Coho Salmon
in the
Upper Bulkley River Watershed

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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1.0 INTRODUCTION

Concern for coho salmon (*Oncorhynchus kisutch*) in the Bulkley River watershed has arisen during the past decade due to significant declines in coho returns causing a number of populations and sub-populations to have reached record low numbers. Recent declines in harvest for coho salmon in Canadian waters has lead to a notable recovery of most populations in the Skeena watershed (i.e. the parent watershed of the Bulkley). Interestingly, the aggregate of coho populations in the Bulkley River watershed (including Upper Bulkley mainstem upstream of the Morice River, Buck Creek, Richfield Creek, and other of its smaller tributary populations) remain at risk of extinction, despite several consecutive years of reduced exploitation. The delayed recovery of this particular aggregate appears to be related to both low escapements and anthropogenic disturbances to the habitat.

Coho behaviour, the suitability of freshwater habitat, and the variability in their life histories in the Bulkley River watershed have not been well documented. Much of our current knowledge is based on, or extrapolated from, studies conducted in a diversity of environments throughout the geographic distribution of coho salmon, from California to Alaska. The general purpose of this project was to collect the relevant information and to store references on a shared data system that can be easily updated to allow the local communities to stay more easily informed with regard to coho biology and management issues. This report provides a summary of the existing information up to June 2001 to provide local communities with an updated understanding of the state of coho populations in their area to help predict coho returns and restore fish habitat. Suggestions toward potential work on topics that will provide better explanations and more detailed understanding of coho production in the Bulkley River watershed are also presented.

The objectives of this study are:

- to collect pertinent data on the life history and status of coho in the Upper Bulkley River Watershed, and compile reviewed references in a literature data system,
- to summarize the life history and historic trends in abundance of coho in the upper Bulkley River Watershed,
- to compare coho data from the upper Bulkley Watershed to coho information for other watersheds in the Bulkley system that have semi-wilderness or enhanced status,
- to identify the factors that appear to have significant effects on coho production in the upper Bulkley Watershed,
- to recommend some applicable restoration activities based on existing information, and
- to identify the data gaps in existing information and recommend studies to address these gaps to enhance our understanding of the population dynamics and to evaluate further restoration opportunities.

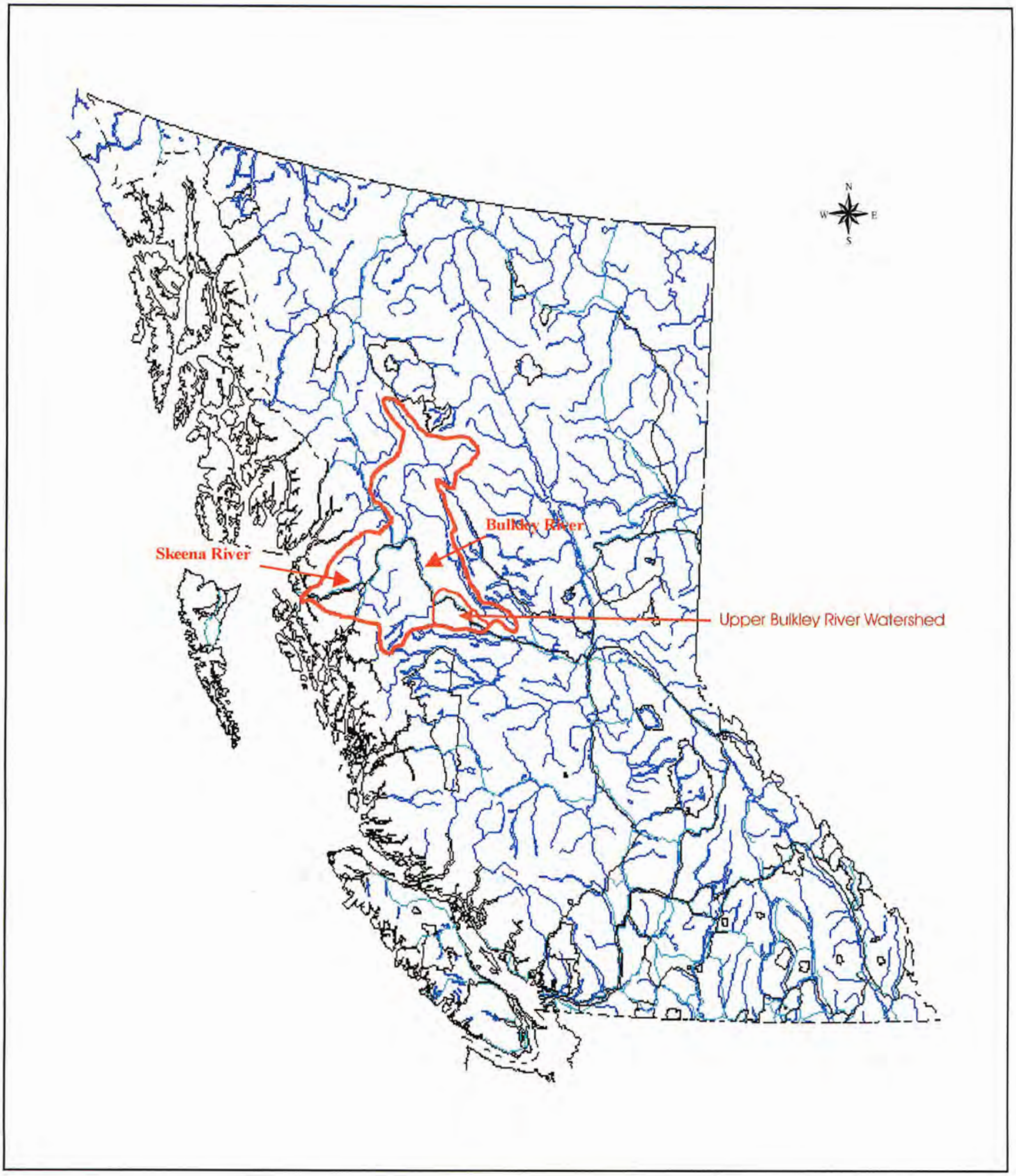


Figure 1. The Upper Bulkley River Watershed within the Skeena River System in British Columbia, Canada.

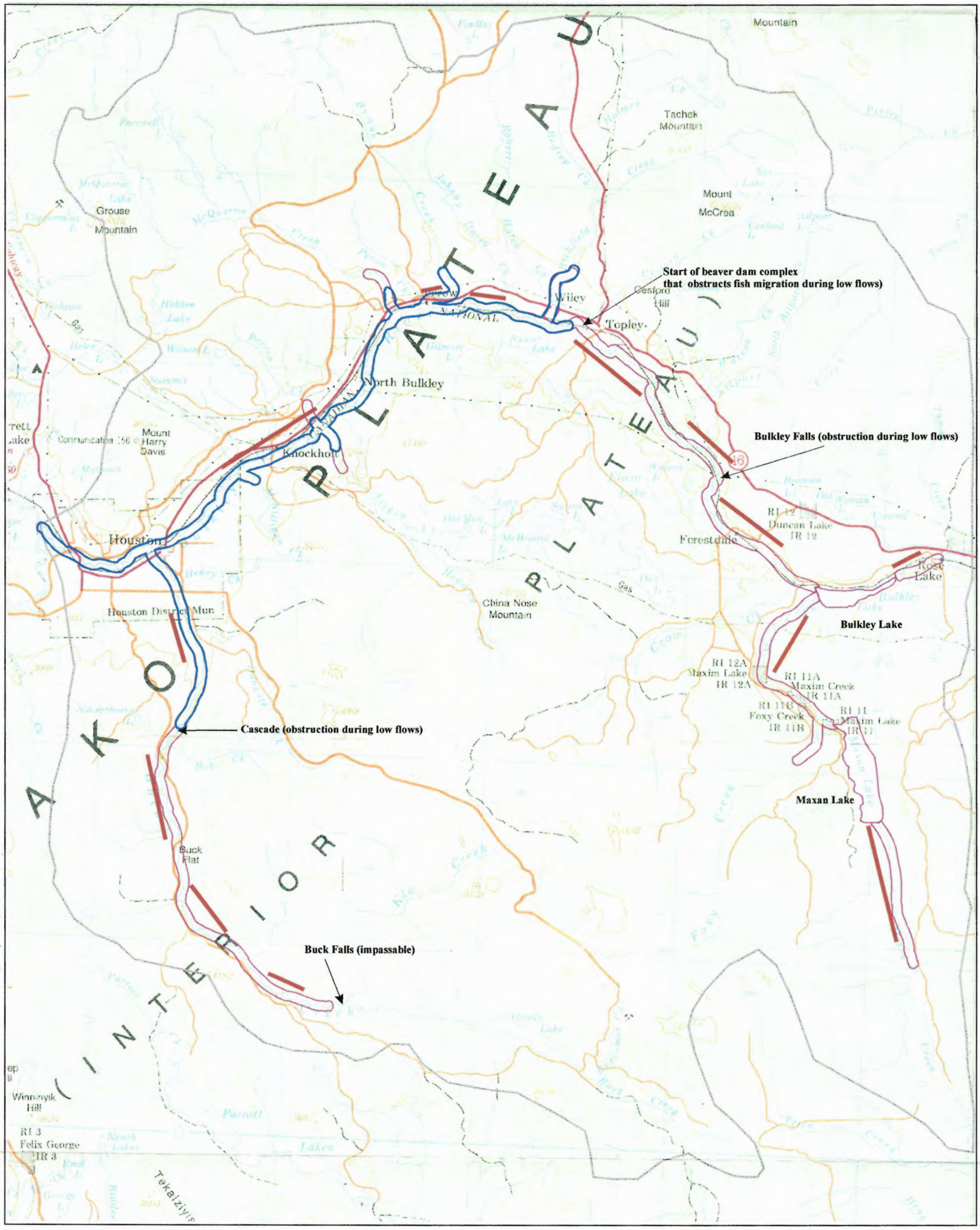


Figure 4. Overview of historical and recent distribution of coho and the suspected concentrations of coho rearing habitat in the Upper Bulkley River watershed.

Excerpt from 1:250,000 NTS Map

N W E S

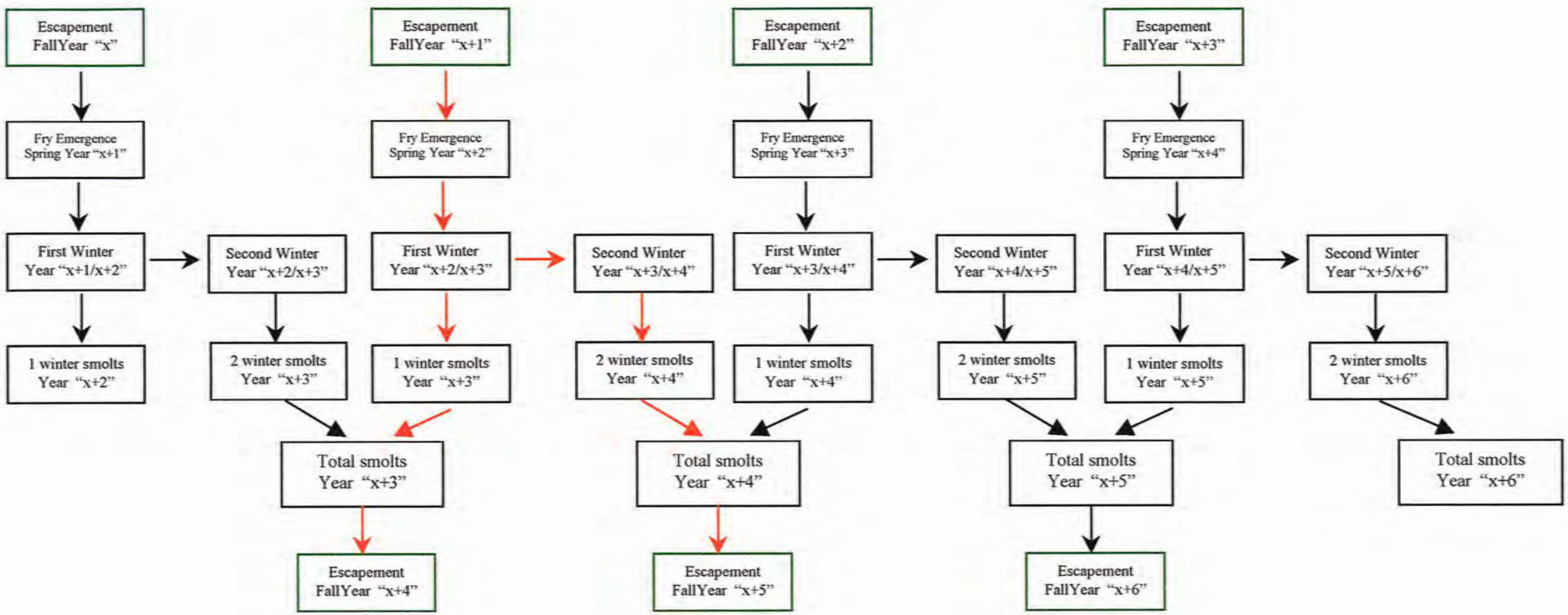
Legend

- Study Area Boundary
- Approximate distribution of coho from 1990-2000.
- Suspected distribution of coho prior to 1960.
- Suspected concentrations of freshwater rearing habitat for coho

2.0 COHO LIFE HISTORY

Coho salmon in British Columbia are known to have a number of different life histories that are dependent on variability of habitat, watershed characteristics, and environmental conditions. The life history of northern populations of coho have been reported to show a trend toward longer terms of freshwater residence in its life history when compared to more southern populations. Sandercock (1991) stated that the 1.1 year life history (i.e. one winter freshwater, one year ocean following emergence) is typical in the United States and southern British Columbia and is predominant for most freshwater systems. This is consistent with the predominance of 1.1 year spawners reported at most southern watersheds from California to southern British Columbia (Fraser *et al.* 1983, Armstrong & Argue 1977, Foerster 1955, Pritchard 1940). Sandercock (1991) also acknowledged the presence of 2.1 year, 3.1 year, and 4.1 year life histories in British Columbia. More recently it is has been documented and better recognized that many populations along the northern coast of British Columbia consist of notable and frequently dominant proportions of 2.1 year and small proportions of 3.1 year returns (Holtby 2000, SKR Consultants Ltd. 2000a, Finnegan 2000). The frequent dominance of a 2.1 year life history coho populations in Northern British Columbia and Alaska clearly adds a new complexity and increased variability to coho recruitment (*see* Figure 2). Some new evidence has also been discovered indicating a possibility of some coho migrate to the ocean shortly after emergence (Finnegan, 2001). Information for some coho populations near the Upper Bulkley River watershed (i.e. Morice, Telkwa, Toboggan, Lachmach, and Babine) provide some examples to help describe variability of the coho life history in Northern British Columbia. The amount of data specific to the life history of coho in the Upper Bulkley is limited, but the following sections summarize the available data and literature in order to outline the present understanding of northern and interior populations.

