissance, était généralement plus importante dans les sites du chevelu secondaire et des tributaires que dans les sites de l'artère principale. Cette constatation était particulièrement évidente durant la saison hivernale, période à laquelle la presque totalité des saumons cohos et des saumons quinnats utilisait les habitats du chevelu secondaire. D'où la recommandation instante de prendre des mesures pour que soit maintenu le taux de productivité de ces habitats.

Pour mieux comprendre et optimiser les facteurs qui font le succès des projets de restauration, il a également été recommandé de poursuivre les études d'évaluation à l'horizon du long terme.

1.0 Introduction

Extensive land and water use practices have altered the natural morphology and function of rivers throughout most of Western Canada. In the interior of British Columbia, activities such as mining, forestry, agriculture, urbanization and hydroelectric and linear developments are among the most notable land use practices which have impacted watersheds.

British Columbia relies heavily on proper watershed management to ensure continued economic value from timber harvesting, fish and wildlife resource use, recreation, agriculture, tourism and domestic water supply (Koning et al, 1998). Salmon are a valuable economic and social resource in British Columbia, although many First Nation, commercial and recreational fisheries have declined or disappeared. Human impacts have led to the extinction of at least 142 documented anadromous salmon and trout stocks in the Pacific Northwest (Slaney et al, 1996), with several other stocks currently threatened and endangered, as is the case of Interior Fraser coho salmon.

Vegetation removal along stream corridors has led to channel instability and fish habitat impacts. The loss of riparian (stream bank) habitat in the Thompson basin watershed has been documented in channel stability assessment studies (Miles 1995a, 1995b, 1996). These reports found that nearly 50% of mapped channel banks in study areas had either no woody riparian vegetation or a narrow riparian corridor less than half the channel width. Re-establishing riparian corridors in the flood-plain forest should be the primary goal of stream restoration (Miles, 2001). Over the past few decades, federal and provincial government programs have focussed on restoring watersheds and fish habitat. With the support and partnership of industry, First Nations, agencies, community groups, funding organizations and landowners, fish habitat restoration projects are being undertaken in many interior watersheds impacted by past land use practices.

'Hard' armouring of stream banks using rip-rap (large rock/boulders) has been a technique commonly used to protect property and developments. In high energy, hydraulically active sites rip-rap has been used extensively to provide adequate bank stability. However, this severely reduces the re-establishment of riparian vegetation and natural stream processes. Alternatively, most recent restoration efforts have been using 'softer' techniques which reduce or replace rip-rap with, for example, tree revetments and extensive riparian planting. These sites promote natural stream bank and riparian stability and recovery. In the semi-arid, southern interior region of British Columbia, large rock is now generally used only as a stabilizing component for fish habitat structures. Recent prescriptions for stream bank stabilization incorporate both structurally engineered and biological requirements. They include structural components that provide fish habitat attributes to meet specific salmonid species and life stage requirements, while maintaining the structural integrity and stability of stream banks for property owners. Several reports and technical circulars, such Fish Habitat Rehabilitation Procedures (Slaney and Zaldokas, 1997) and Riparian Assessment and Prescription Procedures (Koning, 1999), provide fish habitat restoration prescriptions and assessment protocols.

A diversity of restoration projects have been undertaken to re-establish natural stream complexes. Two main approaches in restoring fish habitat are riparian restoration and stabilization and off-channel development. Off-channel projects often utilize groundwater which can provide highly productive rearing conditions for salmonids, in particular juvenile coho. Off-channels can be more productive that mainstem habitats and have been recognized as valuable juvenile coho overwintering habitat (Bustard and Narver, 1975; Nickelson, et al. 1992).

Over the past two decades significant economic investment has been made towards fish habitat restoration. However, inadequate effort has been allocated to post-development evaluation of most fish habitat restoration projects (Babakaiff and Hanelt, 1999). Limited data in the British Columbia Interior regarding the response of juvenile and adult salmon stocks to various restoration initiatives have been collected. Some juvenile utilization data associated with restoration prescriptions are available from work done by Sheng et al. 1990. Other assessment work likely was undertaken but results have not been well distributed.

To help address these data limitations, this assessment study "Juvenile Salmonid Utilization of Selected Habitat Restoration Projects in Southern Interior British Columbia" was undertaken by the British Columbia Interior-South Resource Restoration Unit of Fisheries and Oceans Canada (DFO). The purpose of this study was to assess the utilization by juvenile salmonids of selected restored habitats in a number of watersheds within the Thompson River drainage during different seasons. It focussed on Thompson coho stocks, which are part of the 'Interior Fraser population' of coho salmon designated as "endangered" by the Committee on the Status of Endangered Wildlife in Canada. Rearing habitats were initially assessed during the summer period between early August and early September 2001. Repeat assessments of some sites were undertaken in the fall (late September to late October 2001) and in winter (January and February 2002), during which there was an increased focus on off-channel habitats to evaluate critical, over-winter use by rearing juvenile coho. Specific objectives of this study were:

- Provide baseline data for the utilization by juvenile salmonids (particularly coho) of various habitat restoration sites and techniques;
- Evaluate biological productivity and success of various fish habitat restoration techniques;
- Compare biological productivity of mainstem and off-channel restoration sites;
- Evaluate structural integrity and physical characteristics of restoration sites;
- Field test assessment procedures and assist in the development and refinement of evaluation techniques for the British Columbia Interior region; and
- Provide direction for future fish habitat restoration projects.

In the British Columbia Interior, evaluation of the biological productivity and physical success of habitat restoration projects has become a focus for fish habitat managers. Procedures to assess the biological and structural success or failure of projects are not well developed. In 2001, the Thompson Basin Fisheries Council, Neskonlith and Adams Lake First Nations and local consultants were funded to evaluate existing frameworks and develop standards for assessing restoration structures in the British Columbia Southern Interior. As a result, the Stream Restoration Site Assessment Procedure for Southern Interior Streams (SRSAP) manual and field guide was produced. Most evaluation procedures outline two levels of monitoring:

- Routine monitoring – low intensity, subjective assessment with simple measurements; and
- Intensive (project effectiveness) monitoring - higher intensity collection of physical and biological attributes.

Selected guidelines from the existing SRSAP and provincially-based Watershed Restoration Program (WRP) were used to develop a set of procedures tailored specifically to meet the requirements of this study. In addition, standard procedures for monitoring fish utilization were used.

2.0 Study Area

This project was divided into the following three sub-basins of the Thompson River drainage; Shuswap (**1**), North Thompson (**2**) and Thompson-Nicola (**3**) sub-basins (Figure 1). Although many of the same fish habitat impacts occur throughout the area, each sub-basin was distinct in climatic conditions and salmonid stock status.

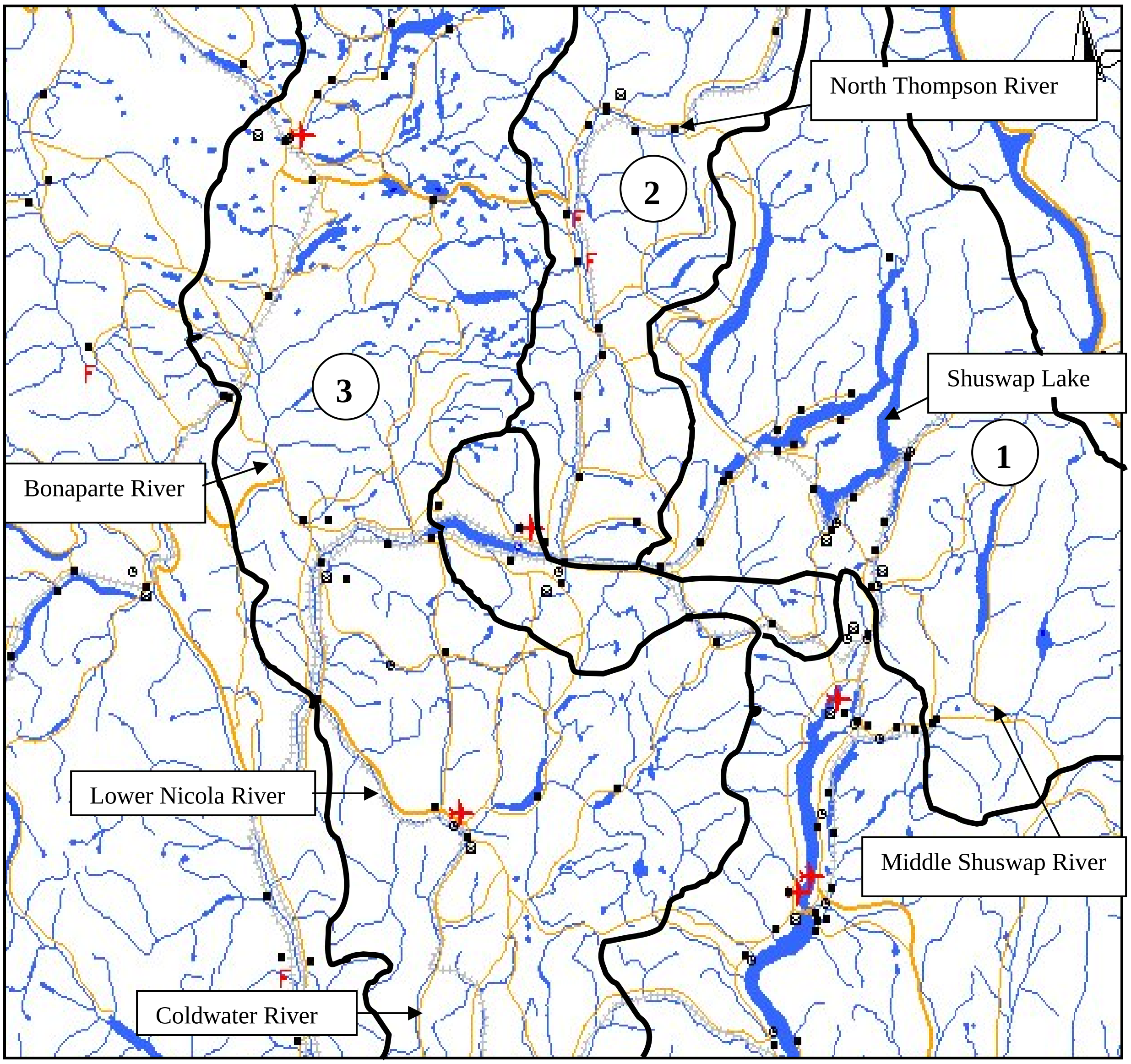

Figure 1: Map of Shuswap (**1**), North Thompson (**2**) and Thompson-Nicola (**3**) sub-basins (from British Columbia Ministry of Sustainable Resource Management)

2.1 Shuswap Sub-Basin

All assessment sites located on watercourses tributary to Shuswap Lake were grouped into the Shuswap sub-basin. These included Salmon River and Bessette, Duteau and Harris Creeks.

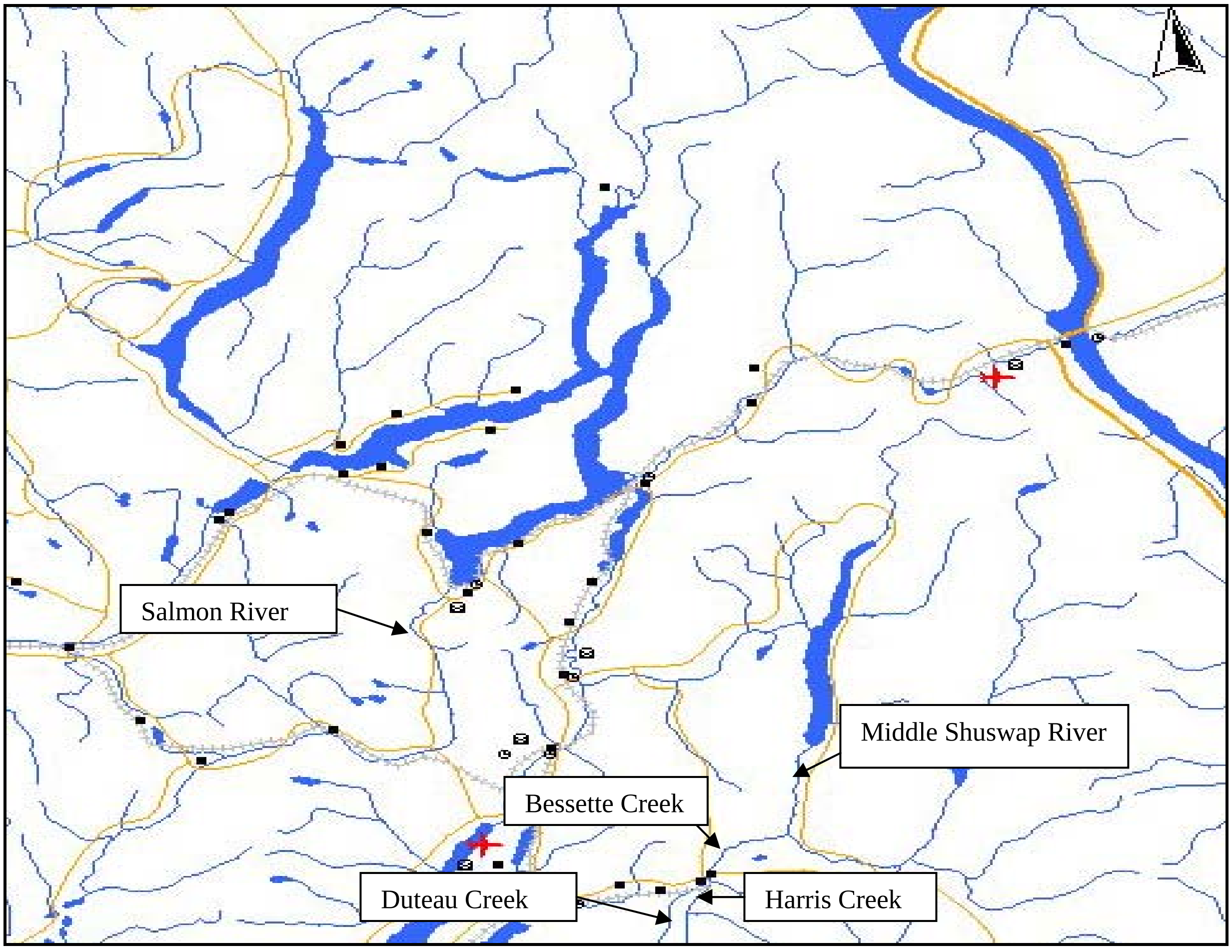

Figure 2: Map of Shuswap sub-basin showing Salmon River and Middle Shuswap River, including tributaries Bessette, Duteau and Harris Creeks (from British Columbia Ministry of Sustainable Resource Management)

2.1.1 Salmon River

The Salmon River watershed encompasses an estimated drainage area of 1,510 km^2 and extends approximately 110 km from Douglas Lake Southwest of Westwold to Salmon Arm where it enters Shuswap Lake. For a significant portion of the year, roughly 30 km of the upper mainstem is isolated by geological conditions that allow the entire discharge of the River to flow 4-6 km subsurface through Westwold. Surface flows through this section generally occur from about mid-March to early July (Obedkoff 1976). Restoration efforts for the Salmon River are all located between Falkland and Shuswap Lake.

Declines in Salmon River salmon escapements have been associated, in part, with water extraction and land use practices. Most notable effects have been from agricultural development and forest practices since the early 1900's. Numerous studies have cited watershed degradation and environmental impacts (Miles 1995b; Burt and Wallis 1997; Neskonlith Indian Band, Neskonlith Fisheries Crew 1993). It has been reported that an estimated 40% removal of forest cover has occurred in the Salmon River watershed since 1901. These forest practices combined with agricultural and linear development have led to loss of riparian vegetation, increased bank erosion, loss of fish habitat, reduced water quality, low flows and high water temperatures. Miles (1995b) estimated that approximately 19.9 km of the river's length exhibits active bank erosion. A fire that impacted the lower Salmon River valley in 1998 created further disturbance to the watershed ecosystem. It is considered that low flows, particularly during warm summer months, are currently the greatest limiting factor in the productive capacity of the Salmon River. In addition to severely reducing productive rearing habitat for juvenile salmonids and creating harmful or lethal water quality and temperature conditions, low flows also cause a passage impediment or barrier for spawning adults entering the Salmon River from Shuswap Lake.

Coordinated restoration efforts in the Salmon River have been ongoing for over a decade. Extensive bank stabilization, livestock exclusion fencing and riparian planting activities have been undertaken to improve water quality and mainstem fish habitat. In 1992, the Salmon River Watershed Roundtable (SRWR), consisting of landowners and agency and First Nation representatives, as well as other interested individuals, began developing formal plans to address the state of the watershed. The SRWR has been the prime focus in promoting and undertaking riparian restoration efforts in the Salmon River and serves as a model for other watershed roundtables. Efforts of the SRWR are being supported by the Pacific Salmon Endowment Fund, the inter-governmental Watershed-based Fish Sustainability Planning process and the Habitat Stewardship Program, among others, to coordinate and strengthen stewardship and partnership interests and to plan and undertake 'on the ground' projects focussed on restoring fish and fish habitat productivity.

Seven existing restoration sites, two control sites and various off-channel habitats and tributary systems were evaluated during August and October 2001 and January 2002 for this study.

