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A discussion paper on possible new stock groupings (Conservation Units) for Fraser River chinook salmon

Document de travail sur les nouveaux agrégats possibles de stocks (unités de conservation) pour le saumon quinnat du Fraser

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ABSTRACT

Implementation of the Pacific Wild Salmon Policy (WSP) will require the identification of stock groupings called Conservation Units (CUs) for all species of Pacific Salmon. To generate discussion on the methodology under development to identify CUs, we present several possible hierarchies for Fraser River chinook salmon, each hierarchy with a range of possible CUs. A review of genetic and non-genetic evidence leads us to identify five or possibly six groups that are substantially isolated from each other, and represent important components in the evolutionary legacy of chinook. Non-Fraser chinook salmon need to be considered before we decide whether these groups (upper-mid Fraser/North Thompson, South Thompson, lower Thompson, lower Fraser spring reds, lower Fraser fall whites, and possibly lower Fraser summer reds) warrant designation as Evolutionarily Significant Units. These groups constitute the first possible tier in several possible CU hierarchies. We further divide these groups according to productivity, marine catch distribution, return timing to freshwater and terminal fisheries management requirements. Since management targets will need to be established for each CU, annual management and assessment costs will be higher when more CUs are identified. However, with more CUs there may be additional fishing opportunities, and therefore these additional costs may be more than paid for. Before we can finalise the number and size of CUs for Fraser chinook we need to better articulate management objectives and consider the potential economic and social costs and benefits of various options.

RÉSUMÉ

La mise en oeuvre de la Politique concernant le saumon sauvage (PSS) de la Région du Pacifique nécessitera l’identification d’agrégats de stocks appelés unités de conservation (UC) pour toutes les espèces de saumon du Pacifique. Pour favoriser la discussion sur les méthodes en voie d’être élaborées pour identifier les UC, nous présentons plusieurs hiérarchies possibles pour le saumon quinnat du Fraser, chaque hiérarchie étant composée d’une gamme d’UC possibles. D’après un examen de données génétiques et autres, nous avons identifié cinq et peut-être six groupes sensiblement isolés l’un de l’autre, représentant d’importantes composantes issues de l’évolution du quinnat. Nous devons prendre en considération le quinnat des autres bassins avant de décider si ces groupes (cours moyen et supérieur du Fraser/rivière Thompson Nord, rivière Thompson Sud, cours inférieur de la Thompson, rouges de printemps du bas Fraser, blancs d’automne du bas Fraser, et peut-être rouges d’été du bas Fraser) doivent être désignés comme des unités évolutionnaires significatives. Ces groupes constituent le premier niveau possible de plusieurs hiérarchies d’UC possibles. Nous sous-divisons ensuite ces groupes selon la productivité, la distribution des prises en mer, le moment de la remonte vers les eaux douces et les impératifs de gestion des pêches en estuaire. Étant donné que des objectifs de gestion devront être établis pour chaque UC, les coûts annuels de gestion et d’évaluation seront plus élevés lorsque d’autres UC seront identifiées. Par contre, un plus grand nombre d’UC pourrait permettre d’offrir un plus grand nombre de possibilités de pêche, ce qui permettra de couvrir l’ensemble des coûts additionnels. Avant de pouvoir finaliser le nombre et la taille des UC pour le quinnat du Fraser, nous devons formuler plus clairement les objectifs de gestion et considérer les coûts économiques et sociaux potentiels des diverses options.

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1. Introduction

The Fraser River watershed (Fig. 1) is the largest Canadian producer of chinook salmon. Most populations of Fraser-origin chinook spawn upstream of Hell's Gate, the most notable exception being the Harrison River population in the lower Fraser. Chinook return to the Fraser throughout the year, with most non-Harrison fish arriving in the lower Fraser between April and September. Harrison fish enter the lower Fraser from September to November (Fraser et al. 1982).

Fraser chinook spawn primarily from August to December, and most spawners are either 3, 4, or 5 years old. Fry emerge the following spring and those that spend one year in freshwater are called "stream-type," while those that rear less than one year in fresh water (typically less than 6 months) are "ocean-type." (Healey 1983). Variability in chinook salmon flesh pigmentation levels exceeds that of other Pacific salmonids, resulting from a phenotypic dichotomy of 'red-fleshed' and 'white-fleshed' forms that is under relatively simple genetic control (Withler 1986, McCallum et al. 1987). Harrison fish are unusual since they are all white-fleshed (most non-Harrison chinook are pink or red-fleshed) and migrate as recently emerged fry directly to the lower Fraser River and its estuary.

Fraser chinook are comprised of a large number of populations. For management purposes, Fraser chinook have traditionally been divided into four major geographical stock complexes, and three timing groups. The geographical stock strata are: upper Fraser (those populations upstream of Prince George and including Nechako), middle Fraser (downstream of Prince George but excluding the Thompson), the Thompson River and its tributaries, and the lower Fraser (numerically dominated by fall-returning Harrison-origin fish) (Fig. 1). The timing groups are categorized into three seasonal runs. The early or spring run is comprised of populations for which the peak of migration through the lower Fraser River occurs before July 15; the summer run migrates through the lower Fraser between July 15 and Sept. 1; and the fall chinook, mostly originating in the Harrison, enter the lower Fraser chiefly after Sept. 1.

Recently, there has been much debate on the objective prioritization of units below the species level (Fraser and Bernatchez 2001). The hierarchical organization of genetic diversity in Pacific salmon was reviewed by Riddell (1993) and more recently by Wood and Holtby (1998). In this paper we use the approach advocated in the (draft) Pacific Wild Salmon Policy (WSP) to identify Conservation Units (CUs) [1].

CUs need to be identified for each species of Pacific salmon. The success of the WSP will require the protection of habitat within each CU and connectivity amongst habitat units. Reference points[2], including a target reference point, will be specified for each CU. The target reference point will define the lower end of the target zone and will reflect the management objective for that CU. A primary concern in identifying CUs is the protection of genetic

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[1] As defined in the (draft) Wild Salmon Policy, a CU is a group of one or more populations that share a common genetic lineage and can be managed effectively as a unit by virtue of their common productivity and vulnerability to existing fisheries. A wild salmon is one whose parents and grandparents spawned naturally.

[2] Estimated values derived from an agreed scientific procedure and/or and agreed model which correspond to a states of the resource and/or of the fishery and can be used as guides for fisheries management (definition from FAO (1997) used in (draft) WSP).

diversity; this was not specifically considered in the stock groupings previously used for Fraser chinook.

The major objective of this paper is to generate discussion on the methodology being developed to identify CUs. We anticipate that the scientific approach used here for Fraser chinook will lead to the development of a generic approach that can be used for other populations. We will propose various stock groupings for Fraser chinook that are designed to ensure the conservation and yet enable effective management of these important fish. We acknowledge that these groupings are provisional and may require revision.

We follow a multiple step approach to identify CUs. First, to make sure that major lineages of genetic diversity are conserved, and thereby ensure that the course of evolution is unconstrained (Waples 1995), we require that a CU should not be larger than an Evolutionarily Significant Unit (ESU) [3]. After satisfying the requirement that important genetic groups have been identified, we will further divide these groups based on their productivity and manageability. The number and size of CUs will vary depending on management concerns.

1.1 Glacial History and Colonization

A brief overview of glacial history and the subsequent colonization of the Fraser River watershed by chinook salmon is provided to aid in understanding distribution of chinook salmon populations within the watershed. During the most recent period of glaciation, most of British Columbia (BC) was covered by ice (Fulton 1969). The glacial maximum occurred approximately 15000 years ago, followed by a period of warming which took about 5000 years to melt the Fraser Glacier (Roed 1995). Anadromous salmon were able to exist in several glacial refugia including the lower Columbia River.