Coho Life History



Note: the small proportions of coho that rear in freshwater for a third winter (i.e. a 5 year life history) is omitted for simplification

Figure 2. General life history and inter-relationship of escapement of coho salmon in the Bulkley River Watershed (red arrows emphasize how the escapement from each year contributes to two years of recruitment).

2.1 OCEAN LIFE

The coho from the Upper Bulkley River spend approximately 12 to 14 months at sea which is typical throughout the range of coho along the Pacific Coast (Sandercock 1991). No coho have been identified to return to the Skeena watershed without at least one winter at sea (Finnegan, 2001). The majority of coho smolts appear to enter the ocean from the Skeena River in May and June. Populations from the more coastal systems enter the ocean from early May to early June, while more interior populations appear to primarily move toward the ocean in late June. Coho smolts from the Upper Bulkley River start migrating in June (SKR 2000a; 2001a,b) and are suspected to reach the Skeena River estuary from late June to early July, and return to the Skeena River the following year from August to early October (Wet'suwet'en 2001; Saimoto *in prep.*). No information on the ocean migration pattern of Upper Bulkley River coho has been documented, but some general data for Toboggan Creek and the Babine aggregates with similar environmental conditions have been summarized by Fisheries and Oceans Canada (Holtby *et al.* 1999). Coho from Toboggan Creek are known to distribute northward into all sectors of the Alaskan fisheries (Holtby and Finnegan 1998) and a few have been identified migrating to the south. Coho salmon from the Upper Bulkley River are suspected to have similar ocean migration behaviours to the coho from Toboggan Creek, which has been monitored using the results from both hatchery and wild smolt tagging operations (SKR 2000a, 2001a,b; O'Neill 1999; Holtby *et al.* 1999). Based on the present monitoring of exploitation by the Alaskan fishery, the migratory pattern of Bulkley River aggregates are suspected to differ somewhat from the Babine aggregate (Holtby *et al.* 1999) and are likely somewhat variable among aggregates and stocks even within the Bulkley watershed. Valuable information on the marine migratory pattern of the Upper Bulkley aggregate should be obtained in the near future based on results from the enhancement project at Buck Creek, one of the main systems in the Upper Bulkley River that was started in 1998 (MacKay 1999, SKR 2000a).

2.2 SPAWNING

In the interior portion of the Skeena watershed, coho are known to spawn from late September to mid November. Spawning areas in the Bulkley River watershed are focused mainly in Toboggan Creek, upper Telkwa River, mid Bulkley River, Upper Bulkley River, Owen Creek, Gosnell Creek, the Morice mainstem upstream of Owen, and in upper Morice River systems. Within each of these aggregates, spawning areas appear to be centred in mainstem habitats, but are also distributed into a number of their smaller tributaries. Temperatures in most of these areas decline below optimal conditions by mid November and ice up appears to frequently limit the window of spawning time (*Saimoto pers. observ.* 2001; O'Neill 1999). Interestingly, the main spawning locations in the Bulkley watershed are closely related to areas with good refuge for fry during spring freshet and suitable overwintering habitat (Finnegan, 2001).

Two unique peaks of migration into the Upper Bulkley have been documented at the Houston adult fence with the first serge occurring in September, followed by a second peak in late October (Glass 2000). Operation of the Bulkley Coho spawning in the Upper Bulkley River has recently been concentrated at the upper most accessible spawning habitat near the confluence of Richfield Creek approximately 38 km upstream of the Morice River confluence and 20 km downstream from Bulkley Lake. Recently, very little spawning has been observed in the lower 20 km of the Upper Bulkley mainstem. Small numbers of spawners have also been observed in

Richfield Creek, Byman Creek, and Buck Creek that are tributaries to the lower portion of the Upper Bulkley River. In the Upper Bulkley River, the majority of spawning appears to occur from late October to early November.

Some demographic data for adult coho passing through the Upper Bulkley fence was obtained for a four year period from 1997 to 2000. An example summary of individual coho data is from the 1998 brood stock (N=92) which had an average weight of 3.3 kg and 550 mm and consisted of 23% four year olds (O'Neill 1999). The proportion of returns that were females in the Upper Bulkley have been recorded as low 0.43 in 1997 to as high as 0.67 in 2000 (Ewasiuk 1998, Glass 1999, 2000). Fecundities have also been variable from year to year, based on brood stock spawners averaging from 2,665 eggs per female in 1997 to 3,745 eggs per female in 1999 (O'Neill 1999). Based on a general review of the available data, the condition and sex ratio of coho returning to the Upper Bulkley has not appeared to play an important role in the declined productivity of this system (Glass 1999, 2000).

2.3 Incubation and Emergence

The range of timing for coho eggs to develop to the alevin stage and then emerge from the gravel is quite variable due to its dependence on factors such as the time of spawning, water temperature, and dissolved oxygen characteristics that can be site specific even within the same drainages. The time for coho eggs to reach hatching in northern British Columbia is also variable from site to site, but has been estimated to commonly range from 42-56 days by McPhail and Lindsey (1970). Interestingly, a number of studies from watersheds with cooler water temperatures similar to the Upper Bulkley, have reported eggs to incubate for around 100 days prior to hatching (Berg 1948, Pravdin 1940) and as long as 137 days (Semko 1948). At the Toboggan Creek Hatchery, the peak hatching of brood stock eggs occurs at approximately 400 accumulated temperature units (O'Neill 1999), which works out to approximately 120 days. Incubation in the gravel may last longer in many locations in the Upper Bulkley River watershed due to the use of groundwater at the hatchery to increase water temperatures during the winter. Although fry emergence from the gravel beds has been documented to occur as early as the beginning of March to as late as the end of July (Sandercock 1991). The yolk sacks of the alevins in Bulkley hatcheries are not usually absorbed until April to May which may closely coincide with emergence and suggests that fry in the Upper Bulkley River watershed may emerge as early as April. More recent evidence also suggests that a proportion of fry in the Toboggan Creek may actually emerge even later in the summer resulting in their misidentification as large fry of the year in the following spring (Finnegan, 2001). The emergence of coho fry in the Upper Bulkley River watershed is suspected to overlap with emergence in Toboggan Creek that appears to occur from May to June (Saimoto *pers. observ.* 2001). Based on their relatively early spawning time and suspected times of emergence, it appears that eggs and alevins are in the gravel for periods of six to seven months (i.e. October/November to May/June) in the Upper Bulkley watershed.

2.4 Freshwater Residence

Juvenile coho salmon are known to rear in freshwater streams and small lakes for up to three winters following emergence (Drucker 1972, Sandercock 1991). Although the distribution of life histories for individual cohorts has not been measured, the assessment of the age distributions of different adult returns indicates a high variability of the age dominance of smolts from individual years. In fact, some central interior populations of British Columbia have had alternate domination of 1.1 year or 2.1 year adults (Holtby *et al.* 1999), which suggests that it may not be uncommon for more than half of the coho juveniles per cohort to stay in freshwater for a second winter. It appears that the variability of the age distributions of spawners are dependent on the number of spawners in the different years, the number of juveniles from the previous year that stayed for a second year, and the environmental conditions of the first winter of each new cohort.

Following emergence of fry from the gravel, and during the first few spring freshets, fry appear to distribute among all available rearing habitats in the system. A large number of these fry are washed or migrate from the system and search for habitats further downstream where rearing habitat may be over-seeded or even unavailable. Deep pools with organic cover and undercut banks, off channel habitat, beaver ponds and smaller tributaries appear to be the most important habitat types for coho refuge (Hartman 1965; Scott and Crossman 1973; Bustard and Narver 1975; Scrivener and Andersen 1982). The tendency of rearing juvenile coho in the central interior of British Columbia appears similar to coastal populations, which appear to select small stream types to minimize their displacement during freshets and for avoidance of metabolically expensive stream sites for winter rearing (Peterson 1982). Overall, larger streams are generally not the primary rearing habitat for coho fry due to commonly more frequent siltation than smaller streams and the inability of small fish to find refuge from the high water velocities during peak flows.

During the initial 10 to 12 months following fry emergence, growth of juveniles is limited to approximately five months when the environmental conditions in the Upper Bulkley River watershed are favourable for growth. In winters, from mid October to late April, water temperatures in the Bulkley watershed remain below 2 °C which results in limited growth and significant declines in condition for rearing juvenile fish (Donas & Saimoto 1999, 2000, 2001; O'Neill 1999). Stream habitat is also known to deteriorate as discharges decline over the winter and oxygen depletion occurs at some sites during ice up of summer habitats, rendering habitat unsuitable for survival. In the upper Bulkley watershed, it appears that winter survival can be a bottleneck for smolt production.

The number of winters of freshwater rearing could be related to physical condition and delayed development, or it may be a genetically inherited trait, or simply due to environmental variation. Whichever is the case, the fact that each cohort distributes over one, two and up to three years in freshwater appears to help the population to endure variations in marine survival. Juvenile coho that do not smolt after their first winter and enter their second winter appear to consist of the smaller size range of their cohort. In the Upper Bulkley River, fork lengths of coho entering their second winter have ranged from 90 to 120 mm which indicates that they were likely too small to smolt following their first winter (Donas & Saimoto 2001).

In summary, the majority of juvenile coho in the Upper Bulkley River appear to rear in freshwater through or two winters following emergence. Different age classes appear to compete for the same habitat types, which makes intra-specific competition play a significant role in smolt production. A number of factors are speculated to play a role in the variability of the length of freshwater rearing, such as the effects of inter-specific and intra-specific competition, environmental conditions, and variations in discharge.

2.5 AGE DISTRIBUTION IN FRESHWATER

The age distribution of juvenile coho rearing in the Bulkley River watershed is variable from year to year and among populations. The reasons for this variability appears to be related to influences such as environment and competition on physical condition and growth of rearing juveniles during their first year after emergence. Unfortunately, coho age data for adults returning to the Upper Bulkley River fence has not been well documented. Toboggan Creek (mid Bulkley watershed) is the nearest location with similar climatic conditions to the Upper Bulkley River watershed where age data from escapements is available. The proportions of 1.1 year returns (i.e. 1 winter in freshwater) for Toboggan Creek have ranged from 0.41 to 0.87 from 1988 to 1998 (Holtby *et al.* 1999). The proportions of 1.1 year returns for the Babine aggregate, located just to the north of the Bulkley watershed, has been as low as 0.23 (1968) and as high as 0.90 (1987). The proportion of 1.1 year returns in these central interior systems is suspected to be related to how much of the available winter habitat is occupied by juveniles from the previous year that stayed for their second winter. Due to intra-specific competition between age groups, smolt production can be significantly influenced by low escapements or stochastic events such as floods or severe summer or winter conditions that effect the abundance of coho spending more than one winter in freshwater. It should also be kept in mind, if fry were to have emerged late in the summer and thus have little growth in their first summer, then age data for some adults may even be missing one winter of freshwater rearing. Based on the existing information, freshwater age distribution and the abundance of different age classes in early spring prior to smolt migration appear to play an important role in smolt production.

2.6 SMOLT MIGRATION

Timing of smolt migration in the Bulkley River watershed has been reported to occur from mid May through to the end of June (Bustard 1986; Beere 1993; Saimoto 1996, MacKay 1999, SKR 1997, 1998, 1999, 2000a,b, 2001a,b,c). Figure 3 provides some examples of the timing and variation of smolt migration from Toboggan Creek. Peaks in movement appear to be related to photoperiod, temperature, and different timings of spring freshets that can be specific to the various coho producing basins. There are often two main freshets each spring including a snow melt in the lower valley frequently occurring prior to a second peak of snow melts at higher elevations near the middle of June. Based on the data collected at Toboggan Creek, the older coho juveniles (i.e. ≥ 2. year) in the Bulkley watershed tend to migrate in the earlier half of the timing window and the 1. year smolts tend to continue migrating into the latter half of the timing window as their growth allows them to reach the size threshold for smoltification. Juvenile coho are also known to migrate primarily from dusk to dawn, and infrequently (likely only short distances) during the daylight hours. Currently, it is assumed that smolt migration in the Bulkley River watershed ends once discharge declines below a critical level in late June, but few studies of smolt migration during summer or fall freshets have been conducted.