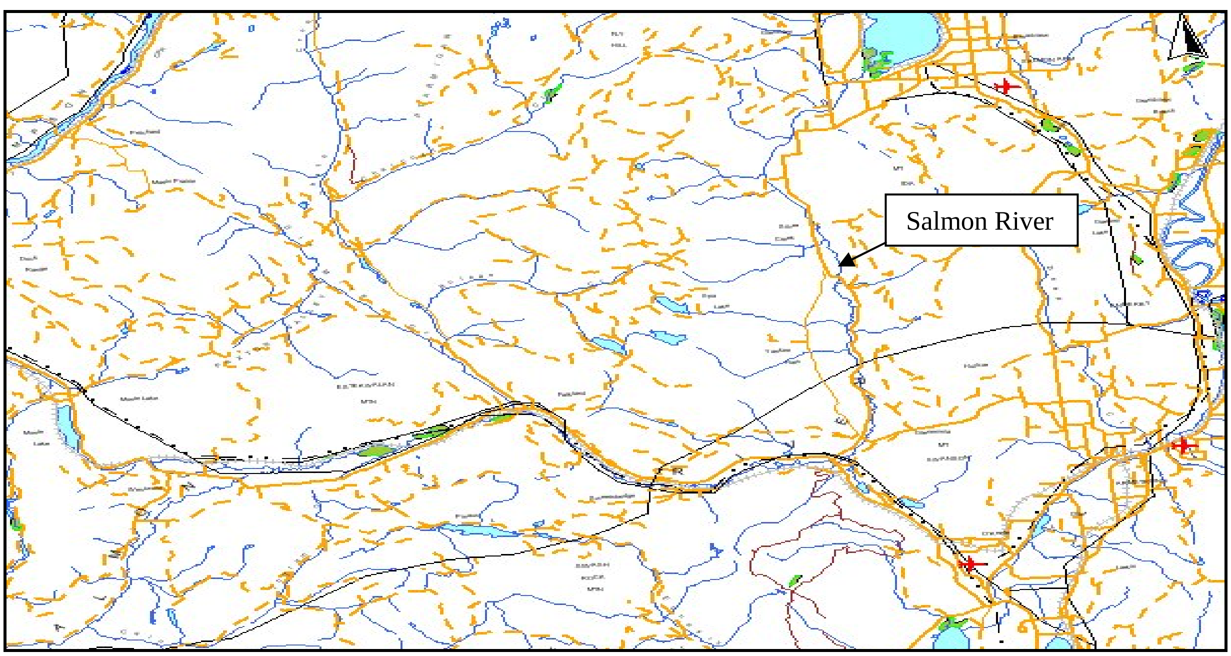

Figure 3: Map of Salmon River (from British Columbia Ministry of Sustainable Resource Management)

2.1.2 Bessette Creek

Bessette Creek forms in Lumby with the confluence of Duteau and Harris Creeks and flows approximately 38 km northeast to its confluence with the Middle Shuswap River (Figure 4). Coho and chinook salmon and rainbow trout use Bessette and its tributaries for both rearing and spawning. The majority of spawning occurs in Duteau Creek. Sockeye occasionally use Bessette for spawning. Agriculture, forestry, urban development and other activities have greatly impacted Bessette Creek and its tributaries. Riparian corridor fencing projects were first initiated in 1989 when 4 km of stream length located upstream of Lumby was fenced to exclude livestock (Lee Hesketh, pers. comm.). Since that time, fencing has been constructed throughout much of the Lumby area along with bank stabilization, tree revetments, riparian planting, development of off-channel habitats and other enhancement projects.

Two riparian restoration projects and one control site were evaluated on mainstem Bessette Creek (downstream of Lumby) in mid-August 2001.

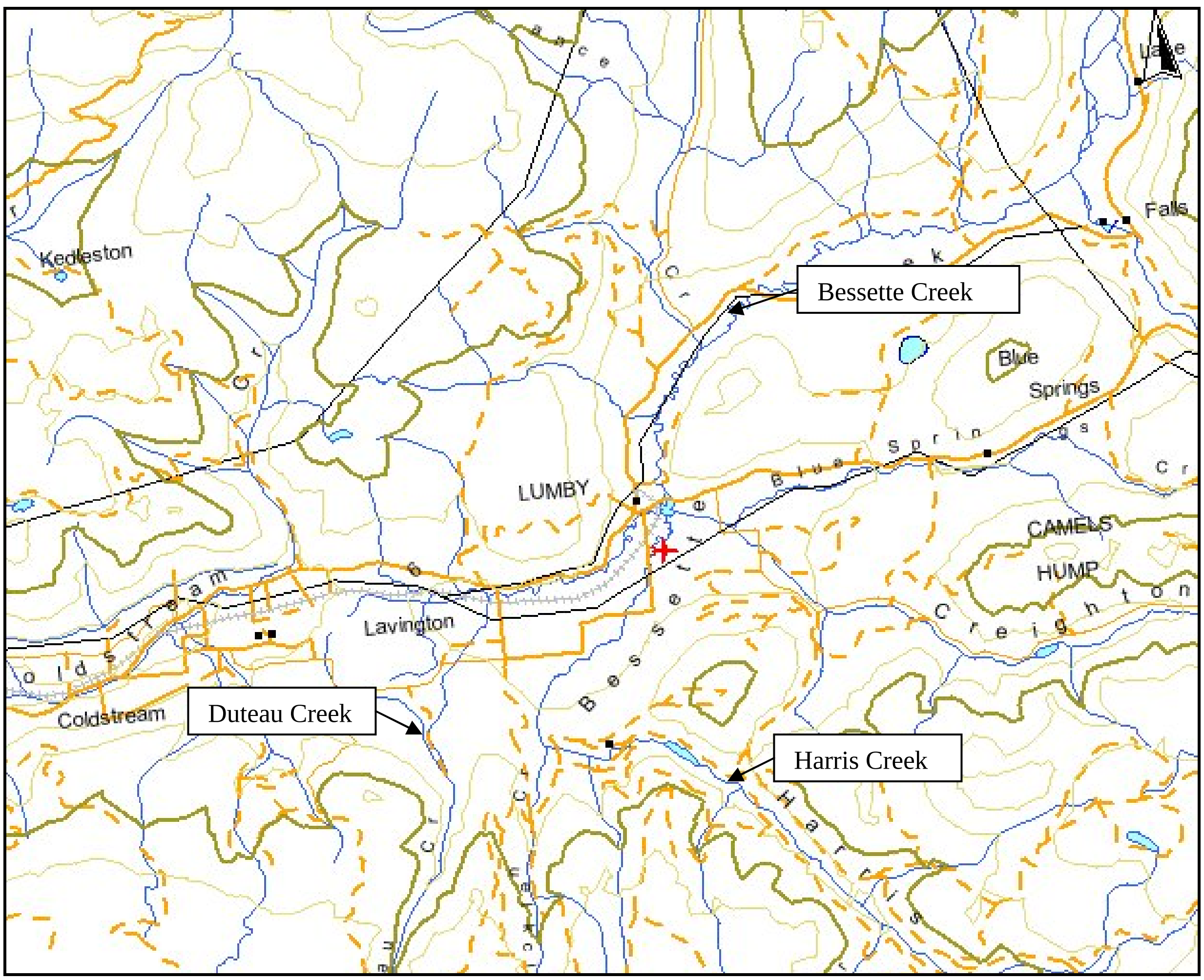

Figure 4: Map of Bessette Creek (including Harris and Duteau Creeks) (from British Columbia Ministry of Sustainable Resource Management)

2.1.3 Harris Creek

Harris Creek has a mainstem length of approximately 32 km and a moderate to high gradient. A cascade obstructs the passage of anadromous salmon stocks approximately 18 km upstream of Lumby. Limited coho spawning occurs primarily in its lower 4 km. Available rearing habitat has been reduced due to siltation, streambed and bank instability, bed load aggradation, low flows and loss of riparian habitat due to logging activities in upper reaches.

Three restoration sites and one control site were evaluated on mainstem Harris Creek during mid-August 2001 and January 2002.

2.1.4 Duteau Creek

Duteau Creek is the main fish producing tributary of Bessette Creek and has a controlled flow regime, operated by the North Okanagan Regional District Irrigation Authority for agricultural and domestic water use. Mainstem length is approximately 50 km with the lower reaches exhibiting minimal gradient and a meandering pattern. There is a gradient (cascade) barrier to the migration of anadromous salmon stocks located at 10.8 km and a dam at 25.6 km upstream of its confluence with Harris Creek. Lawson Creek is the main tributary. A portion of the flow from Lawson Creek has been diverted to support the Reuchel Channel, an adjacent restoration channel developed as rearing habitat for coho. A flow regime for fish and fish habitat protection is in place for Duteau Creek (under review). Coho and chinook spawn from Lumby to Whitevale Road. In August 2001, a smolt pond was constructed downstream of Whitevale Road to assist in imprinting hatchery released coho smolts and to provide productive off-channel rearing habitat. In recent years, escapements of coho and chinook have been relatively low. The average coho escapement from 1995 to 2001 has been about 65 adults. Rearing is thought to occur mostly in the lower sections of Duteau Creek.

Five restoration sites and one control site were evaluated for this juvenile salmonid assessment study on mainstem Duteau Creek (including one off-channel). Sampling was undertaken during late August 2001 and late January 2002.

2.2 Thompson-Nicola Sub-Basin

Sampling in the Thompson-Nicola sub-basin for this study was confined to tributaries of the Thompson River downstream of Kamloops Lake; namely Deadman, Bonaparte, and Nicola (including Coldwater) Rivers (Figure 5).

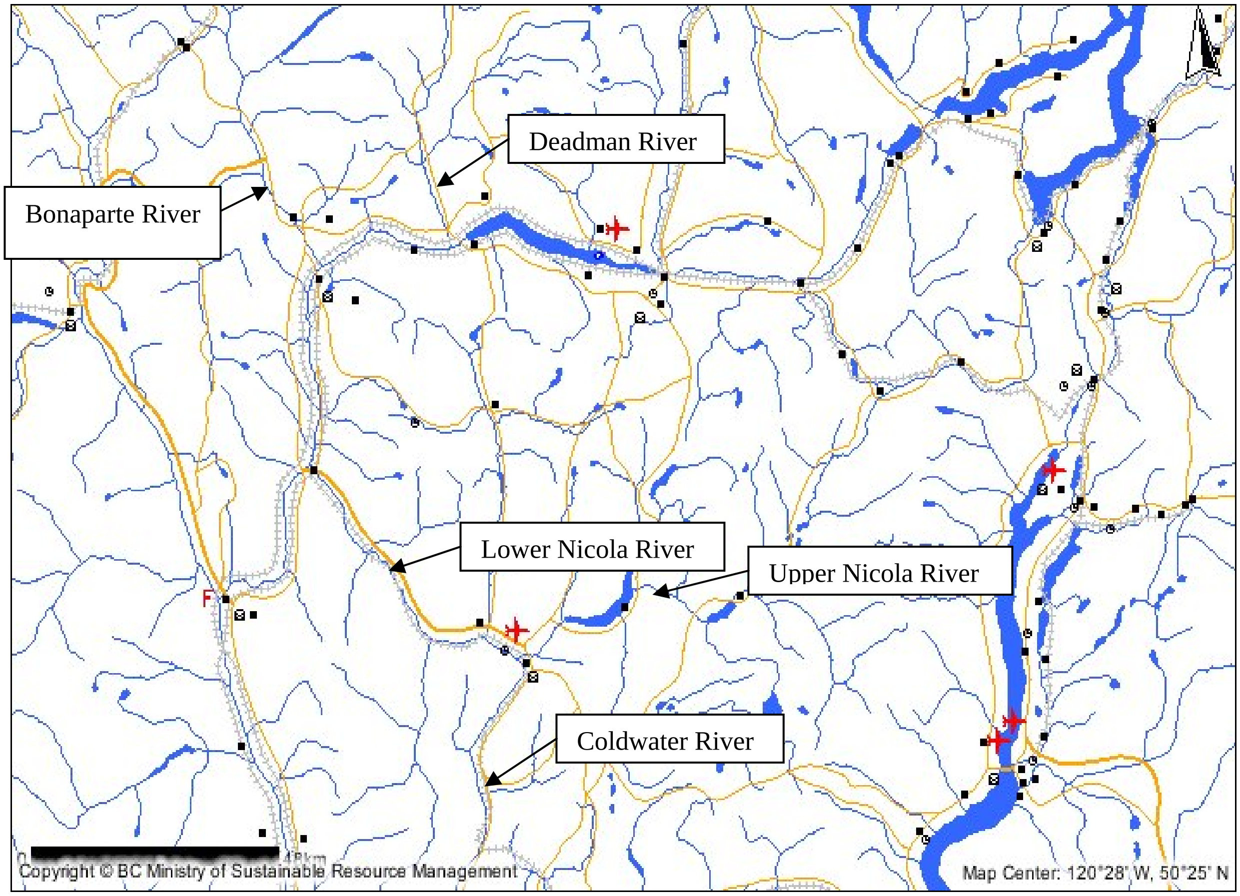

Figure 5: Map of Thompson-Nicola sub-basin (from British Columbia Ministry of Sustainable Resource Management)

2.2.1 Deadman River

Deadman River confluences with the Thompson River approximately 50 km west of Kamloops and the watershed drains approximately 1490 km^2. Criss Creek is the main tributary and encompasses approximately one-third of the drainage basin (Figure 6). Deadman River includes a series of three lakes, two of which are regulated and provide reservoir storage for water use demands during the low flow, late summer period. Several smaller lakes also feed the headwaters of Criss Creek and Deadman River. Ranching has been the primary land use activity since the late 1940's and forest harvesting also occurs within the watershed (Miles, 1995a). Following the flood events of 1990 that caused extensive damage to the river channel, the Habitat Conservation Fund provided funding for the Shuswap Nation Tribal Council (SNTC) to initiate restoration prescriptions, help prevent further deterioration and rebuild habitat attributes (Olmstead et al, 1992). Miles (1995a) assessed channel stability in a study section downstream of Mowich Lake to the Highway 1 bridge. Miles reported that approximately 30% of Deadman River stream banks in this study section were actively eroding and that 67% had either no woody vegetation or a narrow riparian corridor less than half the channel width. Air photo comparisons between 1948 and 1992 revealed vast removal of riparian habitat along this section of river. After the flood events, nearly 5 km of rip-rap were placed between Mowich Lake and the Hwy 1 bridge. Although rip-rap stabilization projects have prevented further bank erosion, re-vegetation of riparian corridors in the semi-arid Deadman River valley is limited.

Deadman River has annual returns of coho, chinook and steelhead in the low hundreds to a few thousand. Pink salmon also return in some years. During mid-1980, a hatchery facility was constructed to help increase salmon stocks. However, since construction water quality issues and disease have affected egg to fry survival and limited production. As a consequence, it is no longer used as a rearing facility for salmon stocks (Dennis Demontier, DFO pers. comm.). Other locations, including Brousseau Channel, which was constructed by DFO in 1998 as off-channel rearing habitat, have been considered as imprinting locations for hatchery stocks prior to release.

Low water conditions are a concern in the Deadman River. In 1977, an agreement was signed with the Deadman River Improvement District guaranteeing minimum instream flows as conditions of water licenses. In September 2001, DFO monitored flows in Deadman River and Criss Creek and concluded that minimum flow requirements were not being achieved (Dean Watts, DFO pers. comm.). Further assessment of flow conditions is proposed to determine if current minimum flow requirements are acceptable for fish and agricultural purposes.

The Brousseau off-channel, three tributaries and five restoration and two control sites on the mainstem, were evaluated for this study. Sampling was undertaken during early September and late October 2001 and early February 2002.

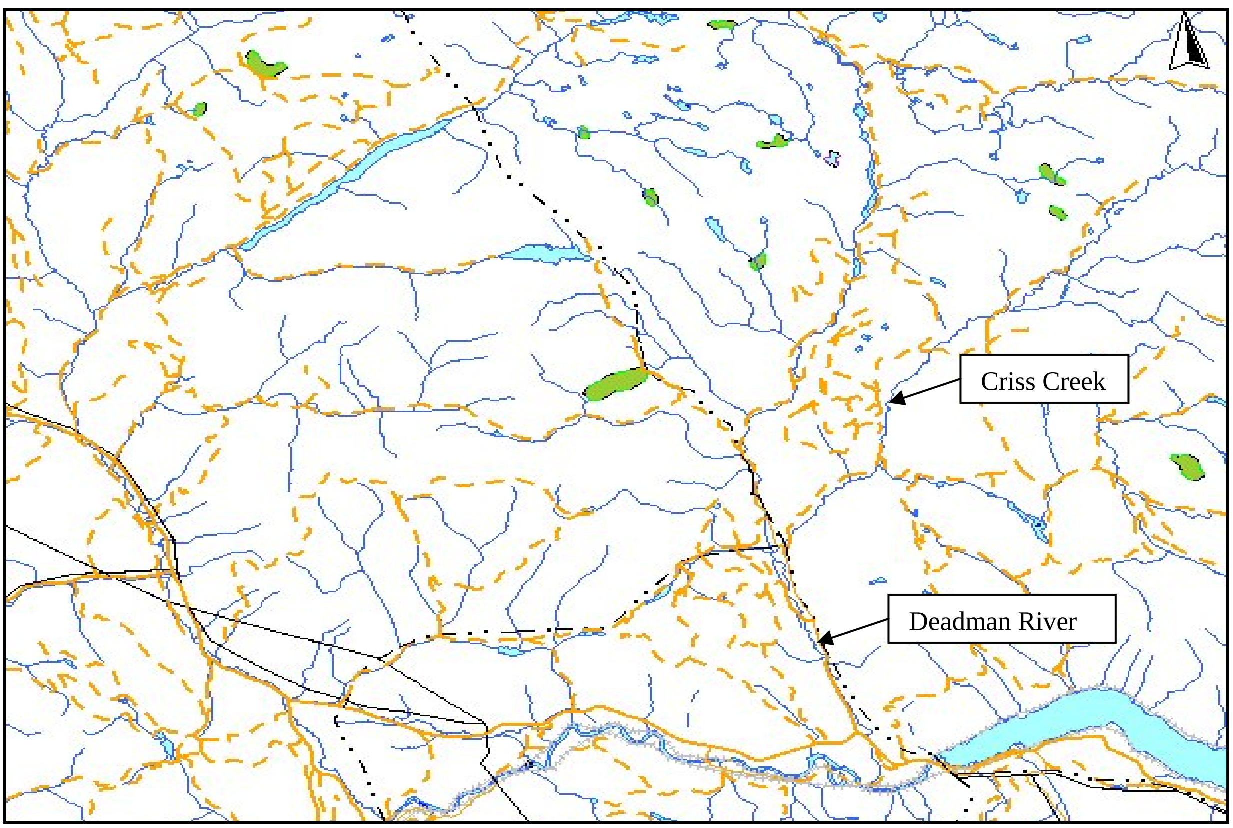

Figure 6: Map of Deadman River (from British Columbia Ministry of Sustainable Resource Management)

2.2.2 Bonaparte River

The Bonaparte River watershed drains approximately 5,000 km^2 of the Fraser Plateau (Tredger, 1980) flowing west out of Bonaparte Lake, through Young Lake, to approximately Clinton and south to its confluence with the Thompson River near Ashcroft (Figure 7). Construction of the Bonaparte fishway in 1989 provided access to the watershed for anadromous salmon. Prior to fishway construction, only the lower 3.6 km of the river to the Thompson confluence supported small populations of chinook, coho, and steelhead. In 1990, flood events occurred similar to those in the Deadman River. Chinook salmon and steelhead stocking programs were significantly increased in 1991 to compensate for juvenile mortality during that flood. Year 2000 returns represented the second cycle of intensive stocking in the early 1990s and more than 5,200 chinook passed through the fishway. Coho escapement in the Bonaparte has increased from 62 in 2000 to the low to mid-hundreds in recent years. Improvements to the operation of the fishway have subsequently been undertaken and should assist passage and reduce fish handling and stress. This could also increase escapements to the upper reaches of the system.