As the ice retreated, a significant portion of the Fraser River drained through the Okanagan watershed and entered the ocean via the Columbia River. At this time, the Fraser canyon was blocked with ice near Hell’s Gate (Fig. 1). As the last ice sheets retreated across the Nicola and Thompson watersheds to the north, a series of glacial lakes was formed which drained to the south or southeast (Mathews 1944). At one point, a much enlarged Nicola Lake drained eastward down the Salmon River and then into the Okanagan watershed. A body of water known as Lake Thompson extended beyond the existing Kamloops Lake near the Deadman River west of Kamloops, up the North Thompson Valley and east up the South Thompson Valley where ice occupying the site of Shuswap Lake diverted waters southward (Mathews 1944).

The Columbia system was a major source of the fish fauna that recolonized the interior Fraser watershed (McPhail and Lindsey 1986). Some chinook salmon presumably colonized the interior Fraser watershed during the period of Fraser-origin waters entering the Pacific Ocean via the Columbia River. Fish presumably entered by postglacial lake connections in the Okanagan-Nicola areas and across the low divide between the Columbia and Eagle rivers into the Shuswap system (McPhail and Lindsey 1986; Northcote and Larkin 1989). In contrast to the inland

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[3] An ESU is a population or group of populations that is substantially reproductively isolated from other populations and represents an important component of the evolutionary legacy of the species (Waples 1991).

dispersal pattern found for most interior Fraser fish populations, many fish now found in the lower Fraser River watershed, including some chinook salmon, colonized along the coast via the sea. The Fraser canyon remains a velocity barrier for many species of fish resulting in a discontinuous distribution of many species and populations within species (McPhail and Lindsey 1986). According to Northcote and Larkin (1989), eight fish species found above the canyon have been unable to establish populations below the canyon.

1.2 Previous Genetic Studies on Fraser Chinook

Using allozyme data, Teel et al. (2000) identified two main groups of populations in British Columbia. The coastal group consisting of 4 subgroups including the lower Fraser. The inland group consisting of 6 subgroups including, mid-upper Fraser, North Thompson, South Thompson, and lower Thompson. Except for the Birkenhead (coastal stream-type) and the South Thompson populations (interior ocean-type), the geographic extent of the inland and coastal groups were thought to correspond with geographic distributions of stream- and ocean-type life histories reflecting post-glacial colonization of by two distinct ancestral lineages. Teel's work supports a coastwide analysis of allozyme variation which indicated a clear genetic separation between populations with stream-type life histories (interior) and those with ocean-type life histories (coastal) (Myers et al. 1998). Stream-type populations extend from Alaska, through northern British Columbia, upper Fraser River, and into the mid- and upper Columbia River Basin tend to cluster together. Ocean-type populations, and populations showing both ocean- and stream-type juvenile migration (mixed-type populations), extend from central British Columbia to the Sacramento-San Joaquin River drainage in California tend to cluster together. The transition zone from ocean- and mixed-type populations in the south to only stream-type populations in the north occurs along the central coast of British Columbia. In this zone, populations such as those in the Kitimat, Atnarko, and Wannock Rivers were between the two larger clusters representing ocean- and stream-type populations. Samples from populations in the lower and South Thompson River, also clustered in an intermediate position. Stream-type populations in the Columbia River Basin were genetically distinct from stream-type populations in the upper Fraser, Skeena, Nass, and Stikine Rivers in British Columbia (Myers et al. 1998).

Allozyme mixed stock analysis provided the first genetically based estimates of chinook stock composition passing through the lower Fraser River at Albion (Waples et al. 1990, Ann Marshall, Wash. Depart. Fish and Wildlife, unpub data), however a limited number baseline populations were used in this analysis compared to those presently available for microsatellites (msDNA).

Minisatellite variation was used to identify 5 distinct groups in British Columbia: Fraser River, east coast of Vancouver Island, west coast of Vancouver Island, southern mainland, and north coast (Beacham et al. 1996). The first msDNA analysis of Fraser chinook investigated variation of 20 Fraser populations using three msDNA markers (Nelson et al. 2001), subsequent analysis investigated the variation at 52 Fraser populations at 13 loci identified seven regional groups: upper, mid, lower Fraser, north, south, lower Thompson and Birkenhead. (Beacham et al. in press). This paper is an expansion of this previous msDNA work examining the genetic variation of 61 Fraser populations using 13 genetic markers.

2. Data Sources

2.1 Genetic Sampling

A total of 114 spawning sites have been identified in the Fraser River (Appendix 1). In this paper we refer to individual spawning sites as populations which may or may not be genetically isolated from other spawning sites. Sample collections from 61 of these spawning sites where the sample size exceeded 30 fish per site (~12,000 fish total) were analyzed for 13 selectively neutral microsatellite loci *Ogo2, Ogo4, Oke4, Oki100, Ots100, Ots101, Ots102, Ots104, Ots107, Ots2, Ots9, Omy325, and Ssa197* (see Table 2.1, Figure 1). Samples were pooled across sampling years due to small interannual variability (Beacham et al. in press). The methods used for DNA extraction, PCR reaction, electrophoresis, and allele scoring are outlined in Nelson et al. (2000) and Beacham et al.(in press).

In 2000 and 2001, the Albion test fishery (Fig. 1) near Fort Langley was used to determine lower river passage of chinook populations migrating upstream. Tissue samples were analyzed from chinook salmon caught in an 8” net fished from April 2 to Oct18 in 2000 and May 14 to Oct 19 in 2001 and a multi-panel net fished from April 1 to August 31 in 2000 and from April 1 to August 31 in 2001. The objective of the multi-panel net is to catch a representative sample since it is known that the 8” mesh catches biases against the smallest and largest fish (Westrheim 1998, Parken and Irvine unpub). A total of 100 fish per week per net type for sampling years 2000 (n=1694) and 2001 (n=2630) was analyzed for 13 microsatellite markers.

2.2 Physical and Biological Information

A variety of physical and biological data were used in the identification of stock characteristics for Fraser chinook. These data were summarized in Appendix 1 for each spawning system. Rood and Hamilton (1995a-k) summarized watershed areas. The peak spawning periods for 2000 and 2001 were obtained from aerial surveys for most streams (DFO, unpublished data), however for those systems without aerial surveys the peak spawning periods were estimated from ground surveys or from people with local knowledge. The most frequent age of maturity was estimated from analyses of scale samples collected in the escapement and maintained in the SCALE database and scale archive library by the Scale Ageing Lab, Pacific Biological Station. Juvenile rearing habitat use descriptions were reported for most populations by DFO (e.g. DFO 1995), and was evident from scale ages. Roberta Cook (Habitat and Enhancement Branch, DFO, Vancouver) provided recent enhancement history.

2.3 Marine Coded-Wire Tag Recoveries

The Mark Recovery Program (MRP) database was queried for mark application and subsequent marine recovery information for all Fraser River chinook populations from 1970 to the present. A similar search was performed on the U.S. recovery database (reporting Alaska, Washington, Oregon and California recoveries). Tag codes identified as ‘transplants’ (i.e. reared and released at a site distant from the broodstock site) were removed from the data to eliminate any potential effect of the rearing environment on subsequent marine distribution and timing. Samples from small tributaries were generally pooled with those of the major system.

Tag recoveries were apportioned to five marine recovery strata (adapted from Johnson 1990): 1) Northern (Alaska, North Coast, Central Coast); 2) West Coast Vancouver Island (Northwest Vancouver Island, Southwest Vancouver Island); 3) Strait of Juan de Fuca (JDF)/Puget Sound; 4) Inside (Johnstone Strait and Strait of Georgia); and 5) Washington/Oregon Coast (Table 2.2). Recoveries are reported as ‘observed’ tags which are the actual number of tags recovered; and as ‘estimated’ tags, which is the number of observed tags recovered in the time-area-fishery stratum, expanded to account for the catch/sample ratio (Kuhn et al. 1988). Those release sites with less than 10 observed tag recoveries we excluded from the analysis.