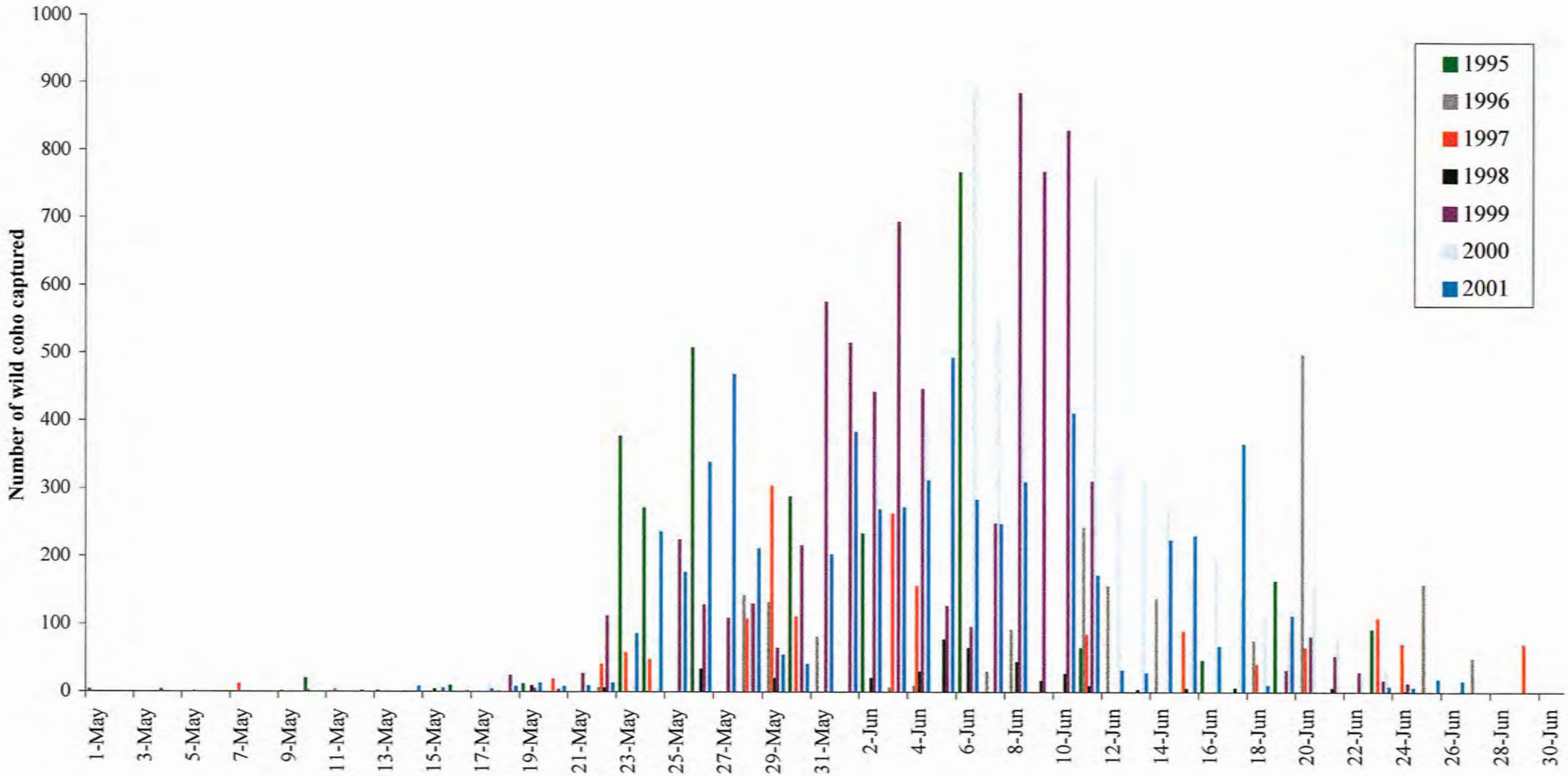


Figure 3. Data from Toboggan Creek smolt enumeration studies from 1995-2001 showing the general trends in the timing of smolt migration in the Bulkley River watershed.

3.0 FACTORS INFLUENCING COHO ESCAPEMENT

Annual escapement of coho salmon to their spawning areas is dependent on smolt production, ocean survival, and exploitation. Due to the high variability of each of these factors, the returns of coho populations display drastic annual fluctuations and temporal trends that can even be variable among aggregates in the same watershed (Holtby *et al.* 1999) and potentially among populations of the same aggregate. Freshwater survival and annual smolt output depends on a complicated scenario that involves a multitude of factors, which influence growth and development of the juveniles of coinciding spawning years. The natural factors that influence ocean survival include climatic changes, unique events (e.g. El Niño), and predation. Exploitation is the reduction of escapement through harvest by commercial, native, and recreational fisheries. A summary of known information with some interpretation and discussion of the variability of smolt production, ocean survival, and human exploitation are provided in the following sub-sections.

3.1 Smolt Production

The highest proportion of coho mortality appears to occur during the rearing phase in freshwater due to variable, but often poor survivals during incubation and freshwater rearing (Sandercock 1991). The smolt production of different populations appear to be limited by the carrying capacity of the available habitat and is thus useful toward evaluating the condition of various populations, monitoring the variability of ocean survival, and modelling how different levels of escapement will influence recruitment. When comparing the smolt production in southern systems to more northern systems, the tendency of fry to remain in freshwater for more than one winter results in lower smolt production due to more than one age class sharing the same habitat. Holtby *et al.* (1999) also suggest that large differences in productivity between interior streams and more coastal streams is evident in the Skeena watershed, which is geographically located in the northern half of coho distribution. Some evidence in the literature supports that stream habitats in more northern and interior systems may have lower overall carrying capacities than southern systems related to their significantly different patterns of discharge (Bustard 1996) and the more extreme winter climate. In the Upper Bulkley watershed, the proportion of coho that delay smolting for a second winter appears to be linked to climate, inter-specific competition, intra-specific competition with same age class and older age classes, and the varying quantity and quality of habitat that is available in different winters. The fact that coho fry in the Upper Bulkley watershed and have been found to enter May with fork lengths ranging between only 40 and 90 mm from 1998 to 2000 (Donas & Saimoto 2001) indicates that size may be related to their delay in smolting. A threshold for smoltification is estimated to be at fork lengths somewhere between 80 and 100 mm (Quinn and Peterson 1996; Gribanov 1948; Sandercock 1991) which appears to explain the occurrence of coho in more northern systems commonly spending more than one winter in freshwater. The fact that the upper Bulkley has had exceptionally low numbers of adult coho returning for the past decade, combined with findings from overwintering studies, support that environmental conditions and possibly habitat quality play important roles in determining whether coho migrate following their first winter of freshwater rearing. In addition, evidence of high mortalities during the winter at streams with very high densities of rearing coho fry (e.g. Toboggan Creek, Donas & Saimoto 2001) suggests that intra-specific competition may influence mortality and reduce growth rates, which may reduce the ability of coho fry to smolt after their first winter. Although some habitats are more productive than others, all habitats where coho are present require management of both summer and winter rearing (Dolloff 1987). How the changes in habitat, environment, age distributions in freshwater, and competition influence coho production in freshwater are discussed in the following sections.

3.1.1 Loss or Degradation of Habitat

The loss or degradation of coho rearing habitat has been documented at locations throughout the entire distribution of coho salmon. A main cause of the significant declines in coho production in the past few decades has been related to some natural catastrophes (e.g. land slides), but mostly to anthropogenic activities that have adversely effected the quality or quantity of freshwater habitat in various watersheds. Anthropogenic activities that have most notably impacted coho production have caused:

- the reduction of limits of upstream distribution,
- blocked access to valuable off-channel rearing habitats,
- degradation of spawning habitat, and
- degradation of rearing habitat.

The building of hydro-electric dams (mostly in the United States) has caused the most significant reduction in the quantity of spawning and rearing habitat for coho and many other anadromous species at numerous locations. The present use of excessive numbers of water licences in many watersheds has also been shown to reduce access to some historically important habitats in watersheds with significant development in their headwaters. Agriculture, mining, and domestic water use are especially influential on discharge in the central interior watersheds, and can result in un-natural obstructions (i.e. insufficient discharge) to fish migration (e.g. Hells Gate in the Fraser River, cascades in the Upper Bulkley River). The total loss of habitat that coho salmon have experienced is immeasurable, but the amounts for individual aggregates or populations within smaller watershed units can be evaluated and restored, or at least compensated for by local communities.

Anthropogenic channelization of naturally wandering streams and rip-rap placement along stream banks have been recognized to remove any of the intricate habitat requirements for coho (Schetterling *et al.* 2001). Off-channel refuges and small tributaries are important habitat for coho during freshet conditions when silted water in the mainstem creates poor conditions and high discharge that can displace fry from the system. The importance of off-channel and slough habitat for coho rearing has exacerbated the consequences of road and railway development, as well as flood control efforts, which have significantly impact coho production. Coho appear to have been the most significantly impacted species from the loss of off-channel and slough habitats due to their preference of this habitat for overwintering.

Degradation of mainstem stream habitats have also been related to anthropogenic activities in many areas of British Columbia. Loss of forest cover and riparian vegetation along stream banks has resulted in a number of significant impacts on stream habitats. Un-naturally high runoffs have been a common cause for loss of habitat diversity and degradation of suitable spawning habitats. The lack of riparian retention during our earlier management strategies of land use development have resulted in the removal of riparian vegetation that has resulted in loss of a common food source (i.e. terrestrial insects, Mundie 1969). Sediment loading associated with cleared and unstable banks is also known to reduce plant and invertebrate populations, thus impacting the trophic layers that produce the main food source required for salmonids (Langer 1980). Land clearing around streams has resulted in long-term loss of large woody debris that is important in many streams for maintaining channel morphology (Meehan 1992). The consequences from these degradations of habitat and reduction of food sources is reduced growth and condition, increased competition and a lower ability of the fish to avoid predation and deal with other stresses such as disease, warm summer conditions (Langer 1980), and winter conditions. Degradation of stream habitats are common in all developed areas, but we have the benefit of having wilderness areas in the Bulkley River watershed for comparison, which allow us to clearly see the losses, describe the degradation of habitats, and evaluate the impact of degradations on coho production in freshwater.

Overall, the loss of access to habitat has been the main cause of the declines in coho production. The degradation of habitat has also significantly reduced the productivity of many watersheds, but some restoration efforts have now been implemented. Nevertheless, restoration and compensation for the overall losses and degradations of habitat have only just begun and will require a great deal more organization, funding, and implementation of restoration, compensation, water management, and forest management activities. The annual returns of coho are heavily influenced by ocean survival, but the key to restoring coho production to its historical ranges of returns in more impacted watersheds will be dependent on restoring the quantity and quality of freshwater habitats to restore smolt production.

3.1.2 Spring to Fall Survival

Coho rearing in freshwater from spring to fall is suspected to have the most influence on smolt production in more southern watersheds, but coho appear less vulnerable to some of the factors in the central interior of British Columbia due to its more moderated summer climate. A number of factors have been proposed to play a role in coho survival following their emergence from the gravel such as:

- the quantity and quality of freshwater rearing habitat,
- the volume and rates of discharge during emergence,
- climatic effects on water temperature, and
- predation.

Land clearing related to agriculture, forestry, mining, and urban development have had a notable impact on the quality and quantity of fish habitats in the more developed watersheds. The loss of riparian vegetation along streams and lake shorelines have resulted in the reduction of an important resource (i.e. terrestrial insects and organic litter) and the natural shading characteristics that are critical toward maintaining the stability of water temperatures during the summer months.

Freshets during the spring months have been recognized to play an important role in the distribution and abundance of juvenile coho in streams (Smoker 1953). Coastal and interior systems are recognized to have significantly different patterns and fluctuations of discharge (Bustard 1986), since coastal systems commonly have higher rates and volumes of discharge during the spring and fall months. The occurrence of high, rapid freshets during the time of fry emergence are believed to effect fry survival by displacing coho fry downstream very quickly giving them less probability of finding suitable refuge. Thus, the more drastic flood events in coastal systems appear to make these systems more vulnerable to displacement of juvenile coho during these months in comparison to more interior systems that commonly have more moderated precipitation. Flash floods are also known to cause the stranding of fry in habitats unsuitable for summer or winter rearing. Other studies have suggested that low summer flows can reduce habitat to the point that coho salmon production becomes limited (Neave 1949; McKernan *et al.* 1950; Wicket 1951; Smoker 1953). The decrease in discharge during the dry months of summer obviously decrease the quantity of fish habitat, but is also known to cause large numbers of fry to become stranded in isolated pools. High water use in agricultural and urban areas is also shown to reduce the quantity and quality of coho habitats during the summer months. This is exacerbated by the fact that peak water withdrawal occurs during the lowest flow, which can reduce river discharge. Overall, the annual and seasonal variability of discharge related to both natural variation and anthropogenic impacts is known to have significant, but highly variable effects on the survival of coho during their main growing portion of their life in freshwater.

The effect of climatic conditions on coho survival during the summer is influenced by a number factors such as the glacial attributes, lake and underground water influences, geographical location, aspect, elevation, terrestrial vegetation, and precipitation of the different watersheds. Many watersheds in the central interior region of British Columbia appear to be less vulnerable, but are not void of summer mortalities related to oxygen depletion and/or high water temperatures. In non-glacially fed watersheds in the central interior, temperature sensitivity seems likely, but little information on the effects of water temperature on coho production in the central interior region have not been documented.

Predation is also recognized to be a significant factor in coho mortality in freshwater (Sandercock 1991). Rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarki*), Dolly Varden char (*Salvelinus malma*), bull trout (*S. confluentus*), northern pike minnow (*Ptychocheilus oregonensus*), and mountain whitefish (*Prosopium williamsoni*) are the most common aquatic predators of freshwater rearing coho. Dippers (*Cinclus mexicanus*), robins (*Turdus migratorious*), crows (*Corvus brachyrhynchos*), herons (*Ardea herodias*), and fish eating ducks (e.g. *Mergus merganser*) are the common bird predators of juvenile coho (Sandercock 1991). Mammals such as mink (*Mustela vison*), and otter (*Lutra canadensis*) are also known to have some effect on freshwater survival of coho salmon (Larkin 1977; Sandercock *1991*). The combination of aquatic, terrestrial, and avian predators adds up to a significant rate of coho mortality that is sustained at relatively consistent levels throughout spring, summer, and fall.

In summary, coho survival during spring to fall months is destined by the quantity and quality of suitable summer rearing habitat, but varies due to levels of competition, predation, and stochastic events within each year and at different locations. In southern systems, where coho rear in freshwater for only one year, it appears that summer survival is the predominant factor on smolt production. In northern coastal systems, rearing in freshwater for more than one year of spring to fall conditions is suspected to have a prominent effect. Interestingly, the different characteristics typical of central interior watersheds suggest that winter habitat and not summer survival may be the dominant factor that dictates smolt production for many populations.