Ranching and urban development are the main sources of habitat impact downstream of Clinton. Forest harvesting practices are the primary factors negatively impacting the Bonaparte watershed upstream of Clinton. Rood and Hamilton (1995) reported that 20% of the Bonaparte basin has experienced logging. The Bonaparte River Roundtable, established in 2000, provides an excellent partnership forum for landowners, First Nations, government and others to address the condition of the Bonaparte River watershed and pursue restoration opportunities. The Roundtable has been increasingly involved in restoration projects.

Six restoration sites and one control site were evaluated on the mainstem Bonaparte River during mid-September 2001. A winter assessment was also conducted on this system and the Hat Creek tributary during mid-February 2002.

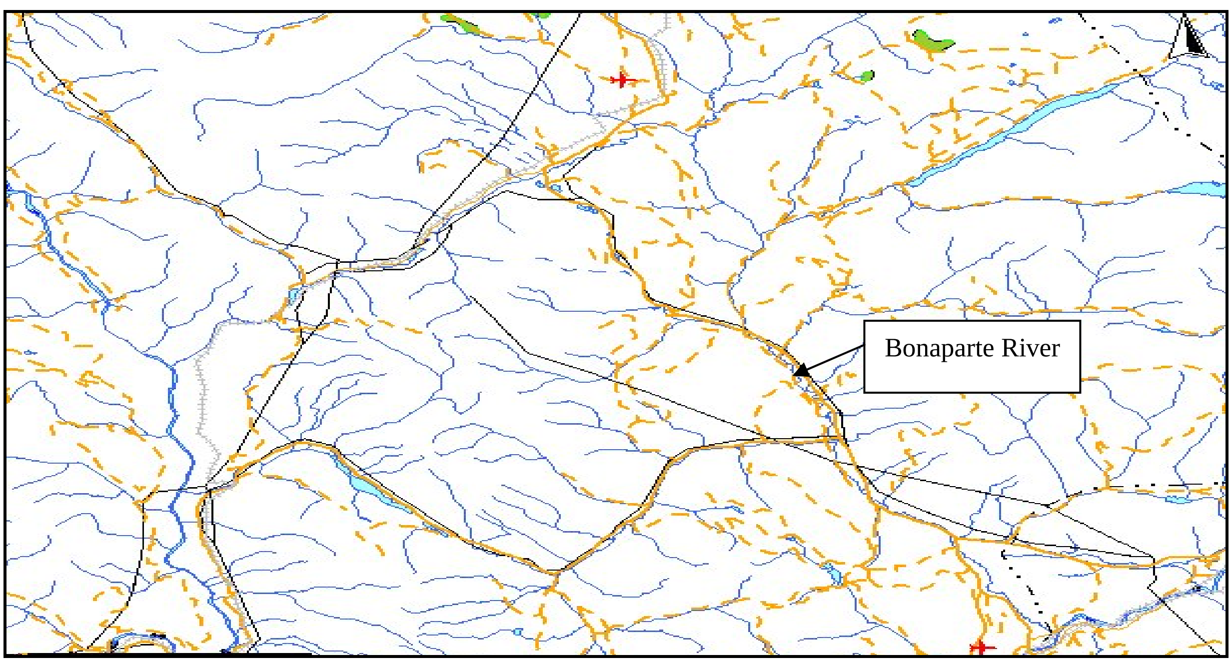

Figure 7: Map of Bonaparte River (from British Columbia Ministry of Sustainable Resource Management)

2.2.3 Nicola River

The Nicola River is a major tributary to the Thompson Watershed and drains approximately 7,227 km^2 of the Interior Plateau. The watershed is an important contributor to salmon stocks and other species (Walthers and Nener, 1998). Populations of coho, chinook and pink salmon and steelhead are present in the watershed. The Nicola mainstem is divided by Nicola Lake and is locally referred to as Upper and Lower Nicola Rivers (Figure 8). The Upper Nicola originates north-west of Kelowna and flows west to Douglas Lake and into Nicola Lake. A dam at the outlet of Nicola Lake regulates downstream discharge. The river flows south-west to Merritt, where it is joined by the Coldwater River, and then northwest to its confluence with the Thompson River at Spences Bridge. Salmon producing tributaries include Coldwater River and Spius, Maka, Guichon, Spahomin and Clapperton Creeks (FRAP, 1998). Logging throughout the headwaters and agriculture land use in the valley have heavily impacted the riparian corridor. This has lead to increased bank erosion and loss of riparian function. High water temperatures associated with decreased riparian vegetation have been documented and prolonged periods of high temperatures have been reported to have detrimental effects on fish populations (FRAP, 1998; Morantz and Haefele, 1996). In addition, irrigation and other water uses account for greater than 50% withdrawal of summer flow (Rood and Hamilton, 1995) and, consequently, high water temperatures. Due to low escapement, an enumeration fence has not operated in the Upper Nicola River since 1999 (pers. comm. B. Michel, NWSFA). DFO's Spius Creek hatchery collects and outplants coho and chinook brood stock for Spius Creek and Nicola and Coldwater Rivers in the Nicola Watershed and coho for the Salmon, Bonaparte, and Deadman Rivers (including summer rearing for Duteau coho fry).

Six restoration sites and two control sites were assessed on the Upper Nicola River mainstem. Equal numbers of sites were assessed during late September 2001 on the mainstem Lower Nicola River, with most sites located on private ranch property just below the outlet of Nicola Lake. Sampling was also undertaken on the Lower Nicola River during mid-January 2002.

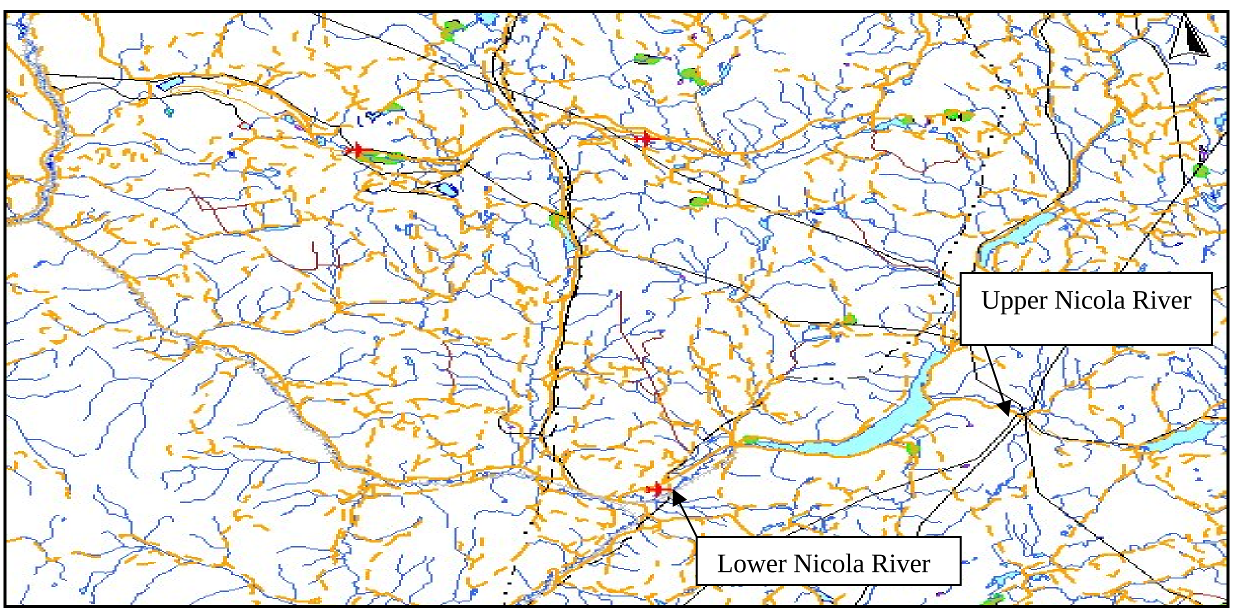

Figure 8: Map of Upper and Lower Nicola Rivers (from British Columbia Ministry of Sustainable Resource Management)

2.2.4 Coldwater River

The Coldwater River is the largest tributary to the Nicola River system and is a major contributor to chinook, coho and steelhead stocks. Sections of the Coldwater River including some tributaries have been designated as "known temperature sensitive streams" as per Section 1 of the Forest Practices Code of British Columbia, Operational Planning Regulation (B.C. Reg. 107/98). The Coldwater River mainstem is approximately 95 km in length and drains approximately 914 km^2 (Figure 9). Forest harvesting, linear and urban development and agriculture impact the watershed. Fish sampling on the Coldwater focussed on off-channel habitat.

One mainstem bank restoration site and four off-channel sites were evaluated during late September 2001 and mid-January 2002 for this assessment study.

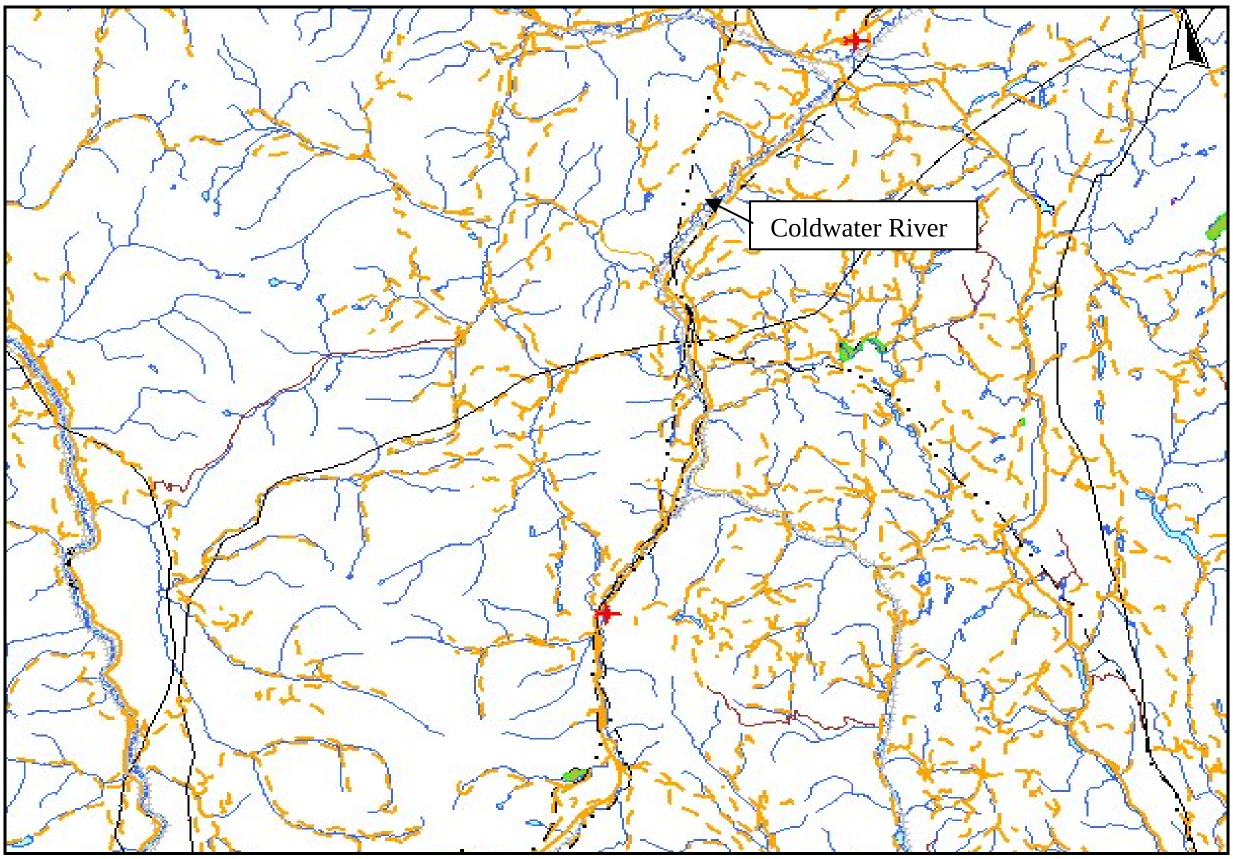

Figure 9: Map of Coldwater River (from British Columbia Ministry of Sustainable Resource Management)

2.3 North Thompson Sub-Basin

Virtually all watersheds in the North Thompson basin have been impacted by forest practices, with logging remaining the major resource activity. The North Thompson supports spawning and rearing populations of chinook, coho and sockeye salmon. Year 2001 marked the first observation of pink salmon escapements, with adults observed in the Clearwater and Raft Rivers. Restoration sites on three North Thompson tributaries were evaluated, including one site on Mann Creek and three (including one off-channel site) on Raft River, with most effort directed in the Louis Creek drainage.

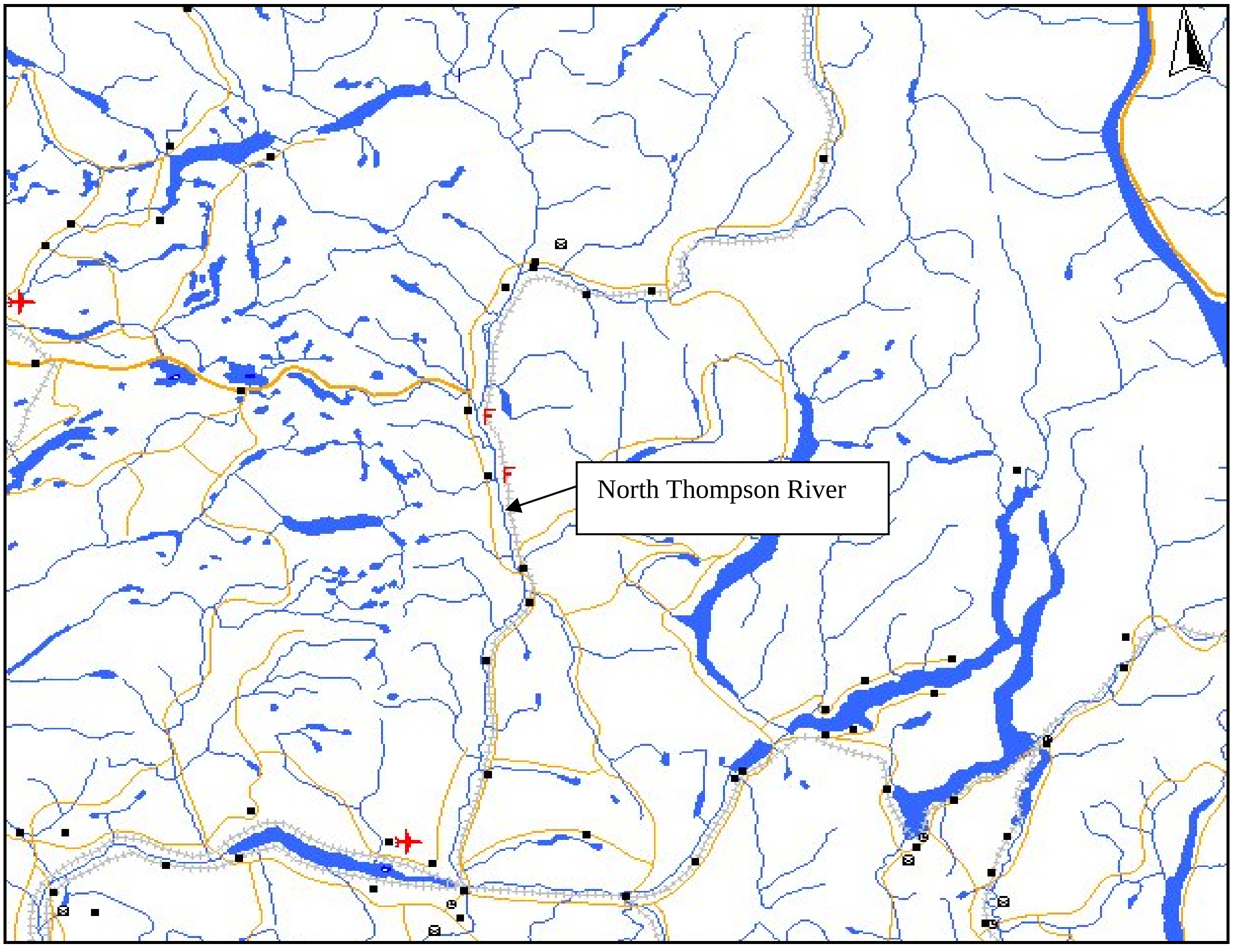

Figure 10: Map of North Thompson River (from British Columbia Ministry of Sustainable Resource Management)

2.3.1 Louis Creek

Louis Creek flows north-west from Eileen Lake to its confluence with the North Thompson River approximately 60 km north of Kamloops (Figure 11). Louis Creek drains an area of 515 km^2 and has a mainstem length of approximately 55 km. Most of the Louis Creek valley bottom is privately owned. Agricultural demands and limited licensed water storage on Louis Creek lead to high water demands that amount to 50 percent of the flow in an average year, and considerably more during drought years (Rood and Hamilton, 1995). Logging practices and recreational activities have also adversely affected stream health and channel stability. McGillivray, Cahilty and Fadear Creeks are major tributaries that flow into Louis Creek from the east. They provide limited habitat due to steep gradients (Miles, 1996). Miles also reported that 50 percent of the mainstem channel has reduced riparian vegetation due to land use practices. A co-operative study, with provincial and federal agencies, First Nations, industry and the University College of the Cariboo (now Thompson Rivers University) was undertaken on a large ranch located on Louis Creek mainstem. This study examined the effect of various cattle grazing and watering practices, riparian fencing installations and planting prescriptions on fish habitat recovery and productivity.