3. Genetic Analysis

3.1 Population Structure

We used five methods to examine levels and patterns of genetic variation within and among the 61 Fraser chinook populations. First, for each population we reported the following indices of genetic variablility: 1) allelic diversity (average numbers of alleles reported by population 2) heterozygosity (mean ratio of heterozygous alleles to sample size across all loci and 3) presence of private alleles (unique alleles occurring in only that population). Computation of allelic diversity, heterozygosity, and number of private alleles were carried out with the program GDA (Lewis and Zaykin 2001). Second, genetic variation was partitioned within and among regional groups and populations. Third, principal component analysis (PCA) was applied to a correlation matrix based on alleles occurring at a frequency of greater than 0.02 in one or more populations. For the PCA analysis, those alleles occurring at a frequency of less than 0.02 across all baseline populations were binned with adjacent alleles (Wood algorithm, Candy et al. 2002). Fourth, was genetic distance analysis, similar to the PCA analysis, this methods relies on differential allelic frequencies to provide a measure of genetic separation between populations. A number of different genetic-distance measures are available and these were found to yield highly correlated results, typically Cavalli-Sforza and Edwards' distance measure are used for population structure analysis (Myers 1998, Nei et al. 1983). Consequently Cavalli-Sforza and Edwards (1967) chord distances were computed between all pairs of populations, and relationships among populations were depicted in a dendrogram using the unweighted pair-group method with arithmetic averaging algorithm (UPGMA) using the program Phylip (Felsenstein 1993). We performed UPGMA cluster analysis on 1000 bootstrapped gene frequency datasets to construct a consensus tree. Fifth, we estimated gene flow among populations within and among regional groups. An indirect measure of gene flow ($N_e m$) (the effective number of migrants per generation) can be estimated (Slatkin 1993) from:

$$F_{st}=1/(1+4N_e m) \tag{1}$$

3.2 Genetic Mixed Stock Analysis

Mixed stock analysis of the lower Fraser Albion test fishery samples used the maximum likelihood method estimation (MLE) to assign stock compositions to the 61 Fraser baseline populations. Multi-locus genotypic frequencies were determined for each population and the Statistical Package for the Analysis of Mixtures software program (SPAM) (Debevec et al. 2000) was used to determine stock composition of the mixture samples. SPAM uses the expectation-maximization and convergent-gradient algorithms for MLE procedures (Pella et al. 1996). Reported stock compositions for mixed stock samples are the point estimate of each mixture analyzed with variance estimates derived from 100 bootstrap simulations. Each baseline population and fishery sample was sampled with replacement in order to simulate random variation involved in the collection of baseline and fishery samples and estimates of stock composition were reported on a stock by stock basis.

For each net-type and year, stock compositions were calculated by time interval providing 1-j estimates. Except for April and May when few fish were caught, daily sample collections were pooled into two week run-timing intervals (e.g. June 1-15, June 16-30, etc.). For each net-type and year, daily catch per unit effort (CPUE) was calculated (Schubert et al. 1998), and the sum of the daily CPUE measurements were determined for j intervals. Peak passage (PP) for a population (i) was determined from the maximum catch per unit effort (CPUE_j) where:

$$PP_i = \max_{ij}(i \text{ proportion of catch}_j \text{ x } \text{CPUE}_j) \tag{2}$$

For each net-type and year PP_i was calculated, consequently for each population there are potentially four independent estimates of peak passage. For example, in year 2000 for the multi-panel net, the mixture sample might indicate the maximum CPUE occurs for the Stuart population during July1-15 time period. If however, a population was not sampled by a net type in one year, then no estimate of peak passage is available.

4. Hierarchical Classification Approach

We wish to ensure that each genetically distinctive lineage is protected within its own CU. Further, populations within a CU should be similar in productivity and vulnerability to fisheries so that each CU can be managed effectively as an aggregate. A CU is meant to be a level in a classification scheme no higher than an ESU. When manageability is used to partition a CU, resulting units have no relationship to degrees of reproductive isolation, and are therefore not synonymous with the classification units typically used in genetic organizational schemes (e.g. population).

The first tier in our hierarchical structuring consists of provisional ESUs. The US National Marine Fisheries Service were the first to apply the ESU concept in a comprehensive way and there is a large body of literature describing the process of ESU identification. For a population or group of populations to be considered as an ESU, they must be substantially reproductively isolated from other populations and represent an important component of the evolutionary legacy of the species (Waples 1991). Genetic variability resulting from evolutionary processes and upon which future evolutionary potential depends is important to the evolutionary legacy of a species (Waples 1995). Waples suggested that if the extirpation of a unit represented a significant loss to the ecological-genetic diversity of the species that would mean the unit should be under consideration as an ESU.

Following the approaches used by others, we examine a variety of types of genetic and non-genetic information to determine whether groups of chinook in the Fraser watershed are substantially reproductively isolated (see Section 5.2). In establishing ESUs for chinook salmon in the USA, Myers et al. (1998) relied chiefly on genetic data and tagging information, supplemented by knowledge of barriers to migration, age at smoltification, ocean distribution, time of freshwater entry, and age at maturation. Waples (1995) points out that genetic data are particularly useful because they reflect levels of gene flow that have occurred over evolutionary time scales. Wood and Holtby (1998) advocated the use of neutral allele frequencies to define genetic units since neutral alleles are not the result of local adaptation. Wood and Holtby suggested that groups exchanging <1 migrant per generation (Equation 1) were almost completely isolated from each other, groups with < 10 migrants per generation were relatively isolated (local populations), and groups with > 10 migrants per generation are partially isolated (subpopulations). However, the degree of genetic exchange that warrants a classification of substantial isolation (i.e. ESU level) has not been quantified.

The second and subsequent tiers pertain to productivity and manageability. Each tier identifies a range of potential CUs and there is not necessarily a preferred scenario. However, it is important to realise that under the (draft) WSP each CU will require target objectives, and assessment to determine whether sufficient spawners have escaped to each CU.

Since this is the first attempt to identify CUs for Pacific salmon, it is not surprising that the procedures to do so are not well defined. In the main body of this report we consider productivity before manageability. Alternative approaches to identify CUs are provided in Appendix 3.

Productivity is loosely defined as recruits per spawner. We would like all populations within a CU to be of similar productivity to reduce the likelihood of less productive populations being overexploited. However, productivity has only been estimated for one spawning system (Harrison River) in the Fraser River watershed and there are insufficient data to directly estimate stock productivity for the remaining systems; thus, rates of recruits per spawner were not used. Stock productivity is directly related to life history stage-specific survival, however these estimates exist for only a few locations (eg. Nechako, Chilliwack, Nicola). We assumed that some spawning systems were relatively more productive than others based on the presence of large lakes upstream of the spawning areas modifying flow and thermal regimes (Parken et al. draft 2002).

After productivity, we decided to order manageability concerns according to the sequence of possible fisheries (but see also Appendix 3). Initially we consider manageability from a marine fisheries perspective, and examine marine recoveries to determine if significant differences occurred among the productivity units previously identified. If they do, we will further partition these groupings. Ideally, aggregates at this level would be reconciled with domestic and international management frameworks.

Next we examine the groupings from a mainstem Fraser River management perspective, investigating major differences in catchability (e.g. run timing) that may lead to further separation of these units. Finally, we examine manageability from a terminal fisheries management perspective. Here we consider the need to subdivide the remaining groups into individual spawning streams.

As mentioned previously the hierarchical structure proposed here is only one possible scenario. If for example productivity proves to be less important to decision-makers and managers than marine distribution and freshwater entry, then productivity could be moved further down in the hierarchy (see Appendix 3).