3.1.3 Winter Survival

Winter mortality for coho in freshwater is suspected to be severe and appears to be a function of habitat quality (Holtby and Hartman 1982, Murphy et al 1984, Quinn and Petersen 1996). Higher mortality rates and often more restrictive habitat requirements during winter have emphasized the importance of this season to coho production. (e.g. Mason 1976; Rimmer *et al.* 1984; Cunjak and Power 1986; McMahon and Hartman 1989; Nickelson *et al.* 1992). Previous studies have estimated mortalities from 27% to 94% of juvenile coho during fall and winter (Bustard and Narver 1975; Crone and Bond 1976; Elliott and Hubartt 1978; Tchaplinski and Hartman 1983; Donas & Saimoto 2001). Bustard (1986) describes the significant differences of discharge during winters that make habitat characteristics and limitations distinctly different between coastal and interior rivers of British Columbia. The critically low levels of discharge in conjunction with extremely low water temperatures and ice conditions are suspected to be the primary bottleneck for smolt production in the interior watersheds (Bustard 1986).

The main factors that influence the habitat limitations for coho in freshwater during winters include the characteristics of discharge, water temperatures, ice formation, and the vulnerability of coho habitats to oxygen depletion. Winter conditions effect coho during their incubation and alevin stage as well as during one to three years of winter rearing prior to smolting. The southern and coastal systems are vulnerable to sporadic and severe flooding events that can cause disturbance or siltation at redds, which can reduce egg to fry survival. Southern and coastal populations are also vulnerable to more frequent flood events causing displacements of rearing coho to more crowded and/or poorer habitats. Colder climate watersheds are less vulnerable to disturbance and siltation, but anchor ice and frazil ice is suspected to influence incubation and alevin survival.

Fish condition when entering the winter appears to be more important for coho survival in the northern half of their distribution. There is considerable evidence that size at which a juvenile coho enters the winter effects its chance of survival (Cedarholm and Scarlett 1982; Holtby 1988; Swales *et al.* 1988; Quinn and Peterson 1996). The factors related to the condition of coho when they start the winter are inter-specific and intra-specific competition and habitat quality. However, inter-specific and intra-specific competition appears to be most related to distribution and habitat selection. The level of competition in coho habitats may be related to a cascading effect of reduced condition during the spring, summer and fall months that may effect winter survival.

In the central interior region of British Columbia, winter habitat limitations appear to have very notable effects on coho survival. Overwintering habitat is suspected to be the main constraint to coho smolt production and this has been well supported by the results from the Upper Bulkley and Toboggan Creek overwintering study conducted by DFO from 1998-2000 (Donas & Saimoto 2001). The density measures in Toboggan Creek showed a tremendous decrease during the winter and it is suspected that the habitats sampled have a maximum survival density well below natural numbers of summer carrying capacities of the same habitat. The majority of information regarding freshwater rearing habitat for coho in the Bulkley watershed strongly supports the fact that overwintering habitat is frequently overpopulated and thus is the main constraint to smolt production.

For watersheds with the more extreme winter climates (e.g. Upper Bulkley River watershed), ice covers the majority of water including the mainstem for sustained periods of time. Declines in discharge during these cold spells of winter and other factors such as anchor ice and shelf ice clearly reduce the quantity of suitable rearing habitat for coho. In the colder climate watersheds, coho survival during the winter becomes dependent on fish condition when entering the winter, critically low water temperature during the winter, oxygen depletion under ice cover, and habitat selection. Fish that select a habitat that may have been good during the summer or fall are often very vulnerable to becoming stranded in the majority of the shallower pools as discharge typically declines during the winter. From November to May in the Bulkley watershed, coho have shown significant declines in condition (g/mm^3) with very little or no growth during the winter months (Donas & Saimoto 2001). Monitoring of overwintering coho in Toboggan Creek and the Upper Bulkley River has supported that high mortalities can occur during the winter (Donas & Saimoto 2001). The critically low water temperatures are also suspected to delay incubation periods and appear to impede the development of fry, which can lead to more than one year of rearing in freshwater. In southern and more coastal systems, winter survival appears less dependent on habitat and fish condition at the start of winter.

Because the productivity of coho populations appears to be limited by the amount of suitable overwintering habitat (McMahon and Hartman; Nickelson *et al.* 1992; Donas & Saimoto 2001), winter survival in freshwater is suspected to be a potential bottleneck for smolt production. Severity of winters for the more northern populations that have less winter precipitation or primarily snow during the winter months appears to also influence coho production. The rare occurrence of high flood events during the winter months in the colder climates reduces displacement of rearing coho, but the trend of decreasing discharge continually reduces the quantity and quality of habitats through the winter. Although survival in optimum off channel habitat has been reported to be as high as 87% in the Nicola River watershed (Swales et al 1985), a large proportion of off channel habitats in the Bulkley River watershed appear highly vulnerable to winter kill (Bustard 1986; Donas & Saimoto 2001). The high risk of winter-kill in many off-channel sites that may have been suitable for summer rearing can significantly effect coho smolt production, but is dependent on climate and the condition of the watershed (Donas & Saimoto 2000).

Predation appears to have a variable effect on winter survival in freshwater dependent on ice cover and water temperatures during the winter months. Fish such as rainbow trout, cutthroat trout, Dolly Varden char, bull trout, mountain whitefish, and northern pike minnows as well as mammals such as mink and otter have less effect on coho survival during the winter months when water temperatures remain below 2 ^{0}C. Cold water temperatures that range from 0 to 4° C, in frequently ice covered streams, significantly reduces the metabolic rates and needs of fish and the needs and predation of piscivorous fish species. In the interior watersheds of British Columbia, when ice covers the majority of streams and lakes, predation is not believed to have a significant effect on coho survival.

In summary, climatic conditions during the winter are highly variable throughout the distribution of coho along the Pacific coast. A general trend of longer freshwater residence and lower smolt production moving south to north and from the coast to more inland areas is apparent and is related to how climatic changes effect winter survival and length of freshwater rearing. In fact, at least in interior watersheds, winter survival appears to be the primary bottleneck for smolt production due to colder winters resulting in more years of freshwater rearing, relatively less suitable overwintering habitat, and an apparent maximum density of winter survivors in the overwintering habitats. A negative correlation between fish densities and winter survival in a central interior population supports that habitat limitations during the winter months may have the most significant influence on coho smolt production (Donas & Saimoto 2001).

3.1.4 Additional Years in Freshwater

Due to size advantages, coho entering their second or third winters in freshwater are believed to limit the available habitat and winter survival of smaller coho that are entering their first winter due to intra-specific competition. In freshwater, juvenile coho are suspected to generally select their freshwater rearing habitat during their initial distribution during spring freshets shortly after emergence. A finding in a small southeast Alaska stream suggests that although meadow and slough tributaries can support higher densities of coho, fish appeared not to move between habitat types that were selected during their initial habitat selection in spring (Dolloff 1987). The consequence of this early habitat selection is that the number of coho juveniles entering their second winter results in significant intraspecific competition for fry entering their first winter since they must compete for the same habitat. There is also good evidence that coho entering their second winter may have significantly higher survival then during their first winter, likely based on their condition (Quinn and Petersen 1996; Donas & Saimoto 2001). The reason for lower survival of younger fish is speculated to be due to their smaller size increasing their vulnerability to extreme conditions that can reduce their health to critical levels faster than for larger fish. The level of competition for the available resources in these habitats may also play role in survival by reducing the overall condition of both age groups even before they enter the winter. In general, fish entering their second or third winters are assumed to be less vulnerable to winter kill due to their greater ability to sustain environmental extremes and declines in condition than smaller fry. In general, notable proportions of northern coho populations spend more than one winter in freshwater and thus have lower fry to smolt survival in comparison to populations with predominantly one winter of freshwater residence. The result of less productive output of smolts is simply due to increased exposure to the factors influencing freshwater survival, and the different limitations of the available habitat. The result of variable proportions of coho rearing for different numbers of years creates large variability in smolt production that makes winter survival important to measure when predicting smolt production and recruitment.

3.2 OCEAN SURVIVAL

During the ocean stage of the life history, coho survival is dependent on exploitation and several natural factors associated with marine habitat and climatic conditions (e.g. El Niño). Although freshwater survival has a more significant effect on the potential range of recruitment, it is ocean survival that has the last influence on recruitment. Where smolt production has been measured, and ocean survival has been evaluated, ocean survival has been found to be quite variable between watersheds and over time. Smolt to adult survival on the east coast of Vancouver Island has been reported to range from 0.5 to 23.1% (Labelle *et al.* 1997). It has been estimated that ocean survival has averaged 2.9 % from 1989-1998 for Toboggan Creek hatchery coho, and this is presently used as an index for Bulkley River coho (Holtby *et al.* 2000). Ocean survival for the Lachmach River, a north coast index system based on wild smolt tagging efforts, has averaged 9.1 % survival during the same ten year span (Holtby *et al.* 2000). Some data from the Oregon coast suggest that marine survival of wild smolts is about double that of hatchery smolts (Nickelson and Lawson 1998), which may explain some of the differences between the ocean survival of coho from Toboggan Creek and Lachmach River. Some more recent evidence from Toboggan Creek and Lachmach have shown similar survival of hatchery and tagged wild coho in the fall of 2001 (Finnegan 2001). However, there are other predictions that the differences between smolt to adult survival for north coast (e.g. Lachmach River) and the northern interior (e.g. Toboggan Creek) populations may possibly be related to ocean migration patterns, different exposures to ocean exploitation, and inaccuracy of exploitation estimates.

Beamish and Mahnken (1998) have recently hypothesised that the regulation of ocean survival for coho occurs in two stages, predation in initial months, and late fall and winter survival based on condition and ocean environment. Beamish and Mahnken (1998) suspect that predation is not the main limitation, and that it is more likely that the physiological condition during the winter plays the main role with fish of certain condition having significantly higher survival. The tendency of low fecundity (an average 24% decrease) in years with low marine survival (smolt to escapement estimates < 0.8%) along the Oregon Coast (Nickelson and Lawson 1998) supports that poor marine conditions significantly influence ocean survival. For example, El Niño events have been associated with increased ocean temperature (Johnson 1988) and have been related to low marine survival for salmon. Nevertheless, during ocean migration, coho salmon are also introduced to a number of different predators in the ocean. In the ocean, coho become vulnerable to dogfish, hake, lamprey, sharks (e.g. *Lamna ditropis*), gulls, loons, mergansers, seals, sealions, and killer whales (*Orcinus orca*) which have varying rates of predation at different areas and on different size classes during the ocean migration of coho (Sandercock 1991).

3.3 EXPLOITATION

Exploitation includes harvest of coho salmon by Alaskan and Canadian commercial fisheries, ocean sport fisheries, freshwater sport fisheries, and Native food fisheries. On the east coast of Vancouver Island, exploitation has been estimated to be as high as 96% (Labelle *et al.* 1997). Exploitation from off shore and Alaskan fisheries appear to have remained relatively constant or slightly increasing for the past few decades, but overall harvest intensity on coho in the Skeena River watershed has been significantly reduced since 1997 in an attempt to restore coho recruitment to its historical levels. Exploitation estimates of the Bulkley River Coho indicator (Toboggan Creek) ranged form 40% to 74% from 1988 to 1997. The more recent management of the B.C. commercial and Native fisheries has reduced the estimates of total exploitation of Bulkley River coho to 28%-35% from 1998 to 2001. These recent reductions of exploitation have resulted in notable recoveries of coho escapement to many systems, but some populations (e.g. Sustut River, Bear River, Upper Bulkley River) have displayed very slow recoveries. Without exploitation, it is suspected that coho systems in the northern interior of B.C. would be continuously well seeded, even following poor ocean survival years, if habitat remains undisturbed. However, exploitation at higher rates has caused some smaller populations to become extinct, and placed some larger aggregates (e.g. Babine River coho) at critically low levels of return. Interestingly, exploitation rates have been found to not be consistently variable for different stocks, and hatchery-reared coho have tended to be subject to higher exploitation (Labelle *et al.* 1997, Finnegan 2001). In general, genetic factors, run timing, and stream location appear to have the largest influences on exploitation rates (Labelle *et al.* 1997). Overall, exploitation has had the most notable impact on escapement, but more strategic management of harvest will ensure optimal or at least conservative escapements that will target optimum smolt production.

4.0 THE STATE OF THE UPPER BULKLEY RIVER WATERSHED

The Upper Bulkley River and its tributaries from the confluence of the Morice River upstream to Maxan Lake have been heavily impacted by relatively recent development since 1950. Many land use activities in the Upper Bulkley River watershed have been linked to an overall degradation of spawning and coho rearing habitat in the system (Mitchell 1997, McKay *et al.* 1997, Remington 1998). The following sections provide a summary of land use activities in the watershed, the present condition of fish habitats, the changes and present state of coho distribution, and the history and outlook on future coho populations in the Upper Bulkley River watershed.

4.1 THE CONDITION OF FISH HABITAT

Land use in the Upper Bulkley River watershed has involved linear development and urbanization, mining, forestry, and agriculture. Each of these activities has been documented to result in alterations of watershed characteristics, water quality and fish habitat in the upper Bulkley watershed over the past century. The impacts on the quality and quantity of fish habitat that have been identified in this system include:

- difficult upstream migration related to decreased discharge,
- loss of access to side channel, off channel and beaver pond areas for rearing,
- decreased water quality due to pollution or increased sedimentation,
- exacerbated peak and low flow conditions causing changes in channel morphology and stability,
- human interference reducing habitat diversity in streams,
- decrease in drainage density via a loss of first order channels,
- increased summer temperatures due to loss of forest canopy, and
- decreased food sources related to loss of riparian vegetation along streams.

A number of these impacts are believed to compound and have significant effects on the survival of juvenile coho in developing watersheds due to the resulting declines in quantity and quality of fish habitat (Dune & Leopold 1978; Hunter 1991; Andoh 1994; Morris & Threivel 1995; Johnston & Slaney 1996). These land use issues are difficult to manage, control, and/or alter, but the first step is to describe the outcomes of these land use activities in order to provide a more complete understanding of the network of limiting factors to coho populations in any particular watershed. The following sections summarize how land use activities in the Upper Bulkley watershed have impacted fish, and particularly coho salmon.