In addition to five sites which were included in the above study, four other mainstem bank restoration sites were evaluated during mid-October 2001 for this juvenile salmonid assessment study.

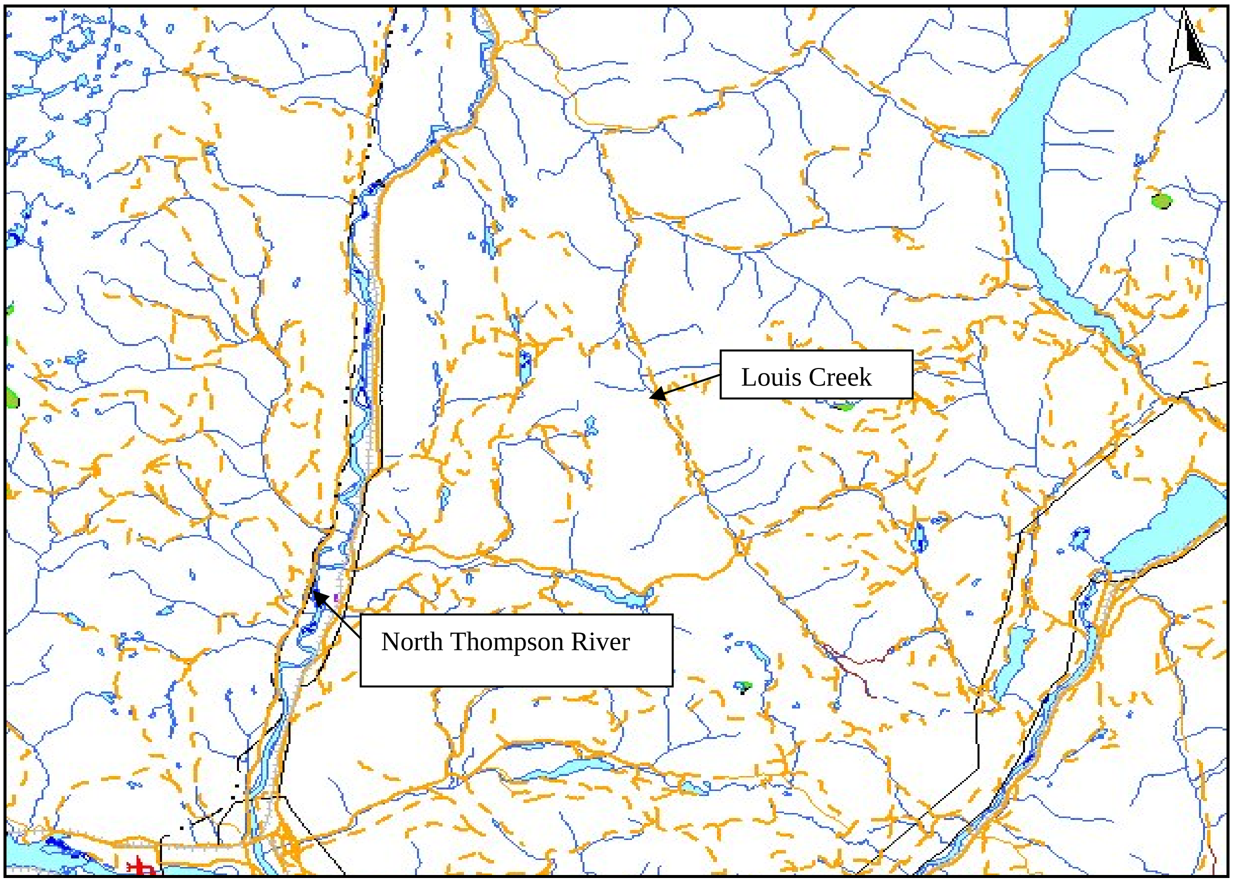

Figure 11: Map of Louis Creek (from British Columbia Ministry of Sustainable Resource Management)

2.3.2 Raft River

Raft River watershed has a drainage area of approximately 625 km^2 (Figure 12). Approximately 40 percent of the total watershed area has been affected by logging, including 25 percent which has been recently harvested (Nener and Wernick, 1998). A waterfall approximately 3 km upstream of the confluence with the North Thompson River prevents anadromous fish passage to most of the Raft River watershed. Below the falls the river supports anadromous populations of coho, chinook and the largest return of sockeye salmon in the North Thompson. Land use practices that have directly impacted the system include cattle grazing, urban and linear development and irrigation demands.

Two stream bank restoration sites and one off-channel site were evaluated during early October 2001.

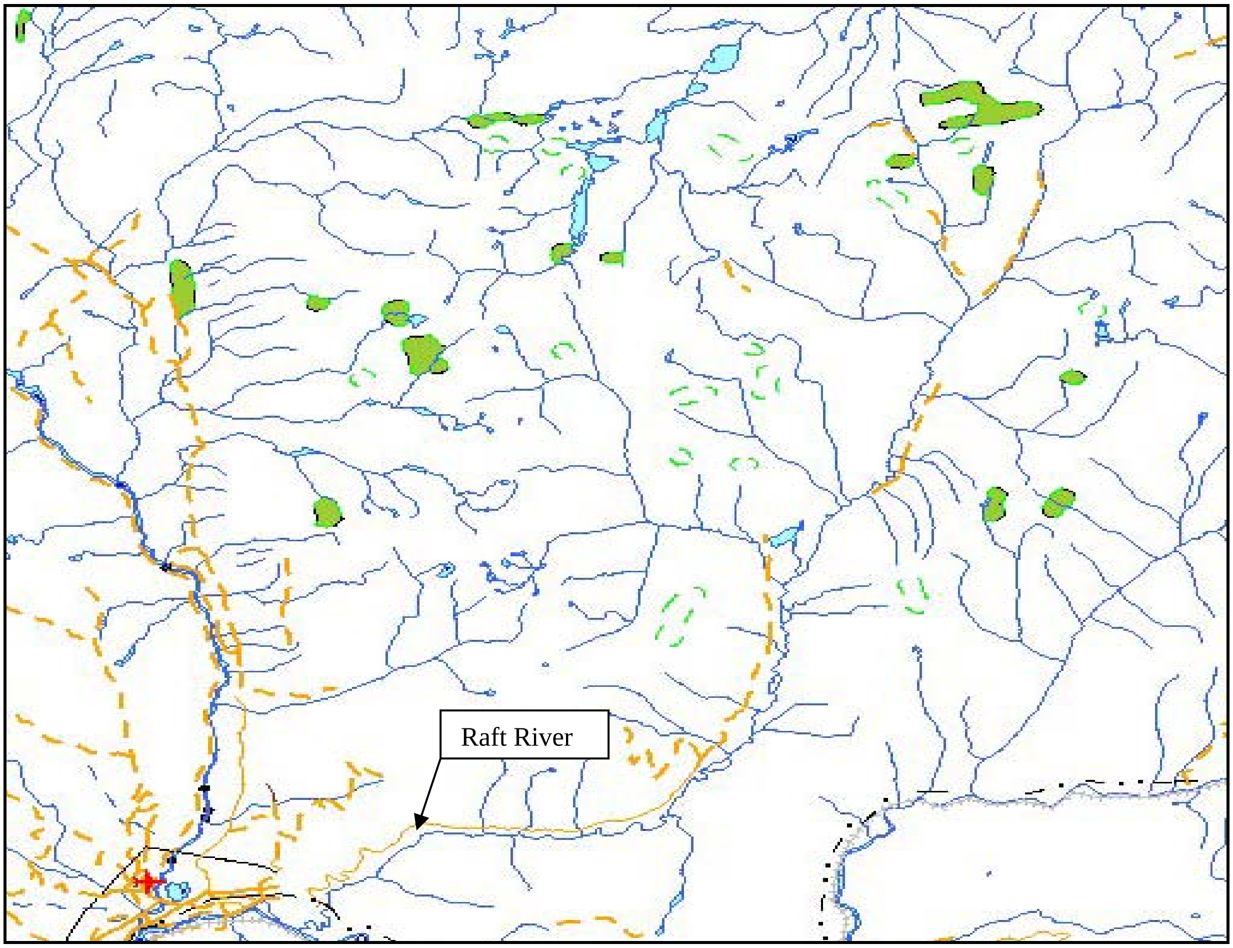

Figure 12: Map of Raft River (from British Columbia Ministry of Sustainable Resource Management)

2.3.3 Mann Creek

Mann Creek enters the North Thompson approximately 12 km southeast of Clearwater. Passage of anadromous fish is prevented by a falls located approximately 6.5 km upstream of the mouth. Upstream of the falls, forest harvesting practices have impacted the system throughout the majority of the watershed. Restoration work undertaken on Mann Creek included installation of instream weirs to facilitate fish passage through the highway culverts and placement of large organic material in several downstream sites exhibiting riparian erosion. In the lower reaches, land clearing for agricultural and ranching purposes has impacted bank stability and riparian vegetation.

One mainstem restoration site was sampled in the reach downstream of the highway during early October 2001.

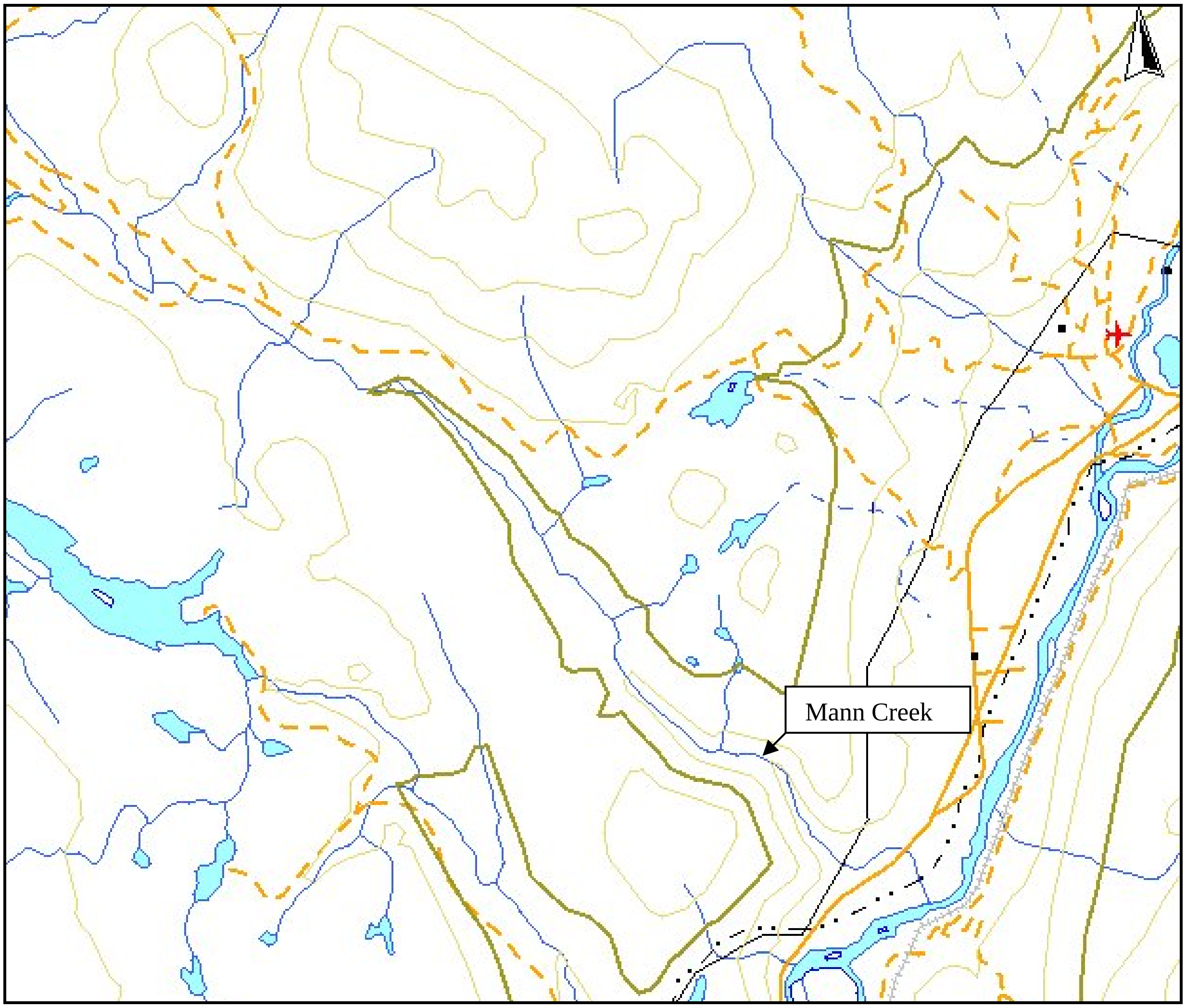

Figure 13: Map of Mann Creek (from British Columbia Ministry of Sustainable Resource Management)

3.0 Methods

3.1 Assessment Procedures

The Stream Restoration Site Assessment Procedure for Southern Interior Streams (SRSAP 2001) report by the Thompson Basin Fisheries Council was used as the framework for developing the assessment procedures used in this assessment study. The methodologies presented in the SRSAP were primarily derived and modified from several, existing restoration assessment frameworks. As field testing is concluded, these methodologies are being modified in the work draft report (Clough, pers. comm.). Additional methodologies for this assessment study were taken from Fish Habitat Assessment Procedures, Riparian Assessment Prescriptions and Procedures and Channel Assessment Procedures (Koning 1999; Gaboury and Wong, 1999; Babakaiff and Hanlet, 1999; and Gaboury and Feduk, 1996).

The methodologies used for this assessment study were modified from the routine assessment procedures outlined in the SRSAP report. Some procedures from the more detailed assessment methodologies in the SRSAP and WRP evaluation procedures where also incorporated as part of this study. An important objective in developing assessment methodologies for specific use in this study was to ensure they were highly reproducible for future assessment projects. The methodologies had a high level of consistency with SRSAP protocols to ensure that information collected could be compared with other restoration site assessments in the Southern Interior region of British Columbia. Information gathered through this study in several watersheds of the southern interior will contribute useful information in furthering the development of assessment procedures.

3.2 Site Information and Selection

Prior to initiating field work, information was collected during July 2001 on each watershed. Site accessibility, landowner permission, local concerns, fish species distribution and degree and type of restoration undertaken were addressed before sampling sites were chosen. On-site visits with DFO Habitat and Enhancement biologists and technicians, local stewardship co-ordinators and First Nations representatives provided additional information for the selection of potential assessment sites.

In each watershed, a control site (section of actively eroding stream bank) was chosen to represent, as best as possible, a riparian condition that restored (assessment or sample) sites would have exhibited prior to restoration. This was done to compare the habitat condition and salmonid utilization of un-restored sites (ie. impacted state) to restored sites (ie. effect of restoration prescriptions). These control sites were selected within the same stream section as the restored assessment sites and, if possible, were located where future restoration work may be undertaken. This could provide valuable pre-restoration information.

Effort was also made in each watershed to sample a variety of restoration prescriptions. These included tree revetments, rock (rip-rap) revetments, rock and large woody debris structures and groynes (utilizing rock or large woody material). A total of forty-two bank restoration sites were assessed. Although this study focused on assessing stream bank restoration and riparian re-vegetation projects, some tributaries and off-channel restoration sites were also sampled for juvenile salmonid utilization. Sampling tributaries and off-channels provided additional information on habitat preference by juvenile salmonids, particularly when utilization of mainstem sites was low (eg. during critical summer and winter rearing periods).

3.3 Assessment Timing

Field assessments were undertaken to monitor the seasonal variation in juvenile salmonid utilization of habitat restoration sites. Sites were initially assessed during the summer (early August to early September 2001). Repeat assessment of some sites was done into the fall (late September to late October 2001) and again in winter (January and February 2002). During winter assessment, there was an increased focus on off-channel habitats to evaluate critical, over-wintering use by juvenile coho.

3.4 Fish Sampling Techniques

Mainstem sample sites (eg. rip-rap, rootwad/rock and tree revetment habitat structures) were isolated using seine nets (15 metre or 30 metre nets made up of #10-¼″ (6 mm) green knotless nylon with floats and lead line). If necessary, rocks were used to help seal the lead line to the streambed and prevent fish moving in or out of isolated areas. During winter sampling, ice conditions prevented the use of seine nets to isolate sample sites. Sampling locations within off-channels and tributaries were chosen mainly on the basis of accessibility and the GEE trapping or electrofishing sites were not isolated by seine nets.

Fish sampling was done using GEE wire mesh minnow traps (42 cm long by 22 cm wide, with 6mm mesh and 15mm end openings). The number of traps used (generally 20-25) depended upon the physical size and characteristics of the sample site. Traps were baited with sterilized (boiled) salmon roe and ‘fished’ for a period of approximately 24 hours. This method was used since it was considered as one of the least harmful sampling techniques and would provide comparable fish presence and abundance estimates of rearing juvenile salmonids. Catch per unit effort (cpue), determined as catch per trap within the standardized 24 hour ‘fishing’ time period, was used to provide a simple and meaningful method of standardizing and comparing catch results among sampling sites. All salmonids were identified to species and fork length and weight measurements recorded. Sites with large catch numbers of salmonids were sub-sampled for lengths and weights.

A limited number of sites were electrofished to determine the relative effectiveness of GEE trapping and to compare GEE trapping catch results with an additional capture technique. To lessen potential harm to fish, electrofishing was minimized and careful attention given to avoid adult fish and redds. Electrofishing was only done during the first sampling period in August. At this time, migrating adult fish were seen in several systems but no redds were observed.

3.4.1 Mark Recapture Population Estimates

When sufficient numbers of juvenile coho were captured at a particular site during the initial 24 hour sampling, a mark-recapture technique was undertaken in an attempt to derive a population estimate. Fish were marked using a very small clip on the dorsal lobe of the caudal fin. Marked juvenile coho were returned to the enclosure for subsequent trapping. Techniques for mark-recapture were purposely varied somewhat over the field season (e.g. the number of days between marking and recapture; changes in the type of bait during recapture) to overcome possible trap avoidance behaviour and increase the success of recapturing marked fish.

3.5 Data Collection

Habitat information was recorded using three data collection forms. The first form was used to collect site identification, structural inventory and channel morphology information. The second form accommodated a site sketch and photo log and the third form was used to collect detailed vegetation information.