5. Determination of Provisional ESUs

5.1 Indices of Genetic Diversity

Allelic diversity ranged from 11.1 for lower Adams to 23.8 for Harrison with an average allelic diversity of 16.6 (Table 2.1). Heterozygosity ranged from 0.77 for Birkenhead to 0.84 for Barrier with a mean heterozygosity of 0.82 for all populations. Birkenhead has the lowest level of heterozygosity at allozyme loci of all the populations sampled throughout British Columbia (Teel et al. 2000). Low levels of heterozygosity for the Birkenhead population likely indicates a small effective population size and very low gene flow from other populations. Forty-one populations had no private alleles (67%), 9 populations had one private allele (15%), 4 populations showed 2 private alleles (7%), 6 populations showed 3 private alleles (10%), and one population (Nechako) had 6 private alleles. The number of private alleles detected will not be independent of the sample size.

When gene diversity data for 6 regional groups of Fraser chinook (lower Fraser, Mid Fraser, upper Fraser, South Thompson, North Thompson, and lower Thompson) were analysed, approximately 95% of genetic variation was contained within populations, with the remainder accounted for by differentiation among regions (3.1%), among populations within regions (1.3%) and among years within populations (0.5%). (Beacham et al. in press).

5.2 Genetic (msDNA) Evidence of Reproductive Isolation

The first two eigenvectors of the PCA explained about 79% of the genetic variability among populations. The scatterplot for PC1 and PC2 showed a clear geographical pattern (Figure 5.2.1). Most populations cluster within the same major drainage. These groupings can be quite distinct from each other. Populations from the upper Fraser have large PC1 scores whereas populations from lower Fraser (including Birkenhead) have smaller PC1 scores. The mid Fraser and Thompson fall between the two extremes with intermediate PC1 scores. High PC2 scores separated the South Thompson from North Thompson (intermediate) and lower Thompson with lower scores. The Birkenhead (lower Fraser), Portage (mid-Fraser), and Maria Slough (lower Fraser) are relatively distant from their geographic groupings. Additionally, Louis (stock code 62), which is a small tributary of the lower North Thompson, clusters with the lower Thompson group and the Thompson-lower (stock code 106) population (mainstem Thompson below Kamloops) clusters with the South Thompson group. Louis and the lower Thompson share an early run timing (see section 6.3). Just as the Thompson –lower spawning site share a late run timing with the South Thompson. Presumably run timing allows these two populations (Louis and Thompson-lower) to share a higher degree of genetic exchange from outside of their geographic grouping.

The UPGMA dendrogram of chord distances for the 61 populations (Figure 5.2.2) showed very similar relationships to the PCA analysis. The three populations Birkenhead, Maria Slough, and Portage each form separate arms between chord distance 0.0185 to 0.133 indicating poor clustering with their respective regional groups. Two large clusters were joined at genetic distance of 0.110. The first group contained lower Thompson and the second group contained the rest of Fraser populations. This is followed by separation of the South Thompson (0.0104), upper/mid Fraser (0.008), North Thompson (0.007), and upper Fraser (0.006). Some genetic outliers exist. Horsey and Walker (upper Fraser) cluster with mid Fraser populations and upper Cariboo a mid Fraser population clusters with upper Fraser populations. As was seen in the PCA analysis Louis clusters with lower Thompson region and the Thompson-lower mainstem clusters with the South Thompson. The upper Adams transplant population with source populations from Finn Creek and lower Shuswap populations (DFO, unpub data) still group with other South Thompson populations.

Bootstrap values at the UPGMA tree nodes indicate the percentage of 1000 trees where populations beyond the node occurred together (Figure 5.2.2). Strongest branching support occurred in 100% of the consensus trees separating Birkenhead from the rest of the Fraser and lower Fraser branch of Harrison, Chilliwack, and Stave. Support for other regional groupings was also high: lower Thompson 99%, North Thompson 81%, Maria Slough 80%, and South Thompson 92%. Consensus at branches between the upper and mid Fraser were lower at 54%. Lowest tree support occurred at nodes where regional groups join, upper-mid Fraser/North Thompson branch with the South Thompson was supported only 22% of the time and the upper-mid Fraser/North Thompson/South Thompson branch with the lower Fraser was supported only 30% of the time.

The scree plot (McGarigal et al 2000 - Figure 5.2.3) shows the genetic distances between branch nodes seen in Figure 5.2.2. The largest changes in genetic distances occurred between the Birkenhead and the rest of the Fraser populations. Additional large steps in genetic distance occurred for the separation of Maria Slough, Portage, and lower Thompson. The last major change in genetic distance occurred with the separation of upper-mid Fraser /North Thompson group marked by the vertical dashed line. This point is marked by an asterisk in the Figure 5.2.2. To the right of this line additional branch nodes are associated with small changes in genetic distance.

Gene flow analysis estimates the effective number of migrants per generation. This approximation assumes an infinite island population genetic model and that the pattern of allele frequencies among populations is due to gene flow not mutation, selection, or random genetic drift and that forces of migration and genetic drift are in equilibrum. Many of the underlying assumptions of this analysis are likely violated in biological systems (Whitlock and McCauley 1999). However, gene flow provides a useful index of the relative relatedness between populations and population groupings. Estimates of gene flow show similar patterns of genetic differentiation seen in the PCA and genetic distance analyses. Estimates of effective number of migrants are much higher within regional groupings and lower between regional groupings. Gene flow is lowest between Birkenhead and all other Fraser groups (1.5-2.6 spawner/generation, Table 5.2). Portage and Maria Slough shows slightly higher levels of gene flow than Birkenhead with greatest gene flow to South Thompson group. Highest levels of gene flow occurs between mid and upper Fraser (11.8 spawner/generation, Table 5.2).

In summary, although the genetic information provides clear evidence of reproductive isolation, estimating the degree of isolation has uncertainties. For example, the genetic results suggest that chinook from the Birkenhead, Maria Slough, and lower Fraser fall white (i.e. Harrison) groups are relatively isolated from each other and other populations sampled. Upper and mid Fraser fish generally group together, perhaps with North Thompson chinook while lower Thompson and South Thompson fish are distinct. Since we only have a limited number of samples from Portage Creek (N=53) and most were collected during one season, we are not confident in this unit. In terms of gene flow, none of the population groups are closed assuming a measure of one migrant per generation, although rates of gene flow between Birkenhead and Maria Slough and other regions is very low, usually <3 migrants per generation. Low levels of heterozygosity for Birkenhead and Maria Slough possibly indicate small effective population size and low levels of gene flow between other populations. Additional analysis beyond the scope of this paper is required to determine the relatedness of lower Fraser chinook and those outside the drainage (e.g. Strait of Georgia populations).

5.3 Non-genetic Evidence of Isolation

A variety of non-genetic sources of information can be considered to substantiate or refute groups identified using genetic data. There is ample non-genetic evidence to support the conclusion that lower Fraser fall white (i.e. Harrison) and spring red (i.e. Birkenhead) chinook are reproductively isolated from each other and other Fraser populations. Both Harrison and Birkenhead fish spawn in the Lillooet/Harrison drainage but they are temporally and spatially isolated from each other. Birkenhead chinook spawn in the Birkenhead River upstream of Lillooet Lake while Harrison chinook spawn below Harrison Lake (Fig. 1, numbers 12 and 43). Birkenhead fish are among the earliest returning chinook to the Fraser watershed (Bailey et al. 2001, see section 6.3) and Harrison, the latest.

Maria Slough (Fig. 1, number 65) fish also appear to be isolated from other populations. These lower Fraser fish are red-fleshed fall spawners so must be isolated from other lower Fraser fall spawners (i.e. Harrison) that are white-fleshed. Maria Slough fish are ocean-type, however they are not immediate migrants like other lower Fraser fall spawners. Maria Slough are similar in life history to many South Thompson chinook and are spatially but not temporally isolated from these fish.