4.1.1 Linear Development

Linear development in the upper Bulkley River watershed includes the development of trails, roads, railways, gas pipelines and hydro lines (Table 1). The first form of linear development through the Bulkley valley was the construction of the telegraph trail, which was initiated in 1886, halted in the same year, and completed between 1899 and 1901 (Hols 1999). The railroad through the valley was completed by 1913 (Shervill 1981, Hols 1999), and its construction resulted in the removal of timber for the purpose of rail tie manufacturing, which was a major source of employment in the early years of the settlements in the valley (Shervill 1981). The portion of the Yellowhead Highway (Highway 16), which currently connects Houston to Prince Rupert was constructed piece meal, and was not completed until 1944. Linear development in the Bulkley valley was relatively minor in the early part of the 20th century. Highway 16 was not completely paved until 1961 (Hols 1999). Roads and trails criss-crossing the valley appeared in earnest after World War II (Shervill 1981, Hols 1999). Road development significantly increased in the mid to late 1960s following the establishment of a large forest tenure created for the purpose of creating a large pulp and timber mill in Houston (Hols 1999, BCCF 1997). The extensive road networks related to forestry in the upper Bulkley watershed is summarized by LaRose and Rencoret (1996). Power was supplied to the community of Houston in the early 1950s by the B.C. Power Commission, and some smaller hydro-electric corridors to service homesteads near Houston were established as early as 1952 (BCCF 1997). The prominent power corridor connecting Houston to Prince George was developed between 1962 and 1967. The road network in the community of Houston was established in 1958. Natural gas pipelines in the watershed may have some effect on fish and fish habitat due to changes in channel morphology, impacts during construction (primarily at stream crossings), and the potential for blow outs (Remington 1996). The network of logging and mining roads, coupled with the Highway 16, the railroad corridor, and the hydro right of ways have resulted in several cases of blocked passage to fish habitat, and reduced quality of fish habitat.

The most notable impacts on coho and coho habitat that are related to linear development in the Upper Bulkley watershed have been the loss of access to important habitat caused by highway and railroad development. A number of side channels (e.g. deep ox bows), and tributaries have been isolated or fish passage has been significantly impeded due to lack of drainage structures and the common use of culverts that are either hanging or at gradients that create velocity barriers to fish. It is these side channels and tributaries that are suspected to contain the habitat that is particularly important to coho salmon for freshwater rearing and high smolt production. The loss of this habitat appears to be related to the fact that coho in the Upper Bulkley watershed had slow response to the significant reductions in exploitation over the past two years.

Table 1. Summary of Linear Development in the Bulkley Valley (sources: Shervill 1981, Hols 1999, BCCF 1997)

Year	Road Development
1886	Start of construction of the Telegraph Trail in the Bulkley River Valley
1899-1901	Completion of the Telegraph Trail
1913	Completion of railroad through the Bulkley Valley
1944	Prince George linked to Prince Rupert by gravel highway
1950	B.C. Power commission completes power line corridor to Houston
1952	Start of sub-corridors for hydro to smaller communities and local homesteads
1958	Development of road networks in the Upper Bulkley River watershed
1961	Pavement completed for Highway 16
1962-1967	Development of the current power corridors

4.1.2 Timber Harvest

Timber harvest in the Bulkley Valley has been conducted to some degree since the initial settlement of the area. In the early 20th century, timber harvest levels were low, with the main purpose of timber extraction being the construction of dwellings, clearing of land, and manufacturing of rail ties (Shervill 1981, Hols 1999). Although a sawmill was established near Telkwa in 1907, actual lumber production in the area was a relatively minor source of employment in the first two decades (Shervill 1981). By 1920 several more mills of small capacity were established in Smithers and Telkwa (Shervill 1981) and during the 1920s more than six million ties were shipped out of the Bulkley Valley and Lakes District (Hols 1999). Portable mills were used in the Houston area since the 1920s, and the first stationary mill (Buck River Lumber) was constructed in 1947 (Hols 1999). The Morice River road was reconstructed in 1954, opening up more forested land for harvesting. Northwood Pulp and Timber purchased this mill in 1972, and later by Canadian Forest Products in 2000. The second large mill (Houston Forest Products) opened in Houston in 1978. The two mills combined are estimated to produce 630 million board feet annually (Hols 1999). Clear cutting in the Morice Forest District portion of the Bulkley valley began in the later portion of the 1960s (Hols 1999). Removal of a considerable proportion of the timber in the valley, particularly since the 1950s, and the lack of reforestation until the late 1960s has likely had some impacts on fish and fish habitat in the drainage.

The most notable impacts on coho and coho habitat that are suspected to be related to past timber harvest in the Upper Bulkley watershed have been:

- higher and faster freshets which reduces the complexity of channel morphology and quality of fish habitat,
- reduced water storage which affects water temperature during the summer and fish migration during years with low precipitation,
- the significant loss of forest canopy and riparian vegetation along significant proportions of streams in the watershed causing channel destabilization, temperature sensitive situations, and reduced input of food resources,
- high silt loads that occur during even light precipitation on deforested areas that affects fish survival directly by aggravating gill tissues, preventing emergence from the gravel, and degrading spawning habitat, and
- the application of pesticides and herbicides (BCCF 1997) that may occasionally raise concentrations to toxic levels.

Some demonstrative projects have been undertaken in order to help restore riparian vegetation along some stream banks and to restore channel complexity in some small streams of the Upper Bulkley watershed. However, broader range goals and objectives toward strategic management of timber harvest in this watershed may be required to start compensating and restoring and sustaining fish habitat with a more long-term objective for the Upper Bulkley watershed.

4.1.3 Agriculture

Agriculture has a long history in the Bulkley Valley, dating back to the early part of the 20th century. The first farms near Houston (then Pleasant Valley) were established as early as 1901, with at least four farms being established by 1904. Farms and ranches existed near Round Lake, Owen Lake, on Buck Flats, Driftwood Creek, near Houston and Smithers in the early days. Water withdrawal for irrigation purposes dates back to 1924, when water from Buck Creek was used to irrigate fields (Hols 1999). In the early 1920s cattle farming, and Timothy seed harvesting intensified in the valley. Crops planted during World War II included spinach and turnips. In the 1940s, agricultural activities consisted primarily of ranching and haying which has continued to be the main agricultural activity.

Land clearing is concentrated in flood plain areas, valley bottoms and adjacent upland areas and was conducted to provide summer grazing and hay lands. Land clearing for agricultural purposes was accelerated between 1945 and 1948 as the provincial government provided bulldozers at per-cost rates (Hols 1999). Until this time, agriculture consisted primarily of "stump farming", where framers planted and harvested crops planted between stumps remaining on cleared land. However, with the use of bulldozers, land clearing was more efficient, and resulted in ability to use mechanized farm equipment. This resulted in a marked increase in cattle farming after the mid 1940s. Currently, there are approximately 23 commercial beef operations and more than 20 hobby farms in the Upper Bulkley watershed. Agricultural activities in the Upper Bulkley watershed continue to focus in the valley bottom of the Bulkley River, on alluvial fans of most tributaries, and on Buck Flats (BCCF 1997).

Agricultural activities have had numerous impacts on fish and fish habitat resulting from land clearing, removal of riparian vegetation, grazing in riparian areas, reduced input of large woody debris, and reduced habitat complexity and channel stability (Dune & Leopold 1978; National Research Council 1992; Adams & Fitch 1995; Stevens *et al.* 1995). Some evidence of these impacts in the Upper Bulkley River watershed has been summarized and presented over the past five years (BCCF 1997, Mitchell 1997, Remington and Donas 2000). Run off from agricultural operations, including fields and feed lots, commonly have high concentrations of nutrient and pathogens, due to pesticides, herbicides and fertilizers applied to the farming operation which can either effect fish growth or cause mortality (National Research Council 1992, Stevens *et al.* 1995). Ranching can result in direct impacts on watercourses as cattle use streams and lakes for watering, trampling the stream banks and disturbing substrates, including salmon redds (Chaney *et al.* 1993, Adams and Fitch 1995, Stevens *et al.* 1995, DFO no date). Effects of trampling streams, the removal of riparian vegetation and clearing of land can have similar impacts to those resulting from forestry operations, namely channel instability, sedimentation, water quality, water temperature and changes in hydrology. Irrigation to increase yield from fields has also been noted to significantly alter flow regimes and the hydrology in the upper Bulkley watershed (National Research Council 1992, Stevens *et al.* 1995, Remington 1996, 1997, Donas and Remington 2000) particularly since periods of peak water withdrawal coincide with low flow periods. Overall, agricultural activities in the Upper Bulkley watershed have effected hydrology, stream stability, riparian areas, water temperature, water quality, nutrient and sediment input (Mitchell 1997).

4.1.4 Mining

Mining activities in the Bulkley valley date back to the later part of the 19th century and the early part of the 20th century. Mineral deposits in the valley consist of copper, molybdenum, gold, coal, silver, lead, zinc, copper, and cadmium (Hols 1999), but only few deposits were mined in the area. Some evidence of Chinese prospectors dating back to around 1860 have been found in the Houston Area (Hols 1999), and the first claim stakes date back to 1899 on Goathorn Creek in the Telkwa watershed (Shervill 1981). Mining activities in the Bulkley River watershed have been concentrated in Hunter Basin and Goathorn Creek (Telkwa drainage), Duthie mines (Hudson Bay Mountain) (Shirvell 1981), Bob Creek (Buck Creek watershed), Silver Queen Mine (Owen Lake) and Equity Silver mine (near Goosly Lake) (Hols 1999). Of these mines, the Equity Silver mine, an open pit mine for silver, gold and copper, was the most recent active mine, operating from 1981 to 1994. Shortly after its opening, the Equity Silver Mine experienced acid rock drainage (ARD) problems, necessitating the instalment of extensive collection and treatment systems. The ARD problem at the mine persists to this day, and wastewater must be continually collected and treated at the mine site. Despite efforts to collect and treat the wastewater, several spills have occurred from the mine site into neighbouring streams (including Buck Creek and Bessemer Creek) prior to 1991 (Hols 1999). One of these spills was estimated as 10,000 gallons of sulphuric acid into Buck Creek in the early 1980s (Hols 1999). The Equity Mine used cyanide to recover metals from the concentrator tailings and some of its breakdown products (nitrogenous compounds) are also known to be toxic to aquatic life. There is currently no active mine in the Bulkley valley, although Luscar (previously Manalta Coal) has interests in surface coal deposits in the Telkwa basin between Goathorn and Tenas Creek.

Mining can directly or indirectly affect fish and fish habitat. Concerns with mining are frequently focussed on the generation of acid rock drainage, which can enter streams, and can affect the suitability of the habitat for fish. ARD is generally 20 – 300 times as acidic as acid rain (National Research Council 1992), and is generated through the oxidation of sulphides (National Research Council 1992, Morris and Therrivel 1995, Remington 1996,Dunne and Leopold 1998). When ARD enters a stream, pH values may drop below acceptable levels for salmonids (National Research Council 1992, Dunne and Leopold 1998) (acceptable pH for freshwater aquatic life is 6.5 – 9 pH units, Nagpal 1995). The concentrations of other minerals (e.g. manganese, aluminium, iron, zinc) can also be elevated due to increased acidity associated with ARD, and these minerals can reach toxic levels in the environment (Canadian Council of Resource and Environment Ministers 1987, Dunne and Leopold 1998). Mineral concentrations can become sufficiently high to form precipitates which settle on the stream bottom as a cement like material, rendering previously suitable spawning and rearing habitat unsuitable to fish (Canadian Council of Resource and Environment Ministers 1987, National Research Council 1992). At mines where ARD problems exist, wastewater may be treated, but such wastewater treatment is expensive. ARD problems also persist for long periods of time after the mines complete their operation (National Research Council 1992, Dunne and Leopold 1998), as is the case with the Equity Silver Mine. In addition to the potential for ARD, and elevated levels of minerals, some of which are toxic, mining can result in altered flow regimes by altering both surface and groundwater flows. Alterations in hydrology can result in locally lowered stream flows, increased water logging and flood risks downstream. The erosion of exposed soils (e.g.

from soil heaps, rock dumps and tailing piles lacking vegetative cover) can cause increased sediment input (Morris and Therrivel 1995). Linear development (e.g. road construction, power lines), clearing of land, and potential for oil pollution from vehicles, machinery, and storage area may also affect streams and lakes in the watershed (Morris and Therrivel 1995).

Mining activities in the Bulkley Valley have included extensive exploration activities, and few smaller localised mining activities. Exploration is frequently conducted by the construction of mining road in the watershed, some at high elevations. Scars from mining explorations are visible throughout the watershed, and the related activities are suspected to have had some impacts. Exploratory mining roads frequently do not have culverts or bridges where streams are forded, and some roads may be constructed with fill, which also has ARD potential, as has occurred at Equity Silver Mine (Remington 1996). Sediment input and altered stream channel morphology from the network of mining roads, and the lack of appropriate stream crossings has likely had some impacts on fish and fish habitat in the system.

The most significant effects of mining on the Upper Bulkley River watershed have been monitored around the Silver Equity Mine since its closure. However, the levels of cyanide and cyanide breakdown products have been declining in the mine tailings ponds since the closure of the Equity Silver mine. Water sampling in the receiving environment, Foxy and Buck creeks was recently conducted and it was established that while nitrogenous compounds were present at elevated concentrations, they did not exceed water quality criteria for freshwater aquatic life (Remington and Donas 2000). Effects from the mine were also noted in benthos species composition and species diversity when comparing upstream and downstream sites in Foxy and Buck creeks. These effects appear to be diminishing since the closure of the mine indicated by the re-appearance of some acid sensitive benthic invertebrates in these streams and diatom algal taxa (Remington & Donas 2000, Perrin 1999). While mining is presently at a relatively low scale within the Bulkley watershed, linear development and the potential for ARD generation, as well as the naturally high level of some minerals in the watershed indicate that mining likely has had some, although probably low level impacts on fish and fish habitat.

4.1.5 Urbanization

The effects of urbanization on fish and fish habitat are relatively localised within the watershed, due to the low overall population densities, and the relatively small size of settlements in the valley. The population in the Nechako Regional District, which includes the Bulkley watershed, accounts for 1.12 % of the population of the province. Smithers is the largest settlement area with a population of 6139, followed by Houston, with a population of 4206, Telkwa with a population of 1417, and the Hazeltons with a population of 1214 (BC Stats 2000). Smaller communities in the valley include Rose Lake, Forest Dale, Topley, Knockholdt, Perow, Walcott, Barrett, Quick, Moricetown, and Hagwilget. In addition, a number of rural residences are scattered throughout the watershed.