3.5.1 Form 1 - Restoration Assessment

Site Identification and Header Information

Header information on Form 1 of the assessment data sheets identified the gazetted and local stream name, date, time, site number and/or site name. Site identification fields also provided for Watershed Code, UTM co-ordinates, Interim Location Point (ILP) and Numeric Identifier (NID). UTM site co-ordinates were collected using a Garmin 12 XL GPS unit. Similar to the SRSAP format, the dates of restoration structure construction, previous site assessments and recent events (eg. flood damage) were recorded.

Structure Inventory

This section is a modified version of the Installation Inventory section in SRSAP and was designed to inventory fish habitat structures or components which comprised the restoration prescriptions in each sample area. The primary and secondary objectives for each component were identified and performance rated, based on a comparison of condition at original construction and at time of assessment. Objectives were performance rated based on structural integrity, hydraulic function, fish habitat value, maintenance requirements, and vegetation recovery (riparian planting) as described in SRSAP. Performance rating for each category was scored as follows:

Score	Performance Evaluation:
1	Failure – objectives not met
2	Poor - functioning to an unsatisfactory or very limited extent
3	Satisfactory to good performance
4	Good to excellent performance
N/A	Based on objectives, this aspect of performance not applicable to this structure

Table 1: Performance Rating Scale (from SRSAP)

Length and width measurements of the actual area sampled for fish presence were taken before isolation seine nets were removed. Comments were recorded regarding any visible bank erosion within the enclosure and the structural condition of the restoration site.

Channel Morphology

Channel condition was part of the channel morphology assessment section on Form 1 of the field forms. Since watercourses are naturally dynamic, monitoring change in channel attributes with different riparian restoration prescriptions over time can help assess long-term success or failure. Visual observations and variables used to describe channel morphology, condition and capacity were collected as part of the basic assessment of each site.

Channel classification (ie. riffle-pool, cascade-pool, step-pool or large channel morphology) was determined between pools from an adjacent reach of stream by identifying substrate composition and the presence of riffles, cascades or steps. The dominant morphology for each channel classification was: gravel and/or cobble for riffle-pools; cobble and boulders for cascade pools; boulders for step-pools; and fine substrates for large channels. All mainstem restoration sites assessed were in low gradient reaches and were classified as riffle-pool morphology.

The water-borne supply of sediment (bed-load) and organic debris can lead to degradation and aggradation conditions in a channel. Increased sediment supply generally leads to streambed aggradation while decreased sediment supply can create channel degradation (Slaney and Zaldokas, 1997). Table 2 summarises characteristics which exemplify degraded and aggraded conditions of riffle-pools.

Channel Type Riffle-Pool	**Degraded**	**Stable**	**Aggraded**
Morphology	Extensive riffles and bars	Repeating riffle-bar-pool sequence	Extensive riffle and runs
	Small shallow pools (due to erosion of riffle crests)	Diverse pool size, shape and depth	Small, shallow pools (due to depositional infilling)
	Channel consists of less than ¼ pool	Channel consists of ½ - ¾ pool environment	Channel consists of less than ¼ pool
	One main channel (primarily single thread)	One or two main channels	Multiple channels on braided bed surface
	Simple, uniform riffle and run shapes	Diverse riffle shapes	Simple, uniform riffle and run shapes (minimal depth variability)
	Limited side channel bar	Mainly diagonal and point bars	Mainly mid-channel bars. Bars elevated at or above elevation of surrounding bank tops. Steep downstream bar faces
Bed sediment	Mainly cobbles and courser textures	Cobble and gravels	Mainly gravel and finer textures
Bank sediment	Mainly cobbles and gravel	Mainly cobbles, gravel and sand	Mainly gravels, sand and cobbles
	Banks primarily sloping and/or overhanging	Large proportion of undercut/overhanging banks	Extensive bank erosion (commonly complete absence of undercut banks)
Large Woody Debris	Limited. Those present are small sized and oriented parallel to banks	Oriented across and spanning the channel	Absent or buried. Those present are small sized and oriented parallel to banks

Table 2: Riffle-Pool Conditions (Channel Condition and Prescriptions Assessment, Hogan et al. 1996)

The level of disturbance was graded as follows, in accordance with the Forest Practices Code Channel Assessment Procedure Guidebook 1996:

Code	**Definition**
D3	Severely Degraded
D2	Moderately Degraded
D1	Slightly Degraded
S	Stable
A1	Slightly Aggraded
A2	Moderately Aggraded
A3	Severely Aggraded

Table 3: Level of Disturbance

Channel patterns were classified visually for each site using the following index in accordance with the Forest Practices Code Channel Assessment Procedure Guidebook 1996:

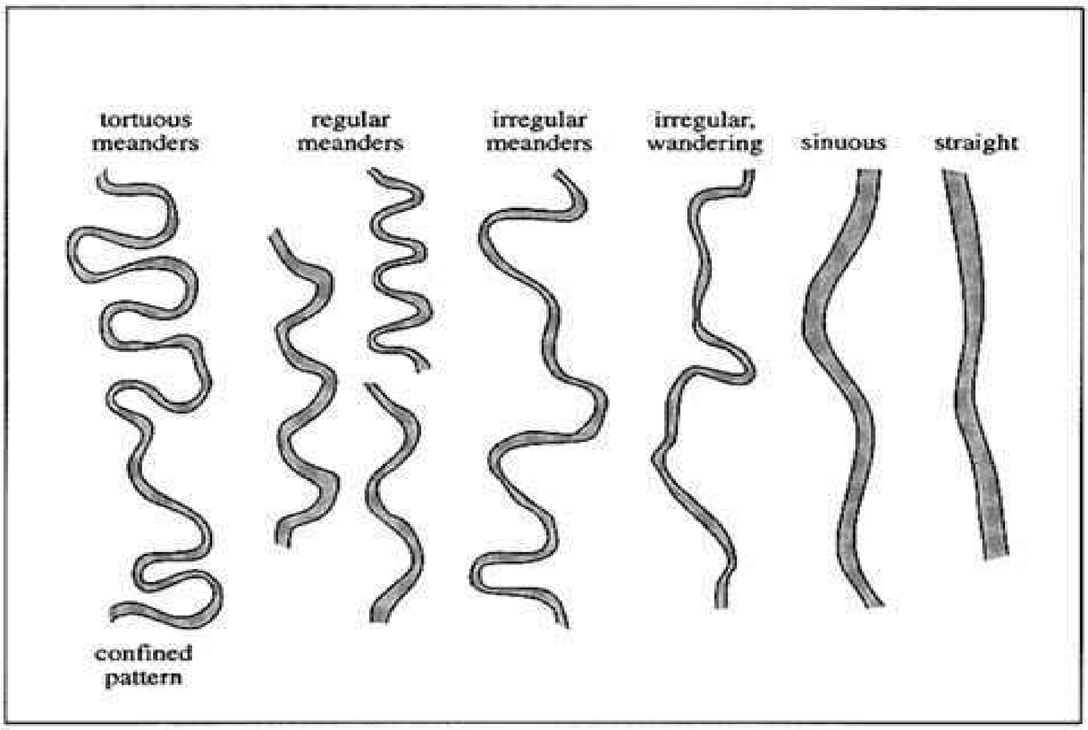

Figure 14: Channel pattern classifications

Bankfull and wetted widths were measured at upstream, middle and downstream points of the sample area. Bankfull width was defined as the width of the water surface which occurs just prior to flooding (Hogan et al. 1996). Since this assessment study was done during low flow conditions in late summer and winter, bankfull width was determined from characteristics such as: material deposited at higher flows; changes in sediment deposition; and topographic bank features (ie. break from steep bank to relatively gentle slope, change in texture of deposited sediment, and highest bank elevation where small woody material has been deposited from freshet flows but where fine woody material is absent).

Substrate

Dominant and subdominant substrate components were identified by visual assessment of stream length between downstream and upstream points of the sample area. Substrate was classified as:

Class	**Size**
Fines	0-.2 cm
Gravels	.2-6.4 cm
Cobbles	6.4-25.6 cm
Boulder	25.6-400 cm
Rock	>400 cm

Table 4: Substrate Classification

Substrate particle sizes (D90 and D values) were measured to provide information on stream morphology. Measurement was taken of the intermediate or B-axis of a particle.

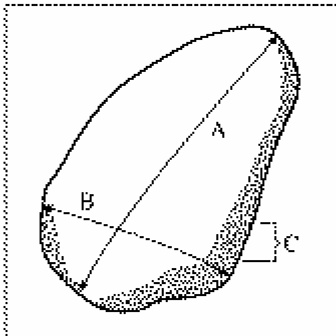

Figure 15: Identification of B-axis used in substrate particle size measurements

The D90 value was defined as that particle larger than 90 percent of the substrate. The D value represents the largest particle that can be hydraulically moved at peak discharge. In determining D values, material which originated from surrounding glacial moraines, colluvial fans or cones or exhibits a covering of old moss or staining should not be considered. Only rounded or partially rounded (not angular) substrate should be used (Hogan et al. 1996).

Bank and Riparian Characteristics

Riparian growth measurement was determined by bank shape, dominant riparian vegetation and stand structure.

Bank shape was classified by the following codes:

Code	Definition	Description
U	Undercut	Protrudes over the water or wetted channel
V	Vertical	Steep sloping/vertical (45^o-90^o)
S	Sloping	Gradual or shallow slope (<45^o)
O	Overhanging	Protrudes over a non-wetted portion of the stream

Table 5: Bank Shape Classification

Dominant riparian vegetation type was classified as:

- N - non-vegetated;
- G - grass/herb;
- S – shrub;
- C – coniferous;
- D – deciduous;
- M – mixed; or
- W - wetland.

Stand structure was classified as:

- INIT - initial succession (bare ground or early herb);
- SHR - shrub;
- PS - pole/sapling;
- YF - young forest;
- MF - mature forest; or
- OF - old forest.

Channel Gradient

Channel gradient was determined using a survey level to determine water elevations at the upstream and downstream limits of restoration sites.

Discharge

Water velocities were measured using a current velocity meter (Swoffer Instruments, Inc, Model 2100 Series) and were recorded at one meter intervals across the stream at 0.6 of water depth.

Water Quality

Temperature and dissolved oxygen (concentration and percent saturation) were measured with a portable dissolved oxygen meter (Oxyguard International, Handy Beta model). Electronic temperature readings were verified on a regular basis with a hand-held thermometer.

3.5.2 Form 2 - Site Sketch/Photo Log

Photo documentation and site sketches are invaluable tools in monitoring changes in the condition of restoration sites over time. They provide a visual representation of the structural assessment and habitat values described on Form 1 of the assessment procedures and also describe structure placement, riparian condition, bars, erosion locations, and other habitat features not included in the structure inventory format (eg. riffle/pool complexes). Several photos were taken at each sample location to represent the structural condition and riparian habitat in the area. Additional photos were also taken to provide detailed information on, for example, fish trapping methodology, specific erosion conditions and riparian planting techniques.

3.5.3 Form 3 - Riparian Vegetation Assessment

Riparian Vegetation Indicators

This methodology was based on the SRSAP manual and Koning`s (1999) WRP Riparian Assessment and Prescription Procedures (RAPP). Average height and percent cover of five riparian vegetation strata layers were collected along the restoration bank being assessed. Separate measurements were taken for 0-5 metre and 5-20 metre riparian widths. In addition, estimated shade and stem diameters of the dominant three or four species of each woody vegetation class were recorded for the 0-20 metre riparian area. In SRSAP methodology, riparian vegetation was assessed for each side of the channel, however, this study only evaluated the specific restoration bank of interest. The number of dead or decadent trees (>30 cm diameter at breast height (DBH)) that could potentially contribute to future large woody debris into the stream system were also recorded.

General Growing Conditions and Local Disturbance Factors (from SRSAP manual)

For this study, it was important to record significant onsite conditions key to the rate of riparian vegetation recovery. Quantitative assessment was not required, but there was a need to note the presence of key conditions that may affect the performance of riparian planting and/or bank restoration structures. Important indicators of site condition are: root to water depth (based on estimated low flows); soil moisture, quality and exposure; herb competition; dominant age class of vegetation; and irrigation schedule. In addition, local disturbances significantly affecting vegetative recovery were noted. This information can be used to explain the degree of vegetative recovery and, in some cases, may direct future re-vegetation strategies and remedial action.

4.0 Results

4.1 Stream Bank Restoration Structures

A total of forty-two bank restoration sites were evaluated during the summer and fall assessments (ie. between August and October 2001). Initial sampling (early August to early September 2001) was undertaken in a number of watersheds during higher stream temperature conditions. Two watersheds in particular (ie. Salmon and Deadman Rivers) were re-sampled in late September to late October 2001 when temperatures were lower and more suitable for rearing salmonid species. Sampling was repeated during the winter months of January and February 2002 in the Lower Nicola, Coldwater, Salmon, Middle Shuswap and Deadman and Bonaparte Rivers to compare juvenile salmonid abundance, species composition and habitat utilization among seasons.

Older restoration sites generally were either tree or rock revetments while more recently restored sites comprised a combination of these techniques to address both bank stabilization and fish habitat requirements. In addition to restoration sites, sampling for juvenile salmonid presence was conducted at control (impacted) sites, off-channel habitats and tributaries. During winter, a greater focus was directed at sampling off-channel habitats. This will provide baseline information for future comparison purposes. Evaluation of juvenile utilization and habitat effectiveness values for various bank restoration techniques will assist in planning and designing future British Columbia Interior restoration projects.

Four general classifications of bank restoration techniques were assessed: 1) tree revetment; 2) rock revetment (rip-rap); 3) rip-rap with large woody debris; and 4) groynes (rock or large woody material). Within each classification, a wide variety of conditions and variables exist that effect fish habitat productivity.

In general, results from GEE trapping show a considerably higher abundance of juvenile salmonids associated with restoration sites compared to control (impacted) sites. Low numbers of fish trapped in many of the assessment areas made it impossible to identify statistically significant relationships between juvenile utilization and habitat restoration techniques. Continued sampling through a long-term assessment program is necessary to identify statistically significant relationships in certain watersheds.

4.1.1 Tree Revetment

Two types of tree revetment structures were observed; traditional tree revetments and spielings. Traditional tree revetments consist of whole coniferous trees anchored to the stream bank. Trees are typically oriented with the butt anchored to the stream bank and the tips facing downstream in the wetted channel. Spielings are constructed by installing vertical stakes along an eroding bank site and weaving live willow cuttings or branches between the stakes to form a 'living wall'. Visible structural failure and bank erosion was noticeable at most of these sites. Older tree revetment structures were generally rated lower for structural integrity when compared to other types of bank restorations. However, many of these sites were built to provide short-term stability (approx. 10 years) and are nearing or have surpassed their designed life span.

(a) (b)

Figure 16: Traditional-style tree revetments (a) Deadman River and (b) Salmon River.

4.1.2 Rock Revetment (rip-rap)

Banks stabilized by rip-rap placement were highly variable in the size and amount of rock used. Most rip-rap sites showed minimal or no structural failure. Any failure was usually a result of unsuitable rock size, slope characteristics or poor protection at the base of the slope. Certain rip-rap applications have exhibited relatively low fish habitat productivity due to poor physical complexity, diversity and hydraulic function. Preliminary data from this study suggest only a weak correlation of juvenile coho utilization with rip-rap sites. Any juvenile coho utilization of rip-rap sites was associated with woody debris trapped within the rocks.

Figure 17: Typical rip-rap bank protection on the lower Nicola River.

4.1.3 Rip-rap with Large Woody Debris

Although the traditional application of only wood (tree revetment) or rock (rip-rap) is still used, integrated techniques combining large woody debris and rip-rap that address a greater degree of bank stabilization, as well as providing fish habitat, are now being used. Rock-based bank restoration with large woody debris (usually rootwads) anchored throughout the site was the common technique assessed. They rated high in structural integrity and provided adequate fish habitat value. The woody debris provided most of the fish habitat value by increasing cover and complexity and providing hydraulic diversity. Fish habitat ratings varied from very poor to excellent depending on woody debris placement and abundance.

Figure 18: Good habitat value provided by rip-rap and large woody debris on Mann Creek.

One problem limiting fish and habitat values at a number of sites is the placement of woody debris structures too high on the stream bank and out of lower stream flows. Although providing some benefit, such placement fails to provide productive instream habitat in the form of cover, shade, physical and hydraulic complexity, and aquatic insect production at low flows.

Figure 19: Elevated rootwad placement provided limited fish habitat value.

4.1.4 Groynes (rock or large woody debris)

The groyne structures assessed consisted of rip-rap and/or large woody debris structures oriented in spurs spaced at specific intervals along the stream bank. Large woody debris is often used between groynes to provide additional fish habitat. These are used to stabilize banks by deflecting the stream thalweg away from the unstable bank and towards the middle of the channel. By deflecting the main stream flow away from the impacted bank, the total amount of rock can be minimized, allowing the opportunity for greater bank re-vegetation. Four groyne sites were assessed as part of this study. All groyne sites were structurally stable and required minimal or no maintenance. Groynes received high values for all effectiveness rating categories, including the highest value for hydraulic function amongst the four classifications of bank restoration techniques.

4.2 Riparian Habitat and Management

Extensive effort has been directed at re-establishing protected stream bank corridors. However, survival of planted cuttings (usually willow) and rooted stock (various species) was low at most restoration sites evaluated. Deadman, Bonaparte and Nicola River sites exhibited the lowest survival of riparian re-vegetation, collectively estimated at less than five percent. A commitment by landowners to properly maintain livestock exclusion areas and riparian vegetation after construction is vital to the success and survival of stream bank vegetation. However, livestock access into some protected stream bank areas was observed. Although watering during summer months can increase survival of planted stocks, at some sites it appeared that irrigation and regular maintenance was ineffective. This may be due to poor irrigation timing or planting technique (e.g. cut stock planted upside down or cut stock not planted deep enough or into groundwater). Cuttings should be planted near the wetted perimeter and into groundwater.

Figure 20: An example of poor re-vegetation success on the Bonaparte River.

Riparian planting in the Shuswap Sub-basin exhibited the greatest survival. Landowner commitment and fence maintenance were very good in the Salmon, Bessette, Duteau and Harris watersheds. Of the sites evaluated, only one riparian site on Duteau Creek showed negative impacts (due to vehicle access).