It is more difficult to provide non-genetic evidence of isolation for interior Fraser chinook groups. The South Thompson genetic group includes fish spawning in the mainstem lower Thompson. These late spawning chinook are temporally isolated from most other interior chinook. Other than the lower Fraser fall whites, there are no other ocean-type chinook that spawn as late as these (Appendix 1). Many of the stream-type chinook within this group are spatially isolated from other populations, many spawn in the headwaters of their natal streams.

Lower Thompson chinook include the early-timed runs to the Coldwater and Spius rivers that are spatially and temporally separated from other populations (Bailey et al. 2001).

The final group that appears to be genetically isolated is the large aggregation of populations returning to the upper Fraser, mid-Fraser, and North Thompson. The main non-genetic evidence of isolation is spatial; chinook populations in these areas spawn well up major tributaries and there is little evidence of straying outside this large geographic region.

In addition to the above, we searched the MRP database for evidence of known straying. Coded-wire tagging studies have shown a high degree of homing fidelity for chinook salmon; stray rates are thought to be about 1%, primarily between adjacent populations (e.g. Quinn and Fresh 1984, Hard and Heard 1999, Candy and Beacham 2000). We found only two cases where “on-site” reared and released CWT’ed chinook were captured from regions other than in their region of origin/release in the Fraser. A Deadman River (lower Thompson) tagged chinook was recovered at Eagle (South Thompson) and a chinook tagged in the Eagle River (South Thompson) was recovered from the Nicola (lower Thompson). Admittedly sampling was not exhaustive and data are sparse but this finding does support the conclusion that the regionally-based units identified are reproductively isolated from each other.

5.4 Evolutionary Significance

The final requirement for a group of populations to be considered an ESU is that they constitute an important component in the evolutionary legacy of the species. As mentioned earlier, our ability to evaluate evolutionary significance is limited by the restricted geographic scope (i.e. Fraser watershed) of our paper. Nevertheless, it is clear that lower Fraser fall white chinook are an important component in the evolutionary legacy of at least Fraser watershed chinook. These Harrison fish are the only chinook within the Fraser watershed known to migrate downstream immediately upon emergence to the estuary (Table 5.4), thus we consider this unusual life history as significant.

Lower Fraser spring red chinook, represented by Birkenhead chinook, also have life history characteristics that appear to be evolutionarily important within the Fraser watershed. As mentioned previously, Birkenhead chinook are among the earliest timed chinook to return to the Fraser. They also have an unusual marine distribution, being caught more frequently in northern BC and Alaska fisheries than any other Fraser chinook (see Section 6.2).

There is some question as to the origin and significance of the one population representing the proposed lower Fraser summer group. Maria Slough chinook are the only red-fleshed ocean-type chinook in the lower Fraser drainage. Maria Slough was a side channel of the Fraser until it was diked in the 1940's after a major flood (G. Dickson, DFO HEB, Inch Creek Hatchery, pers. com.). Genetic analyses (Fig. 5.2.1) show Maria Slough chinook are most similar to fish from the South Thompson. The proposed South Thompson grouping is also dominated by ocean-type fish that typically smolt at between 60 and 150 days. Within the Fraser watershed, since this life history pattern is found only in the South Thompson and at Maria Slough we consider it to be of evolutionary importance. We suggest that the South Thompson grouping satisfies the ESU requirement of evolutionary significance (at least within the Fraser watershed), but we are much less certain that lower Fraser summer chinook represented by Maria Slough fish should constitute their own ESU.

Many lower Thompson tributary chinook also have a life history unique within the Fraser River watershed (Table 5.4, Appendix 1). Almost all go to sea as yearlings, and most return as total age 4. Most are small body sized fish and return to the Fraser early in the season. Their early run timing and small body size allows them to enter spawning streams in early summer when flows are dropping. Later arriving fish, and especially those that are large, are less able to access spawning sites and presumably are selected against.

Our final proposed grouping is the large complex group containing fish from the upper and mid Fraser and North Thompson. Most of these fish return relatively early in the season at total age 5 and smolt as yearlings (Table 5.4, Appendix 1). Many populations from the upper Fraser appear to have adaptations within their early life history that we feel are of evolutionary importance. Bradford and Taylor (1997) found that fry from tributaries of the upper Fraser distribute themselves downstream from spawning areas, often to the Fraser River mainstem, very soon after emergence from the gravel. These fry have apparently adapted to the unstable nature of their natal stream by moving downstream to rear in the larger, more stable Fraser River. Again, these unusual life history characteristics appear to satisfy the ESU requirement of evolutionary significance.

5.5 Provisional ESUs

We assume that the stock groupings identified using neutral genetic markers possess unique adaptive genetic traits that should be preserved as part of the genetic legacy of the species. Genetic evidence supported by PCA, genetic distance, and gene flow analysis suggests strong regional clustering of Fraser River populations. Based on the genetic markers and non-genetic information we suggest five or six provisional ESUs for Fraser chinook: upper-mid Fraser/North Thompson, South Thompson, lower Thompson, lower Fraser spring reds, lower Fraser fall whites, and possibly lower Fraser summer reds. The grouping criteria for the genetic and non-genetic data for ESU determination can be seen in Table 5.5. These provisional ESUs form the first tier of Figure 5.5 (and Appendix Figures 3a-c), and also represent the minimum number of CUs. As already discussed, consideration of non-Fraser chinook populations, specifically Strait of Georgia, east coast of Vancouver Island, and possibly Puget Sound populations is necessary before finalising the lower Fraser ESU.

6. Manageability

6.1 Productivity

As the next step in the hierarchy we classified populations into units of similar productivity (Figure 5.5). As mentioned earlier, a paucity of stock recruit and survival data meant that we needed to develop proxies for productivity, often measured as recruits/spawner. We assumed that watersheds containing large lakes were more productive than those with no lakes or only small lakes. (See Appendix 3 for alternate ways of identifying productivity.) There are various reasons why riverine systems with a large lake moderating influence are usually more productive than systems with a small or no lake moderating influence.

River environments below large lakes tend to favour rapid fish growth. Lake outlets have long been known to have significant quantities of lake-origin plankton (e.g. Chandler 1937) that can be an important food source for young salmonids (Irvine and Northcote 1982) and for other invertebrates that salmon feed on. Increased flow stability resulting from lakes tends to increase the standing crop of phytobenthos (Lowe 1979) which can provide an important source of invertebrates to feeding young salmon (Mundie 1974).

Rivers downstream of large lakes also tend to have high survival rates for salmon. Egg-to-fry survival is related to the quality of the spawning and incubation gravel (Chapman 1988), degree of bedload movement and scour (Montomery et al. 1996), and thermal regime during incubation (Bjornn and Reiser 1991). Lake-fed rivers have stable flows and generally experience less scour and bedload movement, less stream bank erosion, and have better gravel for salmon spawning than non-lake fed rivers do. Stable flows throughout the incubation period reduce the effects of ice scour and border-ice encroachment on the mid-channel where most redds are found. Large lakes tend to act as sediment traps resulting in good egg-to-fry survival rates (Chapman 1988).

Thermal conditions below lakes also tend to favour high egg-to-fry and fry-to-smolt survivals. Stable thermal regimes and warm winter water temperatures reduce detrimental effects of ice (Cunjak et al. 1998). Within the Fraser watershed, large lakes slow down the cooling of river water temperatures in the fall, which remain above freezing more throughout the winter than systems with a small- or no-lake moderating influence (Parken et al. draft 2002). Longer ice-free periods may improve fry-to-smolt survival in stream-type populations because ice formation reduces the amount of high quality over-wintering habitat available (Levings and Lauzier 1991).

Inferences about the relative productivity of spawning systems resulted in partitioning of the upper-mid Fraser/North Thompson and South Thompson groups. Large lakes exist upstream of nine spawning systems in the upper-mid Fraser/North Thompson, six in the South Thompson group, and two in the lower Fraser (Table 6.1.1). All other spawning systems have either small or no lakes upstream of the spawning areas and were not partitioned further based on productivity. Although a large lake exists in the Horsefly watershed (Horsefly Lake), the Horsefly population was not grouped with the lake moderated systems because the majority ofspawning occurs above the moderating influence of this lake.