In general, it is accepted that urbanization effects watershed characteristics such as stream hydrology, channel pattern, and water quality. Loss of forest cover, paving of roads and parking lots, and construction of buildings in relatively high densities decrease the permeability of the soil, and increased water run-off rates, which result in increased peak flow and decreased low flows. These activities have increased run off of water that is sometimes contaminated with salts, oils and hydraulic fluids which effect water quality and fish habitat (Halls *et al.* 1996). Increased peak flows are also known to cause alteration in channel morphology and lead to unnatural bank erosion, channelization, and degraded habitat. Some river dikes have been constructed near some of the settlements in the Bulkley valley, including Houston, Smithers and Telkwa in efforts to reduce flood potential, and lateral movement of the channel. The restrictions to the lateral movement of meandering of stream channels related to dikes and rip-rap is now recognized to decrease habitat complexity, which decreases habitat suitability for salmonids (Hunter 1991). In addition, seepage from septic systems in rural areas and sewage disposal from urban areas has caused increased nutrient loading and biological oxygen demand, as well as concentrations of pollutants in the Bulkley River (Remington 1996, Remington and Donas 2000). Water withdrawal for consumptive use has affected stream hydrology and appears to have significantly altered the annual and monthly discharge in the Upper Bulkley watershed (Remington 1996, Dunne and Leopold 1998, Remington and Donas 2000). Various waste products have been deposited in a number of landfill sites, likely causing some leaching of heavy metals and other contaminants into the groundwater and eventually streams and some lakes in the Bulkley watershed (Remington 1996, Dunne and Leopold 1998, Remington and Donas 2000). Overall, many of the effects of urbanization on coho in the Bulkley watershed have been recognized, and should be monitored and managed more cautiously as the human population in the valley grows and expands.

Increasing water use, the output of untreated, primary, and secondary treatment sewage, and surface runoff containing pollutants are the most notable impacts from urbanizaton in the Bulkley valley. The most obvious effect of urbanization in the Bulkley watershed has been the disposal of sewage. The municipalities of Hazelton, Smithers, Telkwa and Houston all have permits to discharge secondary treatment sewage in the Bulkley River (Remington 1996). In the Bulkley River, elevated periphyton biomass and high nutrient concentrations have been noted near sewage outputs from Houston (Remington and Donas 2000), Hazelton (Remington 1996), and in Dahlie Creek in Smithers (Saimoto and Remington 2000). Sewage disposal at Hagwilget near the confluence of the Bulkley River to the Skeena River has been found to be out of compliance, and toxic to aquatic life on a number of occasions in the past (Remington 1996). Increased biological oxygen demands were found, at least on a seasonal level, at sewage disposal sites for Telkwa, Smithers, Moricetown, and Hagwilget (Remington 1996). Overall, only the lower reaches of some tributaries, and some of the mainstem reaches located in or near settled areas of the Upper Bulkley River watershed, have been affected to measurable degrees (MacKay 1997, Tamblyn & Jessop 2000, Saimoto & Remington 2000).

4.2 Coho Distribution

Coho spawning and rearing in the Upper Bulkley River watershed, above the confluence of the Morice River are commonly referred to as the Upper Bulkley River coho aggregate. The Upper Bulkley River aggregate is made up of several populations that appear to be somewhat distributed to specific areas. Presently, the main centres of spawning populations have been observed to focus in Buck Creek and in the Bulkley River near Richfield Creek. The Upper Bulkley River aggregate also appears to consist of a number of smaller groups of coho that spawn and rear in its moderate sized tributaries (i.e. Maxan, Richfield, Ailport, Byman, McQuarrie, and Aitken creeks). Based on historical records, fall anadromous spawners (i.e. chinook and coho) also spawned as far upstream as Maxan Lake prior to 1970 (*see* Figure 4). During the past few decades, the distribution of coho has been limited to less than half way up the mainstem of the Bulkley River, well below Bulkley Lake and Maxan Creek. In addition, the largest tributary to the Upper Bulkley River (Buck Creek) which drains into the lower portion of the Upper Bulkley has also experienced similar reductions in coho distribution (*see* Figure 4). The recent limits of coho distribution in the Upper Bulkley River and Buck Creek are likely related to both the low escapements and below average discharge during their migratory timing windows. The low discharge during the summer and fall months appears to have increased the number and stability of beaver dam obstructions in the Upper Bulkley River watershed which appears to further impede adult coho migration. The recent infrequency of high enough flows has also made some cascades in the upper Bulkley River and in Buck Creek frequently impassable during the peak time of coho migration. Figure 4 presents the approximate changes in coho distribution, which are suspected to have occurred since the 1960s.

Over the past 50 years, a trend of declining annual discharge appears to have occurred since the 1950's. In the more recent years, the spring peak flow event in the Upper Bulkley River has been lower, and has frequently had only one peak freshet during snowmelts in the spring (Brockelhurst 1998). In conjunction with the increased land use in the Bulkley valley, summer flows appear to have decreased significantly when compared to historic data. In addition, the lack of fall freshets on several occasions in the past few decades appears to have affected the distribution limits of fall spawners in the Upper Bulkley River with few fish being able to migrate upstream of Richfield Creek. Most importantly, the present limits of coho distribution in the Bulkley watershed appear to be restricting coho access to not only valuable spawning habitat in Maxan Creek, but also vast amounts of freshwater rearing habitat. Excellent coho rearing habitat in Maxan Lake, Bulkley Lake, and a very large wetland complex with meandering channels located just upstream of Richfield Creek is presently not being used due to the lack of fish access. Use of a very large wetland complex in the Buck Creek watershed located upstream of the approximately 200 metre long cascade located approximately 12 km upstream of the Bulkley River, has also had limited use during the past decade (SKR *in prep.*). The present limitations to adult migration are clearly related to the poor recovery of the Upper Bulkley Coho aggregate and some recently formed obstructions to fish passage.

4.3 COHO ESCAPEMENT

Estimates of wild coho returns to the Upper Bulkley River ranged between 10 and 278, with an average of only 83 adult wild coho per year from 1989 to 2000, in comparison to an average of approximately 3840 adult coho per year in the 1950s (Holtby *et al.* 1999). An overall decline of returns of other coho aggregates in the Bulkley River watershed indicates that this decline is at least partly related to the ocean conditions, and commercial, native food, and sport fisheries over the past decades. Recent strategies that have been implemented toward better management of coho escapement have included efforts to sustain genetic diversity and the natural distribution of coho throughout the province. As the management of annual coho escapement through our fisheries continues, the loss of habitat and unnatural limits to distribution for coho in the Upper Bulkley watershed become the main constraint to restoring this coho aggregate to its historical ranges of recruitment. Based on the present outcome of drastic reductions in the Canadian commercial fishery, it is becoming apparent that the continuing low escapements for the Upper Bulkley River aggregate are related to loss and degradation of freshwater habitat.

Holtby *et al.* (1999) have summarized the available escapement data for the Upper Bulkley aggregate (*see* Figure 4). Escapements of coho to the Upper Bulkley River watershed have shown disastrous declines since the 1950s. Holtby *et al.* (1999) have provided some conservative estimates of the numbers of wild escapements to the Upper Bulkley River and evaluated returns to have decreased 11% per year from 1970 to 1998. This decline was identified to be approximately double the declines that were estimated by the Babine and test fishery indices, indicating that habitat loss and degradation of fish habitat in freshwater were related to the decline. Interestingly, coho enhancement efforts in the Upper Bulkley River since 1989, and recent reductions in Canadian harvest have not shown complete success in restoring the Upper Bulkley River coho escapement.

More recent escapement for the Upper Bulkley River in 1999 and 2000 were estimated to consist of only 215 and 37 wild coho, respectively (Glass 2000, Tamblyn 2001) which further supports that smolt production may be limiting recruitment for the Upper Bulkley River aggregate. Although, smolt and fry releases in Buck Creek have begun to improve escapement to the Upper Bulkley River (~1400 hatchery and ~700 wild returns in 2001; Donas 2001), the escapement of wild coho to the Upper Bulkley River watershed remains low (see Figure 5). A recent study of coho overwintering habitat has obtained data that provide evidence that some parts of the Upper Bulkley watershed that are presently used by coho may still have been under seeded in 1998 and 1999 (i.e. low winter densities of fry) due to low returns (SKR 2001). Much of the available habitat in the Upper Bulkley watershed was shown to contain significantly lower densities of juveniles than Toboggan Creek that was used to represent a well seeded system (Donas & Saimoto 2001). Although the mixture of 1.1 year and 2.1 year life histories for coho can allow populations to more easily rebound from occasional years of poor returns (e.g. the rebound of Toboggan Creek from low escapement in 1997), consecutive years of low escapement is detrimental. The consecutive years of low recruitment that have occurred in the Upper Bulkley River reduced the smolt production for consecutive years and appear to have created a cascading decline of coho production. The number of years that the upper Bulkley River appears to have been in this downfall may also explain why the recovery of the Upper Bulkley aggregate has been so slow since the recent years of heavy regulations on the Canadian commercial, native food, and sport fisheries.

An estimate of 11 to 30 female coho per km of stream is required by the habitat based model for Oregon coast by Nickleson (1998) to adequately seed the system. This suggests that the presently accessible portion of the Upper Bulkley River requires between 418 and 1140 female spawners to sufficiently seed this system. This range would be dependent on the variability of marine survival and exploitation, but supports the suggestion that the Upper Bulkley River is presently in poor condition. Wild coho escapements have ranged from only 10 to 106 female spawners over the past decade prior to stock enhancement efforts (Holtby *et al.* 1999). Results from the Upper Bulkley overwintering study support that even with the largest return of 545 females in 1999 (hatchery and wild combined), the system appeared to only become optimally seeded with coho juveniles in a few small pockets near the main spawning area around Richfield Creek (Donas & Saimoto 2001).

Overall, the evidence of poor conditions in the Upper Bulkley River indicates that the natural recovery of this aggregate of coho to its historical records is unlikely. The record low escapements to the Upper Bulkley River and the limited response to recent reductions in Canadian harvest suggest that the coho aggregate of the Upper Bulkley River may still be at risk. Other coho aggregates in the Bulkley River watershed appear to have notably rebounded in response to the reductions of Canadian harvest of coho (e.g. Toboggan Creek, and Telkwa River), but the lack of, or delayed recovery of the Upper Bulkley River aggregate supports that anthropogenic alterations of habitat may have significantly altered the capability of coho production in the Upper Bulkley River watershed.

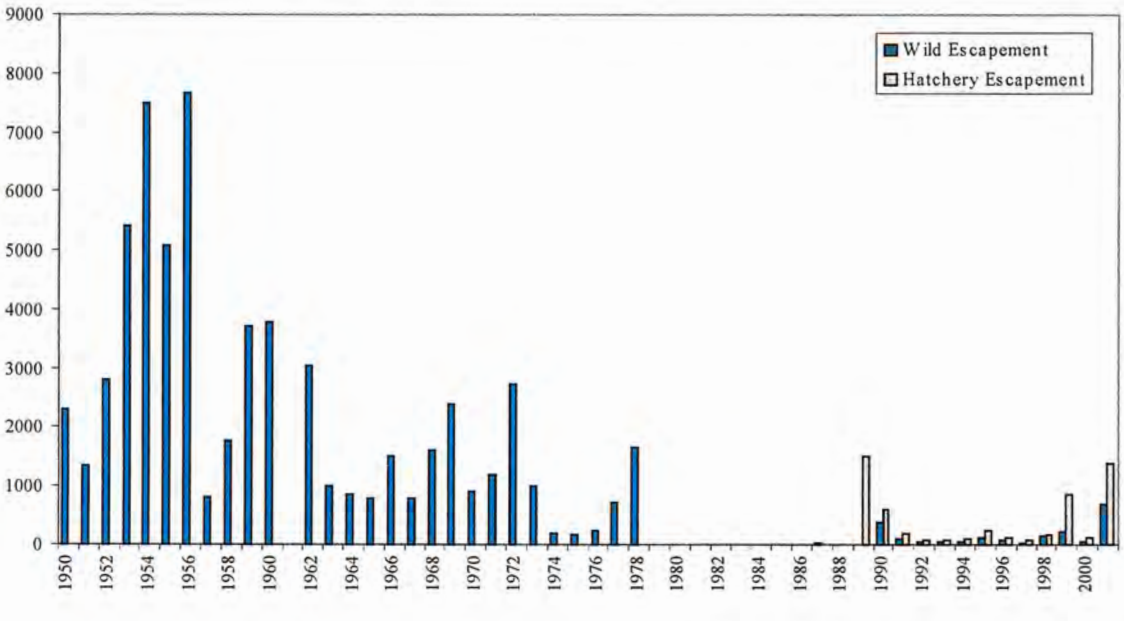


Figure 5. Escapement estimates for the Upper Bulkley Coho aggregate from 1950 – 2001 (Holtby *et al.* 1999, Glass 1999; 2000, Donas 2001).

5.0 FUTURE WORKS

Coho escapements to the Upper Bulkley River have remained at levels that raise considerable concern for the present state of its habitat. Focus on sustaining this presently small and depleted coho aggregate appears to be the short term objective in conjunction with a long-term goal to eventually restore its distribution and escapement to its historical records. The long-term goal will involve extensive efforts toward refinement of the management of our fisheries, negotiations over the water management issues in the area, and restoration of lost habitat. The short-term goals of protecting this endangered coho aggregate will involve many efforts by teams of supportive groups to provide adequate protection and any improvement to the existing habitat in the most effective ways based on the available funding sources. The following sections provide ideas for future work efforts with their objectives toward obtaining a better understanding of how to restore, sustain, and manage the Upper Bulkley coho aggregate.

Table 2. Summary of suggestions and priorities for future work toward restoring coho in the Upper Bulkley River watershed.