A variety of planting techniques have been used to restore riparian areas. This assessment study has identified some trends with respect to successful riparian planting techniques in the British Columbia Interior. Large diameter cut stock generally had considerably better survival than small diameter whips. The greatest survival of whips occurred on the lower slope of restoration banks, usually within 1-2 m of the wetted channel. It would appear that more monitoring and detailed guidelines on planting techniques would improve the success of riparian re-vegetation.

Figure 21: Large diameter cut stock producing good initial re-growth.

4.3 Effectiveness Evaluation

Each bank restoration structure classification was rated for performance by evaluating structural integrity, hydraulic function, fish habitat value and maintenance requirements.

	Mean Present Condition Summary Ratings			
Structure	**Structural Integrity**	**Hydraulic Function**	**Fish Habitat Value**	**Maintenance Requirements**
Tree revetment	2.5	1.5	2.3	3.0
Rock revetment (rip-rap)	3.6	1.4	1.5	3.8
Rip-rap with large woody debris	3.8	1.7	2.3	3.9
Groynes (rock or large woody debris)	3.8	2.5	2.5	3.8
Riparian planting	1.5	N/A	1.1	1.9

Table 6: Mean performance rating for each of four general bank restoration classifications, including riparian planting (1 = failure (not meeting objectives) to 4 = good to excellent - see Methods for detailed rating scale).

Although not included in this study, a more detailed classification of bank restoration techniques may have identified further differences in structural integrity and fish habitat values. For example, there may be differences in rip-rap sites if the use of large versus small rock were compared. Also, distinct changes in the condition of restoration sites may also be apparent if structural age was considered. Defining structure types into more refined groups has distinct advantages for detailed evaluations. In any event, analysis of only one year of data is not sufficient to draw in-depth conclusions from specific structural detail. More monitoring is needed to fully evaluate performance effectiveness and longevity of habitat restoration structures.

Groynes and large woody debris structures exhibited the highest structural integrity and required minimal maintenance. Tree revetments provided adequate fish habitat but received lower ratings for structural integrity and maintenance. Tree revetment structures were considerably older than rock/rootwads and groynes and, consequently, would have been exposed to more high water events. This would be a key factor in compromising structural integrity and maintenance requirements, thus lowering their mean performance rating.

Special consideration should be given to evaluating riparian planting. Riparian re-vegetation is a very important component in restoring stream corridor integrity and assisting the natural recovery of stream ecology. Riparian planting received the lowest mean performance effectiveness rating for structural integrity and fish habitat value. As successful riparian habitats mature, the expected long-term effects of riparian planting should increase effectiveness ratings. To achieve long-term success of riparian re-vegetation, there must be improvements in existing planting techniques. Maintenance requirements for riparian vegetation (eg. irrigation, re-planting) were considerably higher than that for other structural components and, in many cases, were having minimal results.

The mean performance ratings shown in Table 6 do not provide an overall indication of all restoration sites in the British Columbia Interior but are representative of the four stream bank restoration techniques commonly used. Obviously some past restoration sites have not met performance objectives or have completely failed. Lower performance values would be expected if the selection of sites and restoration structures for this assessment study had been broader and included failed sites.

4.4 Off-channel Restoration Development and Tributaries

The development of off-channel habitats has become an increasing focus of fish habitat restoration in many interior watersheds. As part of this study, developed off-channel habitats such as smolt imprinting ponds and groundwater channels and ponds, as well as irrigation ditches, beaver ponds and tributaries, were sampled for fish presence. Physical parameters were also measured, but on a limited basis due to time constraints. These data were used to supplement mainstem biological sampling. In many locations, these off-channel habitats and tributaries produced considerably different results than mainstem sampling.

Maintaining fish passage into off-channel habitats was one concern identified during this assessment project. Of the seven off-channel projects sampled, only two had reasonable fish passage. Of the remaining five sites, four had beaver activity at or near the outlet and one was isolated by mainstem sediment deposition.

4.5 Shuswap Sub-basin

4.5.1 Salmon River

The Salmon River system was assessed during three sample periods, early and late August 2001, mid-October 2001 and early January 2002. Seven mainstem restoration sites and two control sites were sampled and assessed in early August 2001. Several off-channel habitats and tributaries were sampled in late August 2001 for species composition and abundance comparisons. Repeat sampling of the mainstem restoration sites and off-channel habitats was done in mid-October 2001 and January 2002. Cpue at mainstem sites was low during all sampling periods.

Spawning escapements of coho and chinook into the Salmon River are monitored at a fish fence. In fall 2000, 58 coho adults and 355 chinook adults were enumerated at the fence. These low escapement numbers undoubtedly contributed to the low numbers of juvenile salmon identified in the Salmon River system during this study.

In August 2001, Vemco temperature recorders were installed to monitor temperature data at various locations along the Salmon River. Maximum daily temperatures of 21-23 ^{o}C were recorded in mid- to late August 2001.

Mainstem Restoration Site Assessment

Few salmonids were captured at mainstem restoration sites in the Salmon River during all sampling periods. Only 78 juvenile salmonids were captured by 355 GEE traps and minor electrofishing effort (approximately 200 seconds). Rainbow trout were present in the highest abundance (82.1 %) from mainstem trapping during the three sample periods, followed by chinook (16.7 %) and coho (1.3 %). During all three samplings, the highest concentrations of rainbow trout were found in the mainstem upstream of Silver Creek to Falkland. All chinook and coho trapped in the mainstem were captured during the October sampling. Due to extremely low trapping densities at restoration sites, no reasonable comparisons of juvenile utilization and restoration technique were possible. Cpue data for all mainstem, off-channel and tributaries are shown in Table 7.

Salmon River Tributary and Off-channel sampling

Sampling efforts in tributaries produced considerably higher cpue values than mainstem sampling for all juvenile salmonid species. Relative species abundance was also considerably different from mainstem sampling areas. Rainbow trout were trapped in highest abundance (43.0 %), followed closely by chinook (41.8 %) and at a lower proportion by coho (14.3 %). Palmer Creek was the only sampling site where coho, chinook and rainbow trout were found during all three sampling periods (Table 7). Chinook and rainbow were found in Kernaghan and Silver Creeks. During the January sampling period, GEE traps were placed in drainage ditches, fed by an unnamed tributary from Mount Ida. These sites were of particular interest due to recent excavation and ditch maintenance in November 2001. In 13 traps, 2 coho and 4 chinook juveniles were caught in these ditches.

Sampling by M. Wallis (SRWR) in August 2000 produced similar results when comparing species composition and abundance between mainstem and tributaries of the Salmon River.

Location	**No. of traps**	**Cpue**		
		CO	**CH**	**RBT**
Late Summer (early and late August '01)*				
Salmon River Mainstem	134	0.0	0.0	0.1
Palmer Creek	10	0.3	0.6	0.4
Fall (mid-October '01)				
Salmon River Mainstem	101	0.0	0.1	0.2
Palmer Creek	10	1.0	2.3	1.2
Winter (early January '02)				
Salmon River Mainstem	120	0.0	0.0	0.2
Palmer Creek	10	1.2	0.7	1.2
Kernaghan Creek	6	0.0	0.0	0.7
Irrigation Ditch site	13	0.2	0.3	0.0

Table 7: Cpue in mainstem and tributary sites on the Salmon River.

* Kernaghan and Silver Creek electrofishing data not included.

At the time of this study, three groundwater-fed off-channel sites sampled were being considered for restoration development. Fish passage to these areas is inaccessible or limited to high water conditions. One groundwater-fed channel had previously been highly productive but now exhibits limited productivity. Only one juvenile coho was captured in 40 GEE traps. No salmonids were captured at the other two potential off-channel project sites. [Since this study, juvenile salmonid rearing habitat and access has been developed at these three off-channel sites.] The feasibility of developing an existing beaver pond complex adjacent to Silver Creek is also a possibility.

4.5.2 Bessette Creek/Harris Creek/Duteau Creek

Eight restoration sites and three control sites were sampled in the Lumby area. For Bessette, Harris and Duteau Creeks, the cpue values for rainbow were highest, followed by chinook and coho. Low numbers of coho and chinook fry likely reflect low escapement from the previous year. Adult fish counting fences on Harris and Duteau Creeks in fall 2000 recorded 17 and 10 coho adults, respectively. Stream walks recorded 11 and 31 chinook adults in Harris and Duteau Creeks, respectively.

In the mid- to late August 2001 sampling, rainbow trout accounted for the highest salmonid species abundance (83.9 %) in the three systems, followed by chinook (13.8 %) and coho (2.0 %). Trap data for the Harris Creek rip-rap site (approx. 3 km upstream from Lumby) is not accurate due to GEE trap tampering. Data from the August sampling at Bessette, Harris and Duteau Creeks is shown in Table 8. Cpue was significantly higher at restoration sites compared to control sites. At the eight restoration and three control sites sampled, only five coho juveniles were captured.

All coho were captured at sites containing woody debris that was purposely placed to create rearing habitat complexity.

Location	**No. of traps**	**Cpue**		
		CO	**CH**	**RBT**
Summer (mid- to late August '01)				
Duteau Creek	75	0.0	0.1	1.2
Bessette Creek	15	0.2	0.5	1.4
Harris Creek	42	0.0	0.2	1.2
Duteau off-channel	9	0.0	0.0	0.3
Winter (late January' 02)				
Duteau Creek	80	0.0	0.0	1.0
Bessette Creek	15	0.0	0.0	0.3
Harris Creek	45	0.0	0.0	1.8
Duteau Smolt Ponds	5	1.6	0.6	0.8
Golf Course Ponds*	10	0.4	0.1	1.4

Table 8: Cpue of stream bank restoration sites and off-channel sites on Bessette, Duteau and Harris Creeks

* Golf course ponds include an outlet channel to Duteau Creek (all fish trapped were in outlet channel)

Maximum daily water temperatures approached 23 ^{o}C during early August 2001 in Harris Creek. Data from Vemco thermographs at other locations in the Middle Shuswap study area are being collected.

A restoration groundwater channel developed in 1994 and tributary to Duteau Creek (approx. 2 km upstream of Lumby) was the only off-channel sampled during August 2001. Nine GEE traps were placed along an approximate 200 m section of the channel. Shallow water depths limited the choice of trap placement locations in much of the channel. Three rainbow (no chinook or coho) were trapped in this off-channel. Although only a short section of the channel was sampled, low water conditions likely limited access and productivity.

Repeat sampling of all restoration sites previously assessed was done in late January 2002. Lower cpue values for salmonids were observed during the winter assessment and significant changes in relative species abundance were detected in mainstem locations. Rainbow trout made up almost the entire abundance of salmonids captured in the mainstem (98.8 %) with chinook accounting for the remainder (1.2 %). No coho were caught in mainstem restoration sites during the January sampling period.

The relative abundance of salmonid species in smolt imprinting and rearing ponds recently constructed adjacent to Duteau Creek (approx. 6 km upstream of Lumby) were considerably different compared to the mainstem. During the January 2002 sampling, five traps were placed each in the smolt ponds and the mainstem. Eight coho and three chinook were captured in the smolt ponds. In the five mainstem traps adjacent to the smolt ponds, only one chinook was captured.

A second off-channel sampled during January 2002 was a pond complex on golf course property (approx. 1.5 km upstream of Lumby). A beaver dam at the outlet of the pond to Duteau Creek is likely limiting fish access. As a result, no fish were captured in five GEE traps. Five traps were also placed in a short channel connecting the ponds to Duteau Creek. Two coho, one chinook and seven rainbow trout were captured.

Although coho and chinook appear in low numbers in these off-channel habitats, cpue values are consistently higher than in the mainstem.

4.6 Thompson-Nicola Sub-Basin

4.6.1 Deadman Creek & Tributaries

A relative high abundance of coho, chinook and rainbow trout was observed in the Deadman River system. The abundance (cpue values) of salmonids in mainstem reaches was much higher upstream of its confluence with Criss Creek compared to downstream reaches. Six restoration sites, two control sites and a restored off-channel (approx. 25 km upstream of the confluence with the Thompson River) were sampled in early September 2001. Repeat sampling of the restoration sites were done in late October 2001 and early February 2002. Three tributaries were also sampled with six GEE traps each in late October 2001.

Deadman River Stream bank Restoration Structures

Relative species abundance in the mainstem was 60.4 % for rainbow trout, 26.8 % for coho and 12.8 % for Chinook. Mainstem restoration sites above Criss Creek showed higher cpue and greater relative species abundance of chinook and coho juveniles. Cpue data are shown in Table 9.

Location	No. of traps	Cpue		
		CO	CH	RBT
Summer (early Sept '01)				
Deadman River	100	1.7	0.6	3.3
Restored Off-channel	12	3.4	2.6	3.5
Fall (late October '01)				
Deadman River	70	1.1	0.9	3.6
Restored Off-channel	10	3.8	1.9	4.1
Criss Creek	6	0.0	0.2	2.8
Tobacco Creek	6	0.2	0.0	2.8
Gorge Creek	6	0.0	0.0	0.3
Winter (early February '02)				
Deadman River	60	0.4	0.2	1.2
Restored Off-channel	10	2.9	0.2	1.3

Table 9: Cpue for restoration sites, restored off-channel and tributaries on the Deadman River.

Catch success at restoration sites approx. 30 km upstream of the confluence were sufficient to reasonably compare juvenile utilization of various prescriptions. Within a 300 m section of river, three different techniques were used for bank stabilization; ie. rip-rap, rock with large woody debris, and rock groynes with large woody debris. A control site was sampled within this section. The rip-rap site (including the control site) exhibited the lowest cpue of juvenile coho, but the highest for rainbow trout and juvenile chinook (Figure 22). In the two restoration sites utilizing large woody debris and the control site, cpue for chinook and rainbow were less than half the cpue in the rip-rap site. The highest cpue for coho were found at those prescriptions utilizing large woody debris.

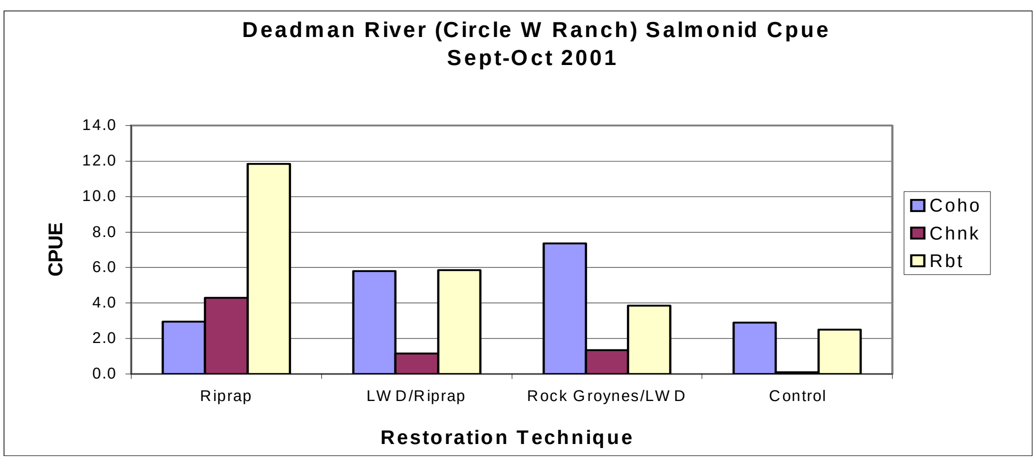

Figure 22: Cpue for salmonids at one control and three restoration sites at Circle W Ranch, Deadman River – September to October 2001.

In view of the relatively large numbers of juvenile fish caught, mark-recapture sampling to estimate juvenile coho populations was attempted at sites on the Deadman River. Mark-recapture trapping was done using GEE traps. However, recapture of marked fish was generally low which may be due to marked fish exhibiting trap avoidance. As a result, data was not adequate for statistical analysis. If population estimates are the primary objective in future assessments, additional techniques to capture fish should be used for recapture purposes.

Spius Creek Hatchery released approximately 15,000 coho fry into mainstem Deadman Creek in spring 2001. Hatchery staff indicated that these fry were released in upper Deadman River, which to some degree likely contributed to the higher cpue observed at the restoration site 30 km upstream compared to lower densities downstream. High cpue values for rainbow trout may reflect contributions from the steelhead population and the several lakes in the upper watershed.

The resistivity counter on Deadman Creek recorded 831 coho adults and 787 chinook adults entering the system in fall 2000. The system supports an annual return of approximately 400 steelhead.

Off-channel and tributary sampling

The restored off-channel and three tributaries were sampled for fish presence in early September and late October 2001 and in early February 2002. Limited natural off–channel habitat exists in the Deadman River system. The restored off-channel was constructed in 1999 and provides approximately 2,200 m² of spawning and rearing habitat. Although cpue was greater than most mainstem sample sites, several factors may have limited the productivity of the channel in 2001. One limitation was a large beaver dam at the downstream end which impeded fish access. The second factor limiting salmonid populations in the channel was a fish trap located at the mid-point of the channel. Installed in spring 2001 to monitor juvenile salmonid out migration from the channel, the trap had not been removed and was left unattended. As a result, passage through the off-channel was impeded and fish mortality occurred.

Length and weight measurements of juvenile coho indicated this restored off-channel may be more productive than the mainstem. The average coho length in the off-channel was 78.9 mm compared to average coho length in the mainstem of 72.9 mm. The largest juvenile coho and chinook were trapped in pools created by beaver activity at the downstream end of the channel.

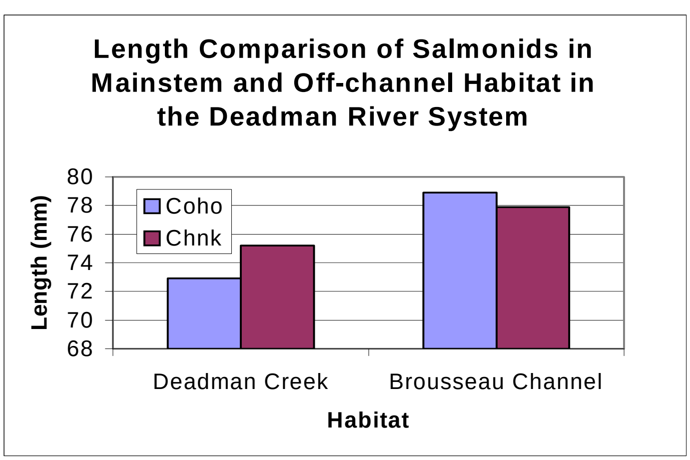

Figure 23: Comparison of coho and chinook lengths in mainstem restoration sites and the restored off-channel October, 2001.