These productivity aggregates generally correspond to the groups identified by the Chinook Technical Committee (CTC) (Table 6.1.2). International management of Fraser River chinook by the CTC uses five aggregates based on similarity in run-timing, life history, and age at return (CTC 2002). The CTC groupings are Fraser Spring-run Age 1.3 (European age designation meaning 1 winter in fresh water and 3 winters in the ocean), Fraser Spring-run Age 1.2, Fraser Summer-run Age 0.3 Fraser Spring-run Age 1.3, Fraser Late-run Harrison. The Bessette system, lower productivity South Thompson group, is the exception and has been grouped with the Fraser Spring-run Age 1.2 aggregate for international management purposes.

6.2 Marine Catch Distributions

The third level of this hierarchy partitioned the productivity units based on marine catch patterns (Figure 5.5). It is important to realize that recoveries can only take place when fisheries are open. Since BC ocean fisheries for chinook occurred chiefly between April and October in years that many upper Fraser populations were tagged, resulting catch distributions provide information about return routes to the Fraser, but not necessarily much information on ocean rearing locations. Recent changes in fishery management have resulted in fall and winter fisheries for chinook off the West coast of Vancouver Island. However, tagging in freshwater has been significantly curtailed thus despite marine sampling, these fisheries have yielded little extra information on the marine distribution patterns of Fraser-origin chinook.

Recoveries of tagged fish from the more productive, large lake moderated systems of the upper-mid Fraser/North Thompson group occurred primarily in northern strata. (Table 6.2). Stuart River and Chilko River tags were recovered predominantly in the WCVI and Inside strata, respectively. Although these recovery frequencies appear distinct, these two strata are also well represented by recoveries from other systems in the group. Lower Cariboo River recoveries are notable in that a significant proportion (0.20) were reported in Puget Sound catches. However, the sample for this group was extremely small (observed N=13). The broad range of well represented recovery strata for this group precludes any further division of the group at this level in the hierarchy.

Tag recoveries from upper-mid Fraser/North Thompson populations with lower productivity (i.e. no large lake moderating influence) were reported most frequently in the southern BC strata, including WCVI , Inside and JDF/Puget Sound (Table 6.2). Proportional recoveries ranged from 0.06 to 0.78 in these strata. Three populations, Willow River, Salmon River and Westroad River were also well represented in the coastal U.S. recovery stratum. However, the small number of recoveries from these populations limits the value of this result. Raft River, for which there is a relatively large sample, appears unusual (along with Finn Creek) in having a significant proportion of marine recoveries in the northern stratum. This may be a function of their tributary status within the North Thompson River system.. As with the previous productivity group, recoveries for this group of populations covered a broad range of strata with variable but significant proportions within stratum. Few tags were recovered in this group.

The South Thompson group show a common pattern of marine CWT recoveries, predominantly in northern waters, with an additional significant proportion in the inside stratum. Frequency of recoveries in the northern strata ranged from 0.44 to 0.71, with proportions of 0.18 to 0.38 in the

Inside stratum. Systems in this group are well represented with large samples, with the exception of the South Thompson River, where additional samples may provide more conclusive evidence for this pattern of marine recovery. In light of the commonality in recovery patterns, between high and lower productivity South Thompson group we cannot justify separating these systems at this level in the hierarchy.

The lower Fraser Spring Red chinook and the lower Fraser Summer Reds are each comprised of one distinct population, delineated at the provisional ESU level as being reproductively isolated and constituting an important component in the evolutionary legacy of chinook salmon (see above). Confirmation of this uniqueness for the lower Fraser Spring Reds (Birkenhead River) is evident in the marine recovery pattern of CWTs. Recoveries of tags from this population are predominantly in northern waters (0.57) with an additional significant proportion (0.31) in the inside stratum. Although represented by a relatively small sample (observed N=44), the pattern of recoveries is very well-defined and unique from other lower Fraser populations. Indeed, it is quite distinct from all Fraser chinook populations, save perhaps for the South Thompson, high productivity group (see above). No CWTs have been recovered for Maria Slough chinook.

Marine CWT recoveries for lower Fraser Fall White chinook (with the exception of Stave River) are reported predominantly in the inside stratum, with some in WCVI fisheries. Stave River recoveries are represented most frequently in the Washington and Oregon Coast recovery area (0.61). The difference in recovery pattern between this population and the other lower Fraser Fall chinook is noteworthy, considering that the Stave River population has been rebuilt from Harrison River stock (the indigenous Stave River population, as well as those from the Coquitlam, Chehalis and Alouette rivers, have been extirpated; see discussion).

In summary, based on this relatively simple analysis, there is not enough evidence to further partition ESU-productivity groupings into additional groupings.

6.3 Lower River Run Timing

The fourth level of the hierarchy partitions proposed ESU-productivity groupings into units with similar lower river entry timing (Figure 5.5). Previous msDNA analysis, primarily from the 1997-1999 First Nations catches, indicated the Birkenhead, Chilcotin-upper, Spius, and Coldwater passed through the lower river in April-May, much earlier than other spring run chinook populations (Bailey et al 2001). Weekly sampling and analysis of the Albion 2000 and 2001 provide the first complete stock composition estimate time series from the April – mid October (Appendix 2). Peak passage was calculated using formula 2. For each population there is potentially four independent estimates of peak run-timing through the lower river corresponding with estimates from the two years of data (2000 and 2001) and the two net types (8 inch and multi panel) (Table 6.3). There were differences in run timing within populations among years and net types, and the timing of passage may be quite protracted, however we categorized run timing into peak passage groupings. River entry is thought to be approximately 1 week prior to passage at Albion (Melanie Sullivan, DFO pers. comm.)

In general, lower productivity populations have a earlier run timing than higher productivity populations. Earlier return time is thought to be required to provide enough thermal units for egg development because incubation temperatures are not lake-moderated. Most fish from the upper-mid Fraser/North Thompson, higher productivity group pass Albion between June 16 and August 31 while the lower productivity group enters between April and July 15. Two possible subgroups exist for this upper-mid Fraser/North Thompson lower productivity group. One group which pass through the lower river very early April-May (Chilako, Cottonwood, and Chilcotin-upper), and a late entry group of North Thompson populations (Finn, Barrier, and Raft) which enter the river from July 15 to August 31. Finn Creek has the earliest peak passage of the three populations (July 1-31) and the earliest peak spawning in mid-August (Appendix 1). Peak passage through the lower river occurs between July 15 and August 15 for the remaining two populations, Barrier and Raft, with peak spawning occurring in mid-September. The South Thompson higher productivity populations arrive July 1 to Aug 31 with the middle Shuswap being the earliest of that group. The South Thompson low productivity grouping enters the river over a wider range of periods extending from May 1– Aug 31 possibly reflecting a wider range of life history types. The lower Thompson are all low productivity with early run timing from April through to July 15. A very early returning sub-group of these populations (Coldwater, Coldwater-upper, and Louis) arrive between April 1 to June 15. In the lower Fraser, Birkenhead fish return in April, Maria Slough fish return from July 16-August 31, and the lower Fraser fall whites (Chehalis, Chilliwack, Harrison, and Stave) return between August 15-September 31.

In summary, the lower productivity upper-mid Fraser/North Thompson CU can be further divided into three overlapping peak passage times: April 1- June 15, May 1- July 15, and July1-Aug 15. The lower productivity lower Thompson CU can be further divided into populations that peak in early spring (April 1 – June15) and later spring (May 1- July 15). The remaining CUs do not require further partitioning based on peak passage through Albion.

6.4 Terminal Fisheries Units

The last level of the hierarchy addresses potential terminal management concerns. In this case, each spawning stream identified in the last tier of (Figure 5.5) could potentially be a separate CU.