Future Works	Priority	*Page #*
Monitor Adult Coho Returns		
Monitor Adult Escapement	High	31
Monitor Adult Migration and Distribution	High	32
Assessments of Coho Smolt Production		
Monitor Buck Creek Smolt Production	High	33
Monitor Upper Bulkley River Smolt Production	High	34
Conduct Winter and Spring Synoptic Surveys	High	35
Assess How Winter Survival may be Influenced by Age/Size Distribution and Densities	Moderate	36
Assess How Growth and Survival may be Influenced by Winter Climate	Moderate	37
Assess How Ocean Survival may be influenced by Smolt Size and Age	High	38
Assess the Habitat Constraints at Vacant Summer Habitats	High	39
Habitat Restoration		
Obtain Detailed Information on Water Use	High	40
Develop a Water Management Strategy	High	41
Assess the Impacts of Beaver Activities on Adult Coho Migration	Moderate	42
Implement Riparian Rehabilitation Projects	Moderate	43
Improve Fish Passage at the Upper Bulkley River Falls/Cascade	Moderate	44
Assess Fish Passage at the Cascade that Impedes Coho Migration in Buck Creek	High	44
Restoration of Coho Overwintering Habitats	High	45
Start a Habitat Restoration/Compensation Project	High	46
Stock Enhancement		
Transport Adult Coho upstream of Partial Obstructions	Moderate	47
Hatchery Fry Releases Upstream of Partial Obstructions	Moderate	48
Smolt Releases in Buck Creek	High	49
Public Education and Promotion	High	50

5.1 Monitor Adult Coho Returns

It will be important to continuously monitor and document the escapement of wild coho and the distribution of wild and hatchery coho until the population has been restored to a target level. A brief outline of the ideas regarding the annual monitoring of the escapement of both wild and hatchery coho and their distribution are presented below.

Monitor Adult Escapement

It is recommended that annual estimates of adult escapements at the Houston adult fish fence continue to provide a constant index of the state and the changes in coho production in the Upper Bulkley River watershed.

Benefits:

- Estimates of adult returns will provide a measurable index for monitoring the productivity of the Upper Bulkley River coho aggregate relative to the historical records.
- Consistent and annual record of adult escapement will develop an index that may be used for estimating the outcome and effectiveness of restoration efforts.
- Operation of the fence will provide easy access for brood collection for hatchery operations to assist with future enhancement efforts.
- The data from this study will be valuable toward proving the theory that smolt production is presently limiting recruitment based on how the recently moderate returns (mostly hatchery spawners from Buck Creek) are found to enhance the number of wild spawners in the future.

Methods:

- Provide some target levels for wild coho escapement to the Upper Bulkley River
- Seasonal operation and maintenance of the Houston adult fish fence.
- Standardize, maintain, and document the methodologies for fence maintenance and data collections.
- The involvement of community groups and volunteers with fence operation and maintenance may also be valuable to allow more public participation and if funding sources decline.
- Ensure the collection of scale samples to allow annual monitoring of the age distribution of returns.
- Application of Floy tags may be valuable toward gaining more accurate escapement estimates during years when fence operation is sporadic or if the operating time is shortened.

Monitor Adult Migration and Distribution

Monitoring the migration of adult coho in the Upper Bulkley River watershed is recommended in order to keep track of the overall distribution and area of habitats that juveniles will occupy each year.

Benefits:

- Recognition of differences in annual distributions of spawners will be important toward explaining the potential variations in smolt production.
- Gathering information on the relative habitat values based on coho abundance in different sub-basins will allow easier prioritisation of future work.
- Monitoring migration for annual estimates of the productivity of habitats in the various sub-basins will inform us of the ongoing state of this coho aggregate.
- Results from this study can be used during the planning and preparation of many other studies related to freshwater rearing for assisting with identifying sampling locations for juvenile abundance and survival rate.

Methods:

- Design and document all methods of the assessments to ensure the consistency of the data over time.
- Conduct annual aerial counts if water levels are suitable in October to acquire estimates of relative fish distribution between Buck Creek and the Upper Bulkley River near Richfield Creek.
- Conduct ground counts in main spawning areas in October to evaluate distribution of adipose clipped returns and proportions of Floy tags.
- Conduct annual ground counts to establish the upstream limits of coho migration in the Upper Bulkley River and in Buck Creek.
- Conduct ground assessments of the Buck Creek cascade located approximately 12 km upstream of the Bulkley River during the peak migration time to assess its restrictions to coho passage during different rates of discharge.
- Conduct ground assessments of the cascade in the Upper Bulkley River during the peak migration time to assess its restrictions to coho passage during different rates of discharge.

5.2 Assessments of Coho Smolt Production

The shortage of fry refuge and winter habitat for coho in the Upper Bulkley watershed appears to have significantly decreased smolt production and has resulted in consistently low annual escapements. A number of factors influencing the natural variability of freshwater survival are still hypothetical. In order to see the success of future restoration efforts, a number of studies are still required to better predict and explain the results. Potential studies related to coho smolt production with their apparent and relative value toward effective management and protection of the Upper Bulkley River coho aggregate are presented below.

Monitor Buck Creek Smolt Production

Annual operation of a rotary screw trap (or possibly inclined plane traps) from May 15th to June 30th to monitor coho smolt migration is recommended.

Benefits:

- The annual estimates of smolt migration will acquire valuable information on winter survival and suitability of habitat in Buck Creek.
- The associated estimates of wild coho smolts will provide an index for evaluating the success of fry transplants toward returning the Buck Creek population to a sustainable abundance.
- The estimates of the wild coho escapements over the life cycles of the next few cohorts will assist with defining the benefits and the future needs for hatchery rearing and releases of juvenile coho into Buck Creek.
- Results will help assess age distribution/proportions of different age classes of smolts and its variability among years.

Methods:

- Operate the rotary screw trap or two inclined-plane traps from May 15th to June 30th.
- Plan and design the operation and co-ordinate hatchery tagging with different age classes releases to allow more accurate smolt estimates.
- Consider moving the trap location further downstream to incorporate wild coho production in the lower 15 km of the watershed into the sampling plan.
- Conduct 8 hour shifts from 20:00 to 04:00 hrs with constant monitoring of the trapping efficiency and regular processing and release of trapped fish.
- Conduct continuous trap efficiency releases throughout the trapping period in attempt to improve the accuracy of smolt estimates.
- Collect age samples from smolts to assist with analyses of age distribution of smolts.
- Provide detailed documentation of the methodologies and results each year.
- Summarize the data after a four to five year period to identify interesting trends.

Monitor Upper Bulkley River Smolt Production

Building and operating a suitable trapping structure for monitoring smolt output from the Upper Bulkley River watershed will help evaluate its level of coho smolt production relative to habitat loss and hatchery enhancements. Trials of monitoring smolt migration have been previously conducted using a rotary screw trap and were relatively successful for capturing coho (Beere 1996). However, the construction of a sturdier and larger inclined plane trap or series of inclined plane traps will likely be safer to operate, more efficient, and will withstand higher rates of discharge.

Benefits:

- Operation of a smolt trap in the lower reach of the Upper Bulkley River will take advantage of the annual smolt releases in Buck Creek to allow for evaluations of the wild smolt production of the Upper Bulkley River aggregate.
- Estimates of wild smolt production each year will develop estimates for the range of smolt production
- Data collected will provide valuable information for the analyses of the age distribution of coho smolts in the Upper Bulkley River watershed and possibly a clearer evaluation of the potential constraints to smolt production.
- The acquired range of annual smolt production will allow useful forecasts of recruitment for the following year and evidence of recovery of the system from past impacts.
- The range of smolt production for the Upper Bulkley River will provide a better perspective of the actual value of future restoration efforts.

Methods:

- Designing and construction of a sturdy and buoyant structure built to withstand high discharge and debris is required to make this project feasible.
- Design and document a plan for operation and select an appropriate location that will provide both safety and good sampling efficiency (e.g. potentially design an attachment to the adult fish fence).
- Operate a modified inclined-plane trap or rotary screw trap from May 15th to June 30th.
- Monitor out-migration of smolts from the release pond in Buck Creek with attempts to stagger their movement throughout the timing window of smolt migration.
- Conduct 8 hour shifts from 20:00 to 04:00 hrs with constant monitoring of the trapping efficiency and regular processing and release of trapped fish.
- Conduct continuous trap efficiency releases throughout the trapping period in attempt to improve the accuracy of smolt estimates.
- Collect age samples from wild smolts to assist with analyses of age distribution of smolts.
- Provide detailed documentation of the methodologies and results each year.
- Summarize the data after a four to five year period to identify interesting trends.

Conduct Winter and Spring Synoptic Surveys

The annual synoptic surveys of juvenile coho densities during early winter and early spring in the Upper Bulkley watershed should be continued in order to help evaluate the carrying capacity of various habitats and the range in smolt production in the Upper Bulkley River watershed.

Benefits:

- More years of sampling for survival indices for winter habitats will provide a clearer understanding of the limitations to smolt production in the Upper Bulkley watershed.
- Determining to what extent winter habitat limits coho smolt production may provide information that will make it easier to obtain more public agreement and involvement with restoration efforts by allowing planners to present a measurable value and predicted outcome for future habitat restoration projects.
- The range of the winter survival index and its relationship to early winter densities may also provide valuable information regarding how different rates of escapement may effect smolt production.
- The comparison of age distribution in early spring to the age distribution of smolts of the same spring should provide estimates of proportions of fry that delay smolting each year of the study.
- The variations in winter survival should help explain the high variations of smolt migration that appears to occur (e.g. winter survival and age data may explain differences of mean wild smolt estimates in Toboggan Creek that has ranged from 35,280 - 89,391smolts).
- Age and size distribution data will be useful toward foreseeing and estimating smolt production if a large enough and random sample of sites allows a correlation between this index to smolt migration estimates.

Methods:

- A meeting to discuss the intensity of sampling that is required to obtain statistically sound results.
- Annual synoptic surveys of juvenile coho indices should be conducted in early winter and early spring.
- Age data for a sub-sample should be retained to allow analysis of age distribution and further comparisons to age distributions of smolts.
- Sampling in a control site such as Toboggan Creek, and possibly another area not influenced by hatchery enhancement projects will be important for assessing the state of winter rearing habitat the Upper Bulkley watershed.
- Provide detailed documentation of the methodologies and results each year.
- Design and implement a detailed assessment of the relationship of minnow trap density indices to actual abundance of coho during winter and spring sampling.

Assess How Winter Survival may be Influenced by Age/Size Distribution and Densities

An evaluation of winter mortality may provide useful indices of the range of densities appropriate for various habitat types and information on survival and competition of different age classes of coho in the Upper Bulkley watershed.

Benefits:

- Acquiring density indices for winter survival in important coho habitat types may allow more accurate and efficient estimates for fry releases into apparently good rearing habitats upstream of the current limits of coho distribution in both the Upper Bulkley River watershed and Buck Creek.
- Assessment of the survival of coho entering the winter in different densities and age distributions will provide valuable foresights into the effects of competition on condition and coho production.
- Conversion of a sub-sample of density indices to actual density estimates will allow us to better predict the amount of coho production that will be obtained from various habitat restoration efforts.

Methods:

- Collection and review of the existing data from previous studies and unpublished data related to winter rearing of coho juveniles.
- Create a model of how winter mortalities fluctuate with different age distributions, size distributions, and densities prior to winter.
- Possible test the assumption of minimal migration of coho during winter rearing.
- Incorporate a detailed scientific design of sampling into the winter synoptic survey of coho abundance to test the hypothetical inter-relationships of age, size, and pre-winter densities.
- Summarize and document the findings to share a better understanding of the effects that longer residences in northern interior climates have on smolt production.

Assess How Growth and Survival may be influenced by Winter Climate

Organization and analysis of the available data collected during the recent Upper Bulkley River/Toboggan Creek overwintering study (Donas and Saimoto 2001) may be useful toward identifying how the variability of winter climates might be affecting winter survival of freshwater rearing coho in the Bulkley River watershed.

Benefits:

- Identifying the relationship of different winters to delayed smolting will be useful toward foreseeing and explaining variations in smolt production.

Methods:

- Collect and review of all the existing data from water temperature data loggers, Bulkley overwintering reports, Bulkley/Toboggan smolt enumeration reports, and relevant Environment Canada weather records.
- Design a general model displaying the hypothetical relationships of obvious trends that are found during data review.
- List criteria for data collection during other related projects that will help with future analyses.
- Provide a scientific design for data collection that will test the hypothetical trends that appear important and attempt to gather data in conjunction with other ongoing studies.

Assess How Ocean Survival may be Influenced by Smolt Size and Age

An evaluation of the existing smolt to adult survival data is needed to test the ideas that fish that migrate from the Bulkley River at smaller sizes may have poor survival during their transition to seawater. Poor survival during smolting by smaller fish may play an important role in the high variance of smolt to adult survival.

Benefits:

- This analysis of data may identify differences of ocean survival for different age/size classes that may help explain the variability of what we have seen occur in past estimates of ocean survival.
- This test is important to test if high numbers of fall fry releases for enhancement may cause high competition and output of smolt in a size range that will have poor ocean survival.

Methods:

- Collect all available data for Toboggan Creek smolts that were previously tagged and released starting in 1999 with different coded tags for two size classes (i.e. fork lengths > and < 100 mm).
- Identify trends from the existing data and provide scientifically sound prescriptions for future data requirements that may be met during other ongoing studies.
- Collect scale samples from adult spawners and from wild smolts from the Upper Bulkley River during future years of other operations (e.g. Houston adult fish fence).

Assess the Habitat Constraints of Vacant Summer Habitats

Identify the potential habitat constraints for apparently suitable rearing habitats in the Upper Bulkley River and Buck Creek watersheds that are presently vacant or with only low densities of rearing coho.

Benefits:

- Evaluation of summer habitat qualities will test if summer habitats are presently a notable constraint to coho production and how it may be related to anthropogenic disturbances.
- Learning the suitability of summer habitats will help with future planning and evaluating the relative importance of other restoration efforts.
- Identifying the relationship of different summers to delayed smolting may be useful toward foreseeing and explaining variations in smolt production.
- Confirmation of the habitats being suitable for summer rearing will help justify proposals to transport adult coho upstream of anthropogenic obstructions.