The restored off-channel also had considerable differences in relative species abundance compared to the mainstem. Relative abundance of rainbow trout, chinook and coho in the channel were 39.3 %, 23.7 % and 37.0 % respectively (mainstem relative abundance was 60.4 %, 12.8 % and 26.8 %).

4.6.2 Bonaparte River

The Bonaparte fishway, operated by the Thompson Basin Fisheries Council and the Bonaparte Indian Band, counted 5,258 chinook adults and 62 coho adults during the 2000 migration. Juvenile salmon catches in the Bonaparte reflected these numbers. Five restoration sites and one control site were sampled in mid-September 2001 and mid-February 2002.

In September 2001, 114 juvenile salmonids were trapped at the six sample sites. The relative abundance of salmonid species was highest for juvenile chinook (57.9 %), followed by rainbow trout (42.1 %). No juvenile coho were captured during the September sampling. Juvenile rainbow trout may be offspring of resident Thompson/Bonaparte fish or anadromous steelhead. Most chinook juveniles were found at sites exhibiting integrated rip-rap and large woody debris and located on Bonaparte Indian Band land upstream of Cache Creek. Most rainbow trout juveniles were found at sites sampled just downstream of the Loon Lake hatchery site. Since overall cpue at most sites was relatively low, little association with species and habitat types was evident.

Location	No. of traps	Cpue		
		CO	CH	RBT
Summer (Sept '01)				
Bonaparte River	90	0.0	0.73	0.42
Winter (January '02)				
Bonaparte River	80	0.01	0.04	0.45
Hat Creek (mainstem & beaver ponds)	6	0.0	0.50	1.33
Off-Channel Ponds (upstream of Bonaparte Indian Band land)	5	0.0	0.0	0.0

Table 10: Cpue for stream bank restoration and off-channel sites on the Bonaparte River.

A considerably different abundance of salmonids was observed in the February 2002 sampling. Of the five restoration sites, only three chinook and one coho were captured. Rainbow trout cpue was very similar to previous samplings, with 35 juveniles captured and the highest cpue was located at two sites approximately 5 km upstream adjacent to Loon Lake Road.

A small trapping effort on Hat Creek at several mainstem sites and a large beaver pond identified chinook and rainbow trout. No coho were found.

4.7 North Thompson Sub-Basin

4.7.1 Louis Creek

Very few salmonids were identified from sampling four restoration sites, three eroding banks and one natural control site in Louis Creek during mid-October 2001. In 115 GEE traps only 79 juvenile salmon were captured. Relative species abundance of salmonids was highest for rainbow trout (82.3 %), followed by coho (15.2 %) and chinook (2.5 %) (Table 11). Ten of the twelve juvenile coho captured were trapped at a recently constructed restoration site on the Mel-Bar Ranch.

The fish fence operated downstream of the Ranch recorded 193 coho and 611 chinook adults in fall 2000. In addition, approximately 26,000 coho fry were released by the Dunn Lake hatchery in May-June 2001.

Sampling at the Ranch property was done as part of an ongoing agriculture study in partnership with the property manager, First Nations, government agencies and industry. The primary focus of the project was to investigate the effects of various livestock management strategies, riparian prescriptions and instream habitat restoration on the aquatic ecosystem and on the recovery of riparian vegetation. Sampling sites included one bank restoration site; a natural control site; and two locations classified as eroding banks that had been recently planted with cuttings, but essentially showed no bank stability. In this case, the control site represented natural stream conditions within this section of river (eg. undercut banks, riparian vegetation and cover, and large and small accumulations of woody debris). In addition to the Ranch sampling sites, three other restoration sites on Louis Creek were selected for assessment.

4.7.2 Raft River and Mann Creek

Two restoration sites on mainstem Raft River, the Raft off-channel and one restoration site on Mann Creek were assessed. Relative species abundance for coho, chinook and rainbow trout in Raft River was 33.4 %, 61.6 % and 5.5 %, respectively. Relative species abundance for coho, chinook and rainbow trout in Mann Creek was 82.4 %, 17.0 % and 0.6 %, respectively (Table 11).

Location	**No. of traps**	**Cpue**		
		CO	**CH**	**RBT**
Fall (Oct '01)				
Raft River	30	0.43	0.77	0.07
Louis Creek	115	0.1	0.02	0.65
Raft Off-Channel	14	1.7	0.3	0.0
Mann Creek	20	13.6	2.8	0.1

Table 11: Cpue for stream bank restoration and off-channel sites on North Thompson tributaries.

Sites in Raft River showed a more even distribution of coho and chinook, however there were distinct differences between mainstem and off-channel sites (Figure 24). In the two mainstem sites, chinook juveniles were most abundant followed by coho and rainbow trout. In the Raft off-channel, coho were most abundant followed by chinook. No rainbow were captured in the Raft off-channel.

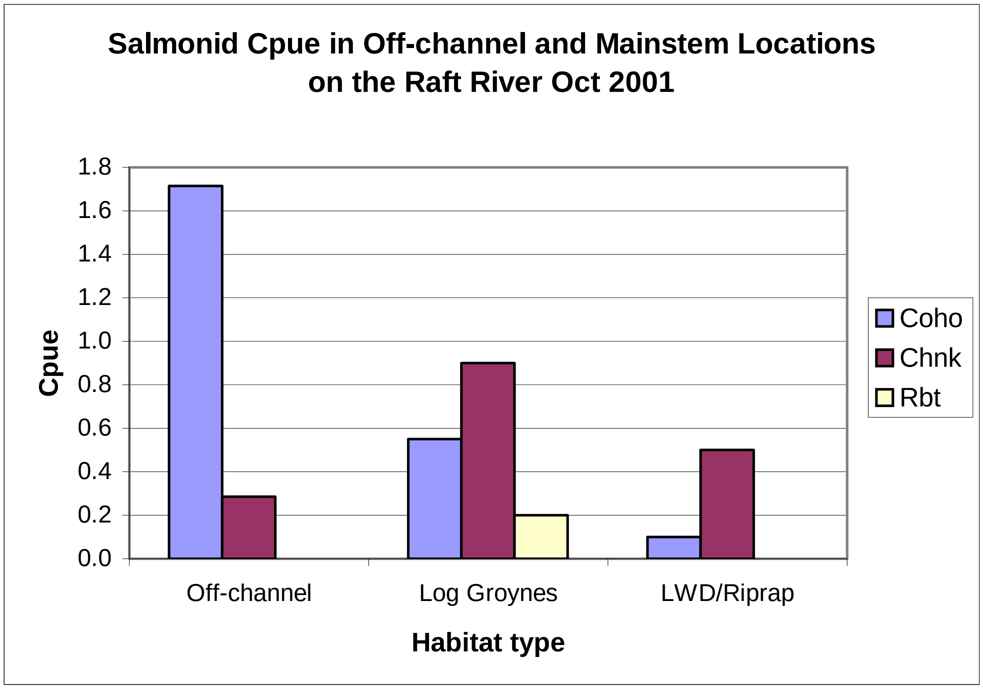

Figure 24: Comparison of Cpue for salmonid species in the Raft River mainstem and off-channel restoration sites.

4.7.3 Upper Nicola River

The Upper Nicola River produced the lowest cpue values for salmonids of all mainstem locations sampled during the 2001 assessment project. In 112 GEE trap sets in mid-September 2001 (including an off-channel approx. 1.5 km upstream from the mouth), only two chinook juveniles were captured. No other salmonid species were trapped in the Upper Nicola mainstem. The eight sites assessed on the Upper Nicola River included four large woody debris/rock sites, one rip-rap bank, two control sites and one off-channel development. The very low numbers of salmonids caught may be due to high stream temperatures during the month prior to sampling. DFO and the now Provincial Ministry of Environment consider all fish bearing streams in the Nicola River Basin as "temperature sensitive". In July and August 2001, daily maximum water temperatures were in the low to mid-twenties. A maximum stream temperature of 25.5 ^{o}C was recorded on August 16th. These temperatures create high stress, low growth, high metabolism and likely lethal conditions for juvenile salmonids. Under these conditions, any additional stressors would likely result in juvenile mortality. Trapping in Spahomin Creek, a mainstem tributary upstream of Douglas Lake, however, did identify a few rainbow and chinook juveniles.

In addition to low cpue for juvenile salmonids, several other indications of poor water quality were noticed during field assessment. In several traps, mortality of sculpin (*Cottus sp.*) was found. Nothing unusual in the trapping methodology could be determined to attribute to the mortality. Adult mortality of pre-spawn kokanee was also noticed throughout the study area and 5 dead adult burbot were discovered in the lower reach just upstream of the Highway 5 bridge.

Due to extremely low numbers of returning adults, enumeration fences have not been operated in the Upper Nicola River in recent years. In 2000, only six coho adults were enumerated by stream walk crews. The Spius Creek hatchery released 20,000 chinook at the Spahomin Creek smolt ponds in 2001. In six traps set near the smolt ponds, one chinook and three rainbow trout were captured. Most juvenile chinook released at the site would have been expected to emigrate by September.

4.7.4 Lower Nicola River

Assessment of the Lower Nicola River was conducted on two ranch properties below the outlet of Nicola Lake. Six bank restoration sites, two control sites, one tributary and an irrigation ditch intake channel were sampled in late September 2001. Repeat sampling of all restoration sites and one control site was done in January 2002.

During the September sampling period, cpue for salmonids in the Lower Nicola mainstem was slightly higher than the Upper Nicola. However, similar to the Upper Nicola, juvenile chinook were the only salmonids captured. In 120 GEE trap sets in mainstem locations, only nine juvenile chinook were trapped. Trapping of tributaries and the irrigation ditch produced considerably higher cpue for salmonid species. Fourteen GEE traps were set in a 2 km reach of Clapperton Creek from its confluence with the Nicola River. Sixty-five juvenile rainbow and one chinook were captured in this reach. Ten GEE traps were also set in the irrigation ditch upstream and downstream of the Finnigan fish screen. In these traps, nine juvenile chinook were captured.

January re-sampling of the mainstem structures produced lower cpue. In 100 GEE traps, two chinook and one rainbow juvenile were captured.

In year 2000, stream walk crews from the Nicola Watershed Stewardship and Fisheries Authority recorded no spawning coho in this section of the Lower Nicola River. DFO’s Spius hatchery released 35,300 chinook fry into the Lower Nicola system.

4.7.5 Coldwater River

Assessment of restoration projects on the Coldwater River focussed on several off-channel habitats. The Zoltan Kuun ponds (groundwater-fed ponds located approx. 45 km upstream of the confluence with the Lower Nicola River in Merritt and developed in conjunction with a fish habitat compensation program for Coquihalla Highway construction), the Juliet off-channel (approx. 50 km upstream of the confluence), and a mainstem section of the Coldwater River adjacent to the Juliet off-channel were sampled in late September 2001 and January 2002. Limited traps were available for the initial sampling in September. In January, twelve GEE traps were also set in a large beaver pond complex approximately 2 km downstream of the Juliet channel. This site was used in the past as a control site for previous assessments of the Zoltan Kuun ponds. Juvenile salmonid cpue values for the Coldwater River system are shown in Table 12.

Location	No. of traps	Cpue		
		CO	CH	RBT
Fall (September '01)				
Juliet Channel	10	38.0	0.3	0.1
Zoltan Kuun Ponds	16	4.1	0	0
Coldwater River	10	13.3	2.8	0
Juliet Channel Groundwater source	3	2.3	0	0
Winter (January '02)				
Juliet Channel	20	13.5	0.1	0.5
Zoltan Kuun Ponds	50	5.2	0	0
Coldwater River	20	0.1	0	0.3
Juliet Channel Groundwater source	10	2.1	0	0.2
Beaver Ponds	20	0.3	0	0

Table 12: Cpue values for salmonids in the Coldwater River system in September 2001 and January 2002.

Cpue values in January were lower than September for all sites on the Coldwater system. Although cpue values in the Juliet off-channel dropped between September to January, values were still considerably higher than all other sites. Cpue values for the Juliet off-channel in September may be skewed due to the fact that one of the hatchery coho release sites was in the Coldwater mainstem immediately downstream of the Juliet off-channel confluence. The Coldwater mainstem had considerably lower cpue values in January compared to the earlier trapping in September. During winter trapping in the Coldwater mainstem, water temperatures were recorded at 1.5 ^{o}C. At this temperature, low catch rates would be expected. The temperature recorded in Juliet off-channel at the same time was 4.5 ^{o}C. This temperature would likely attract overwintering coho and would be a more productive winter habitat. Thermographs have been placed in both the Coldwater mainstem and Juliet off-channel and will provide temperature information throughout the year. Traps were also placed in the excavated channel which supplies groundwater to the Juliet off-channel. Low cpue values of juvenile salmonids were observed in this section, however, access is limited to high water periods when it is connected to the mainstem. Fish access to the Zoltan Kuun ponds and to the beaver pond complex is limited by beaver dams at the outlet of each site and low cpue values observed at these sites are likely a result of access problems. Table 13 shows the average length and standard deviation of coho measured in each of the sample areas.

Location	Coho		
	Total trapped	Avg. Length (mm)	St. Dev
Groundwater source for Juliet off-channel	7	89.6	12.5
Juliet Channel	380	62.9	14.4
Highway Ponds	66	63.3	13.7
Coldwater Mainstem	133	66.9	8.1

Table 13: Comparison of average coho lengths in various habitats in the Coldwater River system.

5.0 Discussion

5.1 Physical Effectiveness

5.1.1 Structural Inventory

Assessment of the structural integrity of stream bank and off-channel restoration in this study has provided an indication of the performance of many restoration techniques and prescriptions. Mean effectiveness ratings indicate that some components of stream bank restoration are meeting performance expectations. However, others require maintenance and indicate a need to change certain riparian restoration practices. Habitat restoration projects that are designed and built to accommodate hydrological considerations, channel characteristics and fish habitat requirements have a much greater potential for being successful and highly productive.

Rock-based (rip-rap) bank stabilization projects generally meet stream bank stabilization objectives, can be a relatively inexpensive method of controlling erosion and require only minimal maintenance. However, they do not provide the intricate habitat requirements for multiple salmonid species (Schmetterling et al. 2001). In the Deadman River watershed where preliminary data was sufficient to make general observations, the habitat preference of juvenile coho showed the lowest association with rip-rap, compared to other restoration techniques. Conversely, rainbow trout showed the greatest preference for rip-rap. However, additional study is required for statistical comparison.

Riparian restoration utilizing extensive woody material is usually undertaken to promote more natural stream bank stabilization, revegetation and hydrological functioning and, in particular, to provide highly productive and preferred salmonid rearing habitat. However, such techniques generally do not last as long as rip-rap. Prescriptions incorporating both rock and woody material address both bank stabilization (and property loss) concerns and fish habitat requirements. Preliminary review of rock groyne structures incorporating large woody debris suggests these sites may create more hydraulic diversity and fish habitat utilization than rock placed uniformly along the bank. The groynes assessed in this study addressed landowner concerns, rated high in structural integrity and were low maintenance. In addition, decreased hard armouring of stream banks between groynes can promote bedload deposition, natural revegetation and stabilization. All groyne sites monitored during this study were recently constructed and have not experienced major high water events. Monitoring these structures after significant freshets will provide more information regarding structural performance and fish habitat productivity.

In evaluating the use of wood in the various techniques described above, some questions arose regarding the proper placement of restoration structures to maximize fish habitat productivity. At some sites, woody material was placed and anchored well above low water levels, in some cases outside the wetted channel. This was particularly evident for rootwad placement. Fully branched coniferous trees appear to provide more intricate and complex habitat by increasing the amount of small woody debris. As a general observation, rootwad structures did not appear to provide as much habitat complexity as full trees.

5.1.2 Geomorphic Factors

Geomorphologic information collected in this study will provide useful baseline data for future comparative monitoring work. As examples, site sketches and photographic documentation and the collection of basic channel characteristics and substrate condition have provided updated information at many sites.

Recommendations for future physical assessments include:

1) Increase the number of geomorphic factors measured and include residual pool, bankfull and wetted channel depths;
2) Assess physical characteristics of off-channel habitats;
3) Document the amount, type and quality of spawning gravel; and
4) Refine performance ratings to include finer (ie. 0.5 point) increments.

5.1.3 Riparian Vegetation

While significant funds have been directed at increasing the structural stability of stream banks, the function of vegetation in stabilizing stream banks seems to have been overlooked. Riparian planting efforts have not achieved expected results at many of the project sites evaluated, particularly in the Thompson-Nicola sub-region. Since re-vegetation of riparian corridors within interior watersheds is a primary component in longer-term fish habitat restoration, there needs to be more consideration and effort focussed on maximizing the success of riparian planting. Observations of successes and failures and recommendations pertaining to alternative techniques used to re-establish riparian vegetation have been made, but it appears that information has been poorly distributed and progress slow to increase success of riparian planting.

Recommendations to increase survival of planted stock include:

1) Explore the feasibility of using 2+ year old tree spade or nursery rooted stock rather than 1 year old stock;
2) Increase planting of large diameter cuttings;
3) Provide increased training and supervision for planters;
4) Include a maintenance component into riparian planting budgets;
5) Provide site specific planting prescriptions; and
6) Focus on lower slopes of the stream bank when small diameter cuttings (ie. willow whips) are planted and ensure that the base of whips are planted below the level of the lowest water table (ie. low stream flow level).

5.2 Biological Monitoring

Although only limited analysis of data from one year of fish sampling was possible from this study, some trends in juvenile salmonid utilization are evident. Comparing the utilization by juvenile salmonids of different stream bank restoration techniques has shown variations in cpue and species composition.