7. Discussion

Ocean-type chinook are predominant below the Fraser canyon and stream-type above the canyon; Healey (1983) proposed that these life history types likely constitute different races. Since salmon were able to colonize the lower Fraser from sea, and the interior Fraser, possibly from the Columbia, it is conceivable that these different life history types are the result of colonization. However, stream-type fish occur in the lower Fraser (e.g. Birkenhead) and ocean-type fish exist in the interior (South Thompson). This combined with our evidence from msDNA markers indicating that stream and ocean-type populations do not appear to be closely related to each other leads us to conclude that postcolonization divergence in life history types occurred.

The ocean-type chinook salmon populations of the South Thompson may have originated from stream-type fish. This may reflect adaptations to environmental conditions conducive to the production of large juveniles capable of smolting in their first year of life (Beacham et al. in press). Genetically controlled local adaptations such as maturity date, timing of arrival in fresh water and at the spawning grounds can evolve quickly, even within less than 50 generations (Quinn and Unwin 1993, Quinn et al. 2000).

Analyses of allozyme genetic markers can result in a different interpretation of stock structure than analyses of microsatellite marker results. The former differentiates first between coastal and interior groups and then considers regional structure while the latter doesn't appear to separate coastal/interior but rather deals predominantly with regional structure. This may be due to differences in mutation rates which are thought to be two to five orders of magnitude greater for msDNA than allozymes (Banks et al. 1999). The consequence of this would be that microsatellites are better able to discriminate among closely related populations but possibly do not show ancestral stock structures as well as allozyme results do.

Inferences about the relative productivity of spawning systems were based on assumptions of higher egg-to-fry and fry-to-smolt survival for systems with large lakes upstream. Only two provisional ESUs were partitioned based on the presence of large lakes. Fish with ocean-type life histories that usually matured at age 4 dominated in systems with large lakes. Fish with stream-type life histories that usually matured at age 5 were generally most frequent in other systems; the Bessette system was an exception, being dominated by stream-type life history fish that were mainly age 4 at maturity. With the exception of transplanted populations (e.g. Chilliwack, Alouette, Chehalis) whose productivity is sustained by hatcheries, the provisional lower Fraser fall white ESU is dominated by the high productivity, lake moderated Harrison population. For the upper-mid Fraser/North Thompson provisional ESU, both productivity groups had stream-type life history and most were age-5 at maturity. Juvenile life history patterns and ages at maturity were relatively uniform within the remaining provisional ESUs. Alternate hierarchical groups can be developed when juvenile life history and age structure or escapement trends are used as surrogates of productivity (Appendix 3).

We focus on naturally spawning groups of chinook in this report. However, there are many systems that have been enhanced (see Appendix 1). Enhancement can be considered as an aspect of manageability. If managers are interested in harvesting enhanced populations separately from natural populations, separation could occur at the terminal management tier.

Our work is the one of the first serious attempts to identify CUs as defined by the (draft) Wild Salmon Policy. The CU is expected to be the basic unit for the management and assessment of Pacific salmon in the future. Harvest management plans, including measurable targets (i.e. reference points) will be required for each CU. Assessment of individual CUs will require annual assessments of whether management has delivered sufficient spawners to each CU (i.e. have targets been achieved?). Longer-term assessment will be required to make sure that genetic diversity within the CU is not being lost.

We present one hierarchy of possible CUs for Fraser chinook in Figure 5.5 and several others in Appendix 3. As one moves down each hierarchy, progressively more CUs are identified. There is no "right" or "wrong" level within a hierarchy, but there are consequences. For instance, reference points need to be selected to minimise the likelihood of losing population diversity within each CU. If the upper-mid Fraser/North Thompson is selected as a CU, only one target reference point would be required for this large aggregate, but it would have to be conservative enough to offer some degree of protection to the lowest productivity populations within the aggregate.

Since RPs will need to be established for each CU, annual management and assessment costs will be higher when more CUs are identified. However, with more CUs there may be additional fishing opportunities, and therefore these additional costs may be more than paid for. Before we can finalise the number and size of CUs for Fraser chinook we need to better articulate management objectives within each potential unit, and also consider the potential economic and social costs and benefits at each level.

Chinook from outside the Fraser need to be considered before Fraser chinook ESUs are finalized. In addition, there are various chinook groups (spatial and temporal) within the Fraser watershed for which we have no or inadequate information (e.g. early timed Chilliwack, summer Birkenhead, Lillooet, Stein, Nahatlatch). We appear to have lost chinook spawning groups and possibly some genetic diversity from within the Fraser watershed already. For instance, four indigenous populations (Coquitlam, Chehalis, Stave, and Alouette) from the lower Fraser have become extirpated since post-contact settlement (M. Foy, DFO HEB Biologist, Annacis Island, pers. com.). HEB is currently working to re-establish natural spawning runs in these systems, primarily by transplanting Harrison origin fish.

In this paper, we propose various potential hierarchies for Fraser chinook salmon. Each of these differ significantly from the current DFO management framework that is based on run-timing and geography. This hierarchal approach considers the conservation of important genetic lineages. More work is required to determine which, if any, of these hierarchies is most suitable for future management and assessment for Fraser chinook. In addition, economic and social costs and benefits of various options need to be considered.

8. Summary

- Implementation of the Wild Salmon Policy (WSP) will require the identification of stock groupings called Conservation Units (CUs) for all species of Pacific Salmon. To generate discussion on the methodology being developed to identify CUs, we present several possible hierarchies for Fraser River chinook salmon.

- Evolutionarily Significant Units (ESUs) are the first tier in each hierarchy. These units can be further partitioned based on management considerations such as productivity, marine catch distribution, lower river run timing, and terminal fishing opportunities.

- Based on a combination of genetic and life history information, five or six provisional ESUs were proposed for Fraser chinook salmon: upper-mid Fraser/North Thompson, South Thompson, lower Thompson, lower Fraser springs, lower Fraser falls, and possibly lower Fraser summer reds. There is much uncertainty whether the lower Fraser summer group is valid because of life history and genetic similarities to the proposed South Thompson ESU. Chinook from outside the Fraser need to be considered before the lower Fraser ESUs can be finalized.

- We present several possible hierarchies where we partition ESUs according to productivity and manageability. The productivity tier is intended to reduce the likelihood of over-exploiting less productive stocks. When productivity groupings have different fishery recovery patterns, these can be further divided. A requirement to manage fisheries terminally could mean that the final tier of CUs would be the individual spawning populations.

- One can have a range of appropriate numbers and sizes of CUs, as long as appropriate RPs are chosen.

- Decisions on CUs are based in part on cost effectiveness. The larger the CU, the lower the annual appraisal cost, but also the lower the potential economic fishery benefit.

- Before we can finalise the number and size of CUs for Fraser chinook we need to better articulate management objectives, and consider the potential economic and social costs and benefits of various options.

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11. Tables

Table 2.1 – Genetic sampling information and indices of genetic variability for 61 chinook salmon stocks in the Fraser River. Stock code refers to Figure 1 and Appendix 1. Sample type is adult (A) or juvenile(J).