Methods:

- Collect and review of all the existing data from water quality reports, water temperature data for the Upper Bulkley River watershed, and relevant Environment Canada weather records.
- Document the findings with recommendations with a list of the data requirements for it to be incorporated into other ongoing studies.
- Evaluate the proportion of summer rearing habitat that causes stranding related to recent declines in discharge.
- Provide a detailed proposal for fry release enhancement opportunities into vacant habitats upstream of the present limits of coho distribution.

5.3 Habitat Restoration

The loss and degradation of coho habitat in the Upper Bulkley watershed has lowered the potential recruitment for this aggregate. Some ideas to where future efforts may be directed in attempt to restore the quantity and quality of coho habitat in the Upper Bulkley River watershed are presented in this section.

Obtain Detailed Information on Water Use

Conduct a detailed survey of water use that will allow modelling of how the existing water licences have influenced discharge in the Upper Bulkley River.

Benefit:

- Documentation of the timing and rates of water use for presentation of the problem with present water use will help communities develop suitable water use strategies.
- This information will allow strategic regulations that will help restore coho migration to valuable spawning and rearing habitats in the Upper Bulkley River and Buck Creek.

Methods:

- Assess how much of the water that is currently allocated is actually withdrawn under the current water licences.
- Design and initiate a study that will clearly define the direct relationship of present water use to declines in discharge and may provide a clearer picture of when timing windows for water restrictions will be helpful to coho.
- Estimate agricultural and domestic water use.
- Evaluate the use of ground water and its potential to affect fall discharge and winter survival.
- Summarize present water use and propose a water management strategy for two or three levels of restoring habitat quality and fish passage.
- Present the findings and recommendations to the public, Ministry of Water, Land and Air Protection, and municipal governments.

Develop a Water Management Strategy

Community groups should co-ordinate their efforts with stakeholders and government agencies toward designing water management strategies, negotiations and submission of feasible applications for the changes that are necessary to increase discharge rates during the migratory timing window of adult coho.

Benefits:

- Restoring easier fish access to the valuable coho habitat in the Upper Bulkley and Buck Creek may give hope to restoring coho escapement of the Upper Bulkley River aggregate to its historical records.
- Restoring access to the upstream portion of the Upper Bulkley watershed may be drastically less expensive than restoration and compensation projects that may need continual maintenance.
- Learning the details and feasibility of changes to water use in the Upper Bulkley River watershed at its present state of development may justify more work and identify funding sources that are needed to compensate for the losses related to present water use.

Methods:

- Create a volunteer committee consisting of a local team of qualified members.
- List, define, and delegate the required duties that will help with presentation of any proposed changes.
- Review the present situation and decide on the options for effective changes to water use in the Upper Bulkley River watershed.
- Provide a presentation of the scenario to begin educating the public of the possibility for changes to the existing water licences.

Assess the Impacts of Beaver Activities on Adult Coho Migration

An assessment of beaver dams during various flow conditions in the Upper Bulkley River and Buck Creek is needed to document the degree to which the larger complexes may be obstructing fish passage.

Benefits:

- Results from this assessment will evaluate the significance that beaver dams in the Upper Bulkley River and Buck Creek are having on the distribution of coho during adult migration.
- Results may provide estimates for what rates of discharge we need to restore fish distribution in the Upper Bulkley River watershed.

Methods:

- Design and implement a sampling schedule for monitoring the stability and obstruction of beaver dams during the timing window of adult coho migration in the Upper Bulkley River and Buck Creek.
- Ensure that sampling times are distributed among specific levels of discharge, two or more years of returns, and within the timing window of adult migration.
- Document all results and attempt to estimate the discharge rates or flood events that may reduce the obstruction of beaver dams to fish passage.
- Design and propose some methodologies that can be implemented to monitor and deviate discharge until water management issues have been solved.
- Consider the relatively high value of beaver ponds for winter habitat when designing improvements of fish passage past large beaver dam complexes.

Implement Riparian Rehabilitation Projects

Implementing work on riparian rehabilitation projects along streams with unstable banks will be important toward the long-term objectives of restoring fish habitat for all species to its natural state.

Benefits:

- Stabilisation of stream banks with riparian rehabilitation projects is an important step toward restoring fish habitat by decreasing sediment loading and moderating floods.
- Bank stabilisation and any control of freshets will inevitably improve habitat complexity and ecological diversity in the system.

Methods:

- Riparian protection/rehabilitation should be strongly promoted on both public and private land since stabilising stream bank is needed to restore spawning and some overwintering habitats.
- Riparian rehabilitation projects that have been completed should be used to help educate and gain further support from the general public.
- Ensure that conditions before and after rehabilitation projects are well documented
- General guidelines for riparian protection/rehabilitation should be written and distributed to all communities and stakeholders (e.g. ranchers) that are near streams obviously impacted by streamside disturbances.
- The available funding for riparian rehabilitation projects should be used in conjunction with encouraging public and volunteer participation to assist with teaching and promoting the objectives of stream restoration efforts.

Improve Fish Passage at the Upper Bulkley River Cascade

Coho migration past the cascade/falls section on the Upper Bulkley River between Morice River and Bulkley Lake should be restored.

Benefits:

- Restoring more consistent and easier adult fish migration past this cascade will provide compensation for low discharge rates that now frequently occur during the timing window of adult coho migration.

Methods:

- Review all available unpublished letters and notes on previous considerations of this improvement to summarize the foreseen difficulties and opinion of the efforts.
- Design a structural change to the cascade that will compensate for the unnatural limits of fish migration to a large proportion of the available spawning and coho rearing habitat in the Upper Bulkley River watershed.
- Ensure that the geological modifications to the cascade are stable and will naturally sustain their structure with no maintenance.

Assess Fish Passage at the Cascade that Impedes Coho Migration in Buck Creek

A detailed field assessment of the cascade in Buck Creek located approximately 12 km upstream of the Upper Bulkley River will be important to evaluate the potential for coho to return to spawn within and upstream of the main rearing area on the Buck Flats.

Benefits:

- A detailed assessment of this cascade will determine the optimum discharge for coho migration and the feasibility of maintaining or restoring fish passage.
- A field assessment of this obstruction will be important toward future management of the hatchery fry and smolt release efforts that are occurring upstream of this cascade.

Methods:

- Prepare a study design and data sheet that can be used by any participants to collect data in a standardised format.
- Assess the quantity of fish held back below the cascade and rate the difficulty of fish passage at various discharge rates.
- Acquire volunteers to assist with observations and data collection for coho migration at the cascade throughout the peak time of coho migration.
- A conceptual design for restoring fish passage may be required if low discharge appears to have a significant impact on coho migration.

Restoration of Coho Overwintering Habitats

Selecting and setting priorities for specific sites that can start to compensate for the amount of coho winter rearing habitat that has been lost, may be the most simple and effective method to help save and sustain the returns of the Upper Bulkley River coho aggregate.

Benefits:

- Documentation of the impact of particular linear developments may provide avenues for securing more funds and support for implementing plans for improving fish passage.
- Restoring access to off-channel habitats with suitable water qualities during winter conditions appear feasible and will have measurable improvements to smolt production for the Upper Bulkley River.
- Off channel habitats are relatively stable and are significantly less vulnerable to flood events that may alter in stream rehabilitation efforts such as root wad placements.
- Rehabilitation or creating winter rearing habitat will also provide coho and other salmonids with valuable summer rearing habitat.

Methods:

- Review literature such as the winter measures of dissolved oxygen done by Bustard (1996), and unpublished letters and notes on the suitability of various locations in the Upper Bulkley River watershed.
- Assess the amount of suitable overwintering habitat that is currently inaccessible due to linear development with inadequate crossing structures.
- Set priorities for all of the observed opportunities such as Silverthorne Creek, side channels along Buck Creek or the off-channels down stream of McQuarrie Creek.
- Conduct winter assessments to help predict the value of different sites relevant to the quantity of habitat and the expected life of the project.
- Provide designs for habitat improvements, such as deepening of channels, root wad placements, or connections to sub-surface water sources, to off-channel habitats where access is restored.

Start a Community Habitat Restoration/Compensation Project

Design and initiate a detailed habitat restoration project near the heart of the community to help educate and gain more support from the public.

Benefits:

- A location with easy public access near the town of Houston will expose more people to the losses and hopefully provide more understanding and support for future efforts toward restoring coho habitats in the Upper Bulkley River.
- Gaining greater support from the local community may help with other efforts related to more sensitive issues on private land or with regard to water use.

Methods:

- Assess the suitability of locations near the town of Houston for a community attempt to help compensate for the impacts that human development has had on coho in their watershed.
- Provide conceptual designs for three options for restoring or compensating for lost coho rearing habitat.
- Design information display boards to summarize the causes of decline and state of coho salmon in the Upper Bulkley watershed.
- Design the requirements for any anthropogenic channels or modifications to existing off-channel habitats to ensure sufficient food resources for summer rearing and adequate oxygen and water temperatures for overwintering.

5.4 STOCK ENHANCEMENT

The depletion of wild coho escapement to record low numbers for the past decade have placed the Upper Bulkley River aggregate of coho at a risk of extirpation. Recovery of wild coho escapements to the Upper Bulkley River has been painstakingly slow despite the implementation of strict regulations on commercial, food, and sport fisheries since 1997. The number of coho returns over the past two years have notably increased, but primarily due to hatchery smolt and hatchery fry releases in Buck Creek for the past three years. During future studies on freshwater habitats and coho rearing in the Upper Bulkley River watershed, stock enhancement will definitely assist with design and testing of habitat restoration efforts.

Transport Adult Coho Upstream of Partial Obstructions

Transporting some adults from the Houston Adult fish fence to spawn upstream of the main refuge habitat in the Upper Bulkley River (e.g. Maxan Creek) and to Buck Creek on the Buck Creek Flats will help improve natural smolt production for the system.

Benefit:

- Transportation of adults upstream of the cascades that appear to have become significant obstructions to coho migration to allow coho to better utilise the habitat until assessments of the barriers are conducted.
- Restoring the opportunity for coho to spawn further upstream in the Upper Bulkley River and Maxan Creek will provide better fry refuge (i.e. wetland reaches, and Bulkley and Maxan lakes) during early spring freshets.
- Transportation of spawners further upstream will logistically lower the fry loss in the critical period during spring freshets when fry are distributing themselves and selecting their freshwater rearing habitats (i.e. too many newly emerged fry are being flushed out of the system from the present spawning locations).

Methods:

- Set a minimum escapement index to allow through the Houston Fence prior to moving spawners upstream to ensure the lower reaches remain adequately seeded.
- Transport a designated number of adult coho by truck to a main release location on the Buck Flats and at the outlet from Bulkley Lake.
- Application of radio-telemetry transmitters to some of the releases may be important to monitor the spawning distribution in the Upper Bulkley River.
- Some sites for the juvenile synoptic surveys should be sampled during the following year to gain some indicator of the outcome from the adult transport.

Hatchery Fry Releases Upstream of Partial Obstruction in Buck Creek

Fry releases in "vacant" habitats upstream of the cascades in Buck Creek provides optimum fry to smolt survival in conjunction with reduced competition and potentially only one winter rearing.

Benefits:

- Fry releases allow hatcheries to take advantage of their abilities to improve egg to fry survival with subsequent rearing in habitat in the Buck Creek watershed that is presently unoccupied by wild coho.
- Rearing of significantly more coho for fry release to a tagging size may be feasible at the Toboggan Creek hatchery facility, even though the number of fry that can be reared through the winter is limited by the amount of available winter rearing channels.
- Annual release of suitable numbers of fry upstream of un-natural obstructions will be beneficial until adult migration is restored to these areas.
- Fry releases in Buck Creek may be useful toward evaluating habitat quality and the potential smolt output for that system.

Methods:

- Continue with hatchery assistance with the Buck Creek coho by releasing surplus fry.
- Consider the feasibility of increasing fry production to assist with efforts to optimally seed the available rearing habitat in the Buck Creek watershed until natural smolt production is restored.
- Ensure that all hatchery fry are released with an external mark (even if they are too small for coded wire tag application) to allow accurate monitoring of wild coho abundance.
- Minimize hatchery releases in the Upper Bulkley River in hopes that natal homing by hatchery releases will help preserve some genetic integrity of the wild populations of coho further up the river (e.g. the Richfield Creek population).

Smolt Releases in Buck Creek

Smolt releases in Buck Creek have been helpful and should be used to sustain the Buck Creek population until sufficient success is made toward restoring fish migration and habitat in the Upper Bulkley watershed.

Benefits:

- Sustaining this hatchery population of coho has gained public interest and hope toward restoring the Upper Bulkley River coho aggregate.
- The partial recovery of coho in Buck Creek and possibly even the entire Upper Bulkley watershed appears to have been closely related to the smolt releases in Buck Creek.

Methods:

- Search for funding sources to support hatchery operations until populations of coho become self sustained.
- Continue with hatchery contributions of annual smolt releases.
- Co-ordinate all smolt releases with other ongoing studies related to fry releases.

5.5 PUBLIC EDUCATION AND PROMOTION

Public education and promotion through newspaper, television, and casual presentations to community groups, industry, and schools will be invaluable toward gaining both public and financial support for sustaining and restoring coho populations in the Upper Bulkley River watershed.

Benefits:

- The investments of time to educate the general public will clearly help with future negotiations and implementation of restoration efforts, particularly water use issues which will affect everyone.
- Providing the public and stakeholders (e.g. CN, MoTH, Ministry of Agriculture, etc.) with information to become more aware of the impacts that Upper Bulkley River coho aggregate has received over past few decades will help gain support and will build on their recognition and desire to become more involved in restoration and compensation efforts.

Methods:

- Search for funding sources from all available sources including local businesses.
- Develop public presentations that can be easily presented by a number of knowledgeable volunteers to gain support and assistance with various projects.
- Design posters for public display that will educate the public on the present condition and losses of coho habitat and the ongoing efforts to restore coho escapement in the Upper Bulkley River.
- Work with the District of Houston an information kiosk, possibly along the trail past the Houston adult fish fence, to display the state and progress toward restoring the Upper Bulkley watershed.

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