Repeat monitoring of sites in this study between August and February has allowed a comparison of seasonal data. In systems where off-channel, tributary and mainstem habitats were sampled and compared (eg. Salmon and Deadman Rivers), the relative abundance of salmonid species was in most cases greater in off-channel and tributary sites. This was particularly the case for juvenile coho, where tributary and off-channel rearing was most noticeable during the critical winter rearing period. Brown (1985) found that juvenile coho entered off-channel sites in October–November. In the tributaries of the Salmon and Middle Shuswap Rivers, almost all coho and chinook were GEE trapped in off-channel habitats during winter. It must be emphasized, however, that despite the strong and consistent trends in this study, these findings are based on small sample sizes. Several factors including woody debris, overhead cover, substrate, and water chemistry, temperature, clarity, velocity and depth affect species utilization and abundance. Bustard and Narver (1975) attribute water depth, velocity and availability of cover as important features determining suitable overwintering habitat. These variables were not assessed in off-channel sites.

In order to preserve the productivity of developed off-channel habitats, it has been identified and recommended in this study that these habitats need to be maintained, in particular, ensuring physical access for both juvenile and adult salmonids.

Assessment of invertebrate populations was not included in this project, but is a critical and much overlooked indicator of stream condition and habitat productivity. Although laboratory identification and analysis of invertebrates can be time consuming and expensive, monitoring invertebrate populations should be considered for future projects.

Water temperature is a critical component affecting habitat utilization and the survival of juvenile salmonids, particularly in the interior or British Columbia where elevated summer water temperatures can reach lethal levels in certain watersheds. As a result of field assessments, the extent of temperature monitoring in mainstem and off-channel habitats has increased to better document habitat limitations and guide future stream restoration strategies.

5.2.1 Methodology

During the biological assessment component of this study, some questions regarding methodology were noted, in particular, whether all sampling sites for fish utilization should have been isolated with nets. Initially, sample sites were isolated to facilitate estimating coho populations (as well as other salmonids) using mark-recapture techniques. However, low capture numbers prevented the reliable derivation of such estimates. Consequently, this project became focussed more on species utilization, cpue and relative abundance. If the objective was to measure rearing populations, then site isolation is necessary.

During this study, sections of actively eroding banks were chosen as control sites to best represent an un-restored (ie. impacted) riparian condition that assessment sites would have exhibited prior to restoration. Cpue data for salmonids was greater in restored habitat than control sites in all watersheds sampled. To better reference the biological effectiveness and salmonid utilization of restored stream banks in future assessment studies, additional sites representing more stable, naturally functioning stream banks in good condition could also be sampled.

5.3 Continued Monitoring

A relatively large number of off-channel and mainstem riparian fish habitat restoration projects have been completed in the British Columbia Interior by DFO and partnership groups. In contrast, very little assessment of the physical and biological effects of these projects has been undertaken. Although the objective is to maximize fish productivity and structural longevity in habitat restoration works, little is known of the actual success in this regard, particularly in the longer-term.

Many stream processes and riparian associations in natural, undisturbed systems provide fish habitat through subtle, complex physical and biological interactions which are difficult to re-create. Often minor or transient aspects of fluvial morphology (eg. overhanging banks, small back channels) provide the framework for critical and limited fish habitat attributes (Kellerhals and Miles, 1996). In attempting to re-establish some of these naturally productive stream complexes and attributes, a number of specialized habitat restoration techniques have been developed for specific mainstem and off-channel applications. Longer-term monitoring of restoration projects is required by Fisheries & Oceans Canada and their partnerships in the British Columbia Interior to better understand the success of restorative techniques and to adapt and refine prescriptions. This will help maximize aquatic productivity based on the collective resources expended by agency and partnerships and help promote an adaptive management approach to resource restoration.

Community-based, volunteer stewardship organizations and programs are increasingly assuming lead roles in coordinating and undertaking fish habitat restoration projects. As a direct result, communities are becoming more aware of aquatic habitat sensitivities and the need for their protection and individual landowners are becoming more involved with stewardship organizations and fish habitat restoration.

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Appendix A – Summaries of instream and riparian assessment sites

Summary of instream and riparian restoration assessment sites on Salmon River - August and October 2001 and January 2002

Site (distance from confluence with Shuswap Lake)	Date of Const.	Utm Coordinates		Restoration Treatments	Primary Objectives
		Northing	Easting		
30 km	1994	333305	5593521	Tree revetment and riparian planting Rip-rap	Improve fish habitat R/B stability
30 km	1994	333305	5593521	Riparian planting Rip-rap	Improve fish habitat R/B stability
39 km	1995	320415	5594625	Tree revetment and riparian planting Rip-rap Fencing	Improve fish habitat L/B stability Livestock exclusion
11 km	1996	320415	5594625	Riparian planting Rip-rap Fencing	Improve fish habitat R/B stability Livestock exclusion
5 km	1996	333517	5616472	Riparian planting Rip-rap Fencing	Improve fish habitat R/B Stability Livestock exclusion
5 km	1996	333425	5616496	Tree revetment and riparian planting Rip-rap Fencing	Improve fish habitat R/B stability Livestock exclusion
28 km	-	333397	5598139	Rootwad, tree revetment and riparian planting	Improve fish habitat
9 km		330953	5612582	Rootwad, tree revetment and riparian planting Rip-rap Fencing	Improve fish habitat L/B stability Livestock exclusion
28 km	N/A	333509	5597984	Control site (eroding bank)	N/A
31 km	N/A	333280	5603416	Control site (eroding bank)	N/A

Summary of instream and riparian restoration assessment sites on the Bessette Creek system – 2001

Site (distance from confluence with Middle Shuswap)	Date of Const.	Utm Coordinates		Restoration Treatments	Primary Objectives
		Northing	Easting		
Bessette Creek					
3 km	1998	360893	5570666	Rootwad/large woody debris and riparian planting Fencing	Improve fish habitat Livestock exclusion
Site (distance from confluence with Bessette – Lumby)					
Harris Creek					
2.5 km	1998	360326	5567236	Rootwad/large woody debris Rip-rap Fencing	Improve fish habitat R/B stability Livestock exclusion
4 km	2000	359447	5565992	Rootwad/large woody debris and riparian planting Rip-rap Fencing	Improve fish habitat R/B stability Livestock exclusion
4 km	2000	359321	5565856	Rip-rap Fencing	R/B stability Livestock exclusion

Summary of instream and riparian restoration assessment sites on Duteau Creek – 2001

Site (distance from confluence with Bessette - Lumby)	Date of Const.	Utm Coordinates		Restoration Treatments	Primary Objectives
		Northing	Easting		
4-5 km * (Golf course)	N/A	356679	5566448	Spieling Rip-rap Fencing	Provide fish habitat L/B stability Riparian protection
4-5 km *	N/A	356436	5566471	Tree revetment and riparian planting Rip-rap Fencing	Provide fish habitat L/B stability Riparian protection
4-5 km *	N/A	357069	5566535	Riparian planting Fencing	Improve fish habitat Riparian condition
4-5 km *	N/A	357155	5566501	Rip-rap Fencing	L/B stability Riparian protection
4-5 km * Off-channel ponds	2002	-	-	Off-channel rearing habitat (trees, rootwads) and access	Strategic enhancement and stable off-channel rearing
Smolt ponds	-	-	-	Off-channel rearing habitat (trees, rootwads)	Strategic enhancement and stable off-channel rearing

*sampled January 2002

Summary of instream and riparian restoration assessment sites on Deadman River - September and October 2001 and February 2002

Site (distance from confluence with Thompson)	Date of Const.	Utm Coordinates		Restoration Treatments	Primary Objectives
		Northing	Easting		
10 km *	1991	645089	5631549	Tree revetment and riparian planting Fencing	Improve fish habitat Livestock exclusion
10 km *	1999	643425	5635733	Tree revetment and riparian planting Rockspurs, Rip-rap Fencing	Improve fish habitat L/B stability Livestock exclusion
28 km *	1999	643262	5647561	Tree revetment and riparian planting Rip-rap Fencing	Improve fish habitat R/B stability Livestock exclusion
28 km *	1999	643048	5647468	Rip-rap Fencing	R/B stability Livestock exclusion
28 km *	1999	-	-	Rootwad, tree revetment and riparian planting Rockspur and geotextile	Improve fish habitat R/B stability
				Fencing	Livestock exclusion
28 km *	-	643104	5647456	Control site (eroding bank)	N/A
10 km	-	643604	5635484	Control site (eroding bank)	N/A
Off-channel *	1999	-	-	Off-channel rearing habitat (trees, rootwads) and access	Stable off-channel rearing habitat

*sampled February 2002

Summary of instream and riparian restoration assessment sites on Bonaparte River - September 2001 and February 2002

Site (distance from confluence with Thompson)	Date of Const.	Restoration Treatments	Primary Objectives
38 km	-	Tree revetment and riparian planting Fencing	Improve fish habitat Livestock exclusion
24 km	1999	Rootwad, riparian planting Rip-rap and geotextile Fencing	Improve fish habitat L/B stability Livestock exclusion
16 km	2000	Rootwad, riparian planting Rip-rap Fencing	Improve fish habitat R/B stability Livestock exclusion
24 km	2000	Rootwad, riparian planting Rip-rap Fencing	Improve fish habitat R/B stability Livestock exclusion
38 km	2001	Rockspur and rip-rap Fencing	L/B stability Livestock exclusion
24 km	-	Control site (eroding bank)	N/A

Summary of instream and riparian restoration assessment sites on Louis Creek - October 2001 (North Thompson River)

Site (distance from confluence with North Thompson)	Date of Const.	Utm Coordinates		Restoration Treatments	Primary Objectives
		Northing	Easting		
35 km	1998	708511	5650304	Rootwad, tree revetment and riparian planting Rip-rap, Geotextile Fencing	Improve fish habitat L/B stability Livestock exclusion
35 km	1998	708297	5650460	Rootwad, tree revetment and riparian planting Rip-rap and geotextile Fencing	Improve fish habitat L/B stability Livestock exclusion
15 km	2000	707130	5661512	Rootwad, riparian planting Rip-rap Fencing	Improve fish habitat L/B stability Livestock exclusion
30 km	2001	707801	5652217	Tree revetment, rootwad and boulder cluster	Improve fish habitat
30 km	2001	707624	5652298	Riparian planting	Improve fish habitat
28 km	2001	-	-	Riparian planting	Improve fish habitat
26 km	-	707479	5654353	Control site (eroding bank)	N/A
29 km	-	707664	5652617	Control site (undisturbed)	N/A

Summary of instream and riparian restoration assessment sites on Raft River and Mann Creek 2001 (North Thompson River)

Site (distance from confluence with North Thompson)	Date of Const.	Utm Coordinates		Restoration Treatments	Primary Objectives
		Northing	Easting		
Raft River					
2.5 km (old Highway crossing)	1998	294329	5724609	Rootwad and riparian planting Fencing	Improve fish habitat Livestock exclusion
3 km	1998	294325	5724628	Rootwad Rip-rap	Improve fish habitat L/B stability
Mann Creek					
1 km	2000	698438	5717520	Rootwad/large woody debris and riparian planting Rip-rap and geotextile Fencing	Improve fish habitat L/B stability Livestock exclusion

Summary of instream and riparian restoration assessment sites on Lower Nicola River - September 2001 and January 2002

Site (downstream distance from Nicola Dam)	Date of Const.	Restoration Treatments	Primary Objectives
0.5 km	-	Rip-rap and planting	Bank stability and improve fish habitat
1.5 km	-	Rootwad and planting Fencing	Improve fish habitat Livestock exclusion

Summary of instream and riparian restoration assessment sites on Upper Nicola River - 2001

Site (distance from confluence with Nicola Lake)	Date of Const.	Restoration Treatments	Primary Objectives
Six sites and control between 0.5-2.5 km	-	Rip-rap, rootwad, planting, rock/log revetment Fencing	Improve fish habitat and bank stability Livestock exclusion

Appendix B – juvenile salmonid catch results and water quality at selected sites

Salmon River and tributaries - salmonid catch results for August 2001

Site (distance from confluence with Shuswap Lake)	Site Description	CO	CH	RBT	Temp. (^{0}C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
Mainstem							
11 km	Rip-rap	0	0	0	19.3	10.8	116
30 km	Tree revetment	0	0	3	17.8	10.2	106
	Rip-rap	0	0	12	17.8	10.2	106
28 km	Rootwad/rip-rap	0	0	0	15.0	9.9	97
	Control	0	1	0	15.2	10.0	98
31 km	Control	0	0	0	21.4	9.9	112
39 km	Rip-rap	0	0	1	20.7	9.6	107
5 km	Tree revetment	0	0	0	17.1	10.4	106
	Rip-rap	0	0	0	16.6	10.5	106
9 km	Tree revetment/rootwad	0	1	3	N/R	N/R	N/R
	Total:	**0**	**2**	**19**			
Tributaries/Off-channels/Ponds							
2 km Palmer Creek	Natural tributary wood weirs	3	6	4	N/R	N/R	N/R
11 km Kernaghan Creek	Natural tributary	0	6	8	N/R	N/R	N/R
Silver Creek	Natural tributary	0	4	18	N/R	N/R	N/R
20 km	Developed off-channel	0	0	0	N/R	N/R	N/R
9 km	Isolated groundwater pond	0	0	0	N/R	N/R	N/R
	Total:	**3**	**16**	**30**			

Salmon River and tributaries - salmonid catch results for October 2001

Site (distance from confluence with Shuswap Lake)	Site Description	CO	CH	RBT	RMWF	Temp (^{0}C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
Mainstem								
11 km	Rip-rap	1	2	0	0	N/R	N/R	N/R
30 km	Tree revetment	0	0	5	0	N/R	N/R	N/R
28 km	Rip-rap	0	0	0	0	7.0	12.1	99
39 km	Rip-rap	0	1	15	0	N/R	N/R	N/R
5 km	Tree revetment Rip-rap	0 0	3 0	0 0	0 0	7.1 7.0	12.3 11.3	101 92
9 km	Tree revetment and rootwad	0	4	0	0	6.3	11.2	90
	Total:	**1**	**10**	**20**	**0**			
Tributaries/Off-channels/Ponds								
15 km	Isolated beaver ponds at Silver Creek	0	0	0	0	7.5	7.8	64
2 km	Palmer Creek (natural tributary)	10	23	12	0	N/R	N/R	N/R
20 km	Developed off-channel	1	0	0	0	N/R	N/R	N/R
22 km	Isolated groundwater ponds and channel	0	0	0	0	8.4	6.9	56
38 km	Developed smolt ponds	0	1	0	50	N/R	N/R	N/R
	Total:	**11**	**23**	**12**	**50**			

Salmon River and tributaries salmonid catch results for January 2002

Site (distance from confluence with Shuswap Lake)	Site Description	CO	CH	RBT	RMWF	Temp (^{0}C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
Mainstem								
11 km	Rip-rap	0	0	0	0	3.3	12.7	94
30 km	Tree revetment	0	0	9	0	N/R	N/R	N/R
28 km	Rip-rap	0	0	1	0	2.7	12.5	97
39 km	Rip-rap							
5 km	Tree revetment Rip-rap	0 0	0 0	0 1	0 0	3.5 “	12.8 “	96 “
9 km	Tree revetment/ rootwad	0	0	1	0	3.2	12.6	92
	Total:	**0**	**0**	**12**	**0**			
Tributaries/Off-channels/Ponds								
11 km Kernaghan Creek	Natural tributary	0	0	4	0	2.2	12.4	89
2 km Palmer Creek	Natural tributary	12	6	13	0	N/R	N/R	N/R
	Total:	**12**	**6**	**17**	**0**			

Duteau Creek and off-channel salmonid catch results and water quality data for August 2001

Site (distance from confluence with Bessette - Lumby)	Site Description	CO	CH	RBT	RMWF	Temp (^{0}C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
Mainstem								
4-5 km	Tree revetment	1	2	10	0	16.1	9.5	96
	Spieling	1	4	26	0			
	Riparian planting	0	2	9	1	16.9	9.3	95
	Riprap	0	1	23	0	16.1	9.5	96
5 km	Rock/rootwad	0	1	15	0	14.3	9.9	96
	Control (eroding bank)	0	0	6	0	14.3	9.9	96
	Total:	**2**	**10**	**89**				
Off-channel								
2.5 km	Shallow/sediment bottom	0	0	3	0	N/R	N/R	N/R
	Total:	**0**	**0**	**3**	**1**			

Duteau Creek and off-channel salmonid catch results and water quality data for January 2002

Site (distance from confluence with Bessette - Lumby)	Site Description	CO	CH	RBT	RMWF	Temp (^{0}C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
Mainstem								
5 km	Rock/rootwad	0	0	8	0	N/R	N/R	N/R
4-5 km	Tree revetment	0	0	24	0	N/R	N/R	N/R
	Spielings	0	0	26	0	N/R	N/R	N/R
	Riparian planting	0	0	5	0	N/R	N/R	N/R
	Rip-rap	0	0	18	0	N/R	N/R	N/R
6 km Below Whitevale Rd 5 GEE traps	Fine to course gravel substrate – above weir	0	1	3	0	N/R	N/R	N/R
	Total:	**0**	**1**	**84**	**0**			
Off-channel								
6 km Smolt ponds	Shallow/sediment bottom-developed ponds (LWD, rootwads)	8	3	5	0	-0.1	13.6	92
4-5 km Golf course ponds above Beaver dam 5 GEE traps	Shallow/sediment bottom-no access thru dam	0	0	0	0	1.4	9.0	63
Pond outlet below beaver dam 5 GEE traps	Sediment bottom	2	1	6	0	N/R	N/R	N/R
	Total:	**8**	**3**	**5**	**0**			

Harris Creek salmonid catch results and water quality data for January 2002

Site (distance from confluence with Bessette - Lumby)	Site Description	CO	CH	RBT	RMWF	Temp (^{0}C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
Mainstem								
4 km	Rip-rap/planting Rip-rap/rootwad	0 0	0 0	22 16	0 0	N/R	N/R	N/R
2.5 km	Rock/rootwad groynes/planting/ fencing	0	0	36	0	0.8	13.1	92
	Total:	**0**	**0**	**74**	**0**			

Bessette Creek salmonid catch results and water quality data for January 2002

Site (distance downstream from confluence of Harris and Duteau - Lumby)	Site Description	CO	CH	RBT	RMWF	Temp (^{0}C)	Dissolved Oxygen (ppm)	Oxygen Saturation (%)
Mainstem								
4 km	Tree revetment and spieling	0	0	5	0	1.0	13.0	91
	Total:	**0**	**0**	**5**	**0**			