Stock Code	**Population**	**Year Sampled**	**Sample Type**	**Hatchery or Wild**	**Number of Fish**	**Allelic Diversity**	**Heterozygosity**	**Private alleles**
1	Adams-Lower	1996 2001	A	H	166	11.1	0.832	0
2	Adams-Upper	1993 1997 2001	A	H	45	20.5	0.801	0
8	Barriere	2000 2001	A	W	43	14.9	0.844	3
10	Bessette	1998 2001	A	W	41	11.8	0.810	0
12	Birkenhead	1991 1993 1994 1996-2001	A	H	208	13.9	0.771	3
14	Bonaparte	1996	A	H	308	17.9	0.817	0
15	Bowron	1995 1997 1998 2001	A	W	176	16.5	0.823	0
16	Bridge	1994-1996	A	W	425	19.9	0.836	1
19	Cariboo-Upper	2001	A	W	171	16.6	0.828	0
21	Chilako	1998	A	W	45	18.3	0.828	1
22	Chilcotin-Lower	1996 2000 2001	A/J	W	232	18.5	0.837	0
23	Chilcotin-Upper	1995-1998 2001	A/J	W	277	17.5	0.822	0
24	Chilko	1994 -1996 1999 2001	A	W	220	18.3	0.817	1
25	Chilliwack	1994 1995 1998	A	H	220	21.9	0.854	3
26	Clearwater	1997 1998	A	W	262	19.1	0.827	1
27	Coldwater	1994-1997	A	H	222	17.6	0.822	0
28	Coldwater-Upper	2001	J	W	138	12.8	0.793	0
29	Cottonwood	1995	A	H	53	12.5	0.816	0
30	Deadman	1996 1997	A	H	202	17.3	0.823	0
31	Dome	1991 1994-1996	A	H	360	18.0	0.825	3
32	Duteau	2001	A	H	42	11.2	0.797	0
33	Eagle	1995 2001	A	H	41	13.3	0.802	0
35	Elkin	1995 1996	A	W	235	16.5	0.834	0
36	Endako	1996-1998 2000	A	W	87	15.2	0.827	0
38	Finn	1996 1998	A	W	147	16.5	0.800	2
39	Fontoniko	1996	A	W	63	12.8	0.801	0
40	Fraser-Tete Jaune	1993-1995 2001	A	W	488	17.8	0.826	0
41	Goat	1995 1997 2000 2001	A	W	69	15.2	0.833	0
43	Harrison	1988 1992 1994	A	H	388	23.8	0.861	3
46	Holmes	1995 1996 2001	A	W	117	15.9	0.824	0
47	Horsefly	1996 1997	A	W	58	11.7	0.817	0
48	Horsey	1995 1997 2000 2001	A	W	36	11.2	0.827	0
50	Indian Point	1995	A	W	47	14.0	0.820	0
61	Little	1996 2001	A	W	158	19.6	0.843	1
62	Louis	1996 1997 2000 2001	A	H	394	16.3	0.773	1
65	Maria_Slough	1999 2000 2001	A	H	213	13.7	0.776	0
66	MacGregor	1997	J	W	126	15.5	0.815	0
69	Morkill	2001	J	W	208	16.3	0.821	0
75	Nechako	1991 1992 1994-1996	A	W	578	23.5	0.836	6
77	Nicola	1992 1994 1995 1997	A	H	299	17.9	0.815	0
78	North Thompson	2001	A	W	115	18.6	0.840	0
81	Portage	1995 1996 2001	A	W	53	13.3	0.837	0
83	Quesnel	1990 1994-1997	A	W	565	21.8	0.830	3
84	Raft	1995 1996 2001	A	W	186	20.0	0.836	1
86	Salmon-PG	1996 1997	A	W	263	17.9	0.821	0
87	Salmon-SA	1995 1996 1997	A	W	130	16.0	0.823	2
91	Shuswap-Lower	1994-1997	A	H	356	20.3	0.822	1
92	Shuswap-Mid	1994 1995 1997 2001	A	H	376	18.9	0.811	0
93	Slim	1995 1996 1998 2001	A	W	204	17.1	0.820	0
97	South Thompson	1996 2001	A	W	246	21.8	0.836	0
98	Spius	1996	A	H	61	13.8	0.804	0
99	Spius-Upper	2001	J	W	116	11.6	0.772	0
100	Stave	1999-2001	A	H	253	20.8	0.865	1
102	Stuart	1991 1992 1994-1996	A	W	555	22.0	0.834	0
103	Swift	1995 1996 2001	A	W	373	17.5	0.813	2
105	Taseko	1997 1998 2001	A	W	103	15.4	0.793	2
106	Thompson-Lower	2001	A	W	173	22.3	0.844	0
107	Torpy_River	2001	A/J	W	170	16.4	0.827	0
108	Walker	2001	?	W	39	11.3	0.799	0
112	Westroad	1996 1997	A	W	39	13.1	0.853	0
113	Willow	1995-1997 2000	A	W	83	15.3	0.827	0
ALL						**16.6**	**0.821**	

Table 2.2 - Marine recovery strata as defined for Fraser River chinook coded-wire tags.

Recovery Stratum	Mark Recovery Areas
Northern	Alaska regions 101-189, B.C.Statistical Areas1-12
WCVI	B.C.Statistical Areas 21-27
Inside	B.C. Statistical Areas 12-18, 29A & F and Washington Areas 6A and 7-7D
JDF/Puget Sound	B.C. Statistical Areas 20 and Washington Areas 6B, 8-13
Wash/Oregon Coast	US Marine Areas 1-4

Table 5.2 - Mean pairwise estimates of gene flow among and between regional groups using 13 neutral microsatellite loci. Birkenhead, Portage and Maria Slough are individual populations. Lower Fraser (LWFR), mid Fraser (MDFR), upper Fraser (UPFR), lower Thompson (LWTH), North Thompson (NOTH), and South Thompson (SOTH) are regional grouping of populations. Standard deviation is in brackets.

	Portage	Maria Slough	LWFR	MDFR	UPFR	LWTH	NOTH	SOTH
Birkenhead	2.02	1.58	2.65(0.13)	1.97(0.19)	1.79(0.09)	1.60(0.18)	1.96(0.05)	2.21(0.43)
Portage		2.73	3.84(0.44)	4.81(0.62)	4.07(0.43)	2.71(0.41)	4.82(0.59)	4.98(0.85)
Maria Slough			2.83(0.16)	2.79(0.39)	2.64(0.21)	2.65(0.35)	2.96(0.32)	4.02(0.43)
LWFR			65.57(11.82)	4.68(0.68)	4.13(0.36)	3.81(0.71)	4.19(0.75)	4.38(1.07)
MDFR				15.42(13.15)	11.77(6.31)	5.16(1.51)	9.15(3.53)	5.38(1.26)
UPFR					24.00(18.70)	5.06(1.45)	6.81(2.42)	5.62(1.23)
LWTH						16.98(13.49)	4.88(1.37)	4.26(1.15)
NOTH							18.86(13.66)	6.19(1.50)
SOTH								22.33(25.48)

Table 5.4 - Summary of dominant life history characteristics by region for Fraser chinook salmon.

Geographic Location	Rearing Type	Smolt Age	Dominant Return Age	Return Time Flesh Colour	Example Population	Unique in Fraser?
LWFR	Ocean	Immediate fry	4 yr	Fall Whites	Harrison R.	Y
LWFR	Stream	1 yr	5 yr	Spring Reds	Birkenhead R.	Y
LWFR	Ocean	60-150 day	4 yr	Summer Reds	Maria Slough	N
SOTH	Ocean	60-150 day	4 yr	Summer R/W	Lower Shuswap R.	N
LWTH	Stream	1 yr	4 yr	Spring Reds	Nicola R.	Y
NOTH	Stream	1 yr	5 yr	Spring/Sum R/W	Finn Cr.	N
MDFR	Stream	1 yr	5 yr	Spring/Sum R/W	Chilko R.	N
UPFR	Stream	1 yr	5 yr	Spring Reds R/W	Dome Cr.	N

Table 5.5 - Grouping criteria for provisional ESU determination based on genetic and life history information. The question marks indicate uncertainty in groupings. Groups connected by a dashed horizontal line are considered not distinct from each other.

<table>
<tr><th></th><th>UPFR</th><th>MDFR</th><th>NOTH</th><th>LWTH</th><th>SOTH</th><th>LWFR Summer Reds</th><th>LWFR Spring Reds</th><th>LWFR Fall Whites</th></tr>
<tr><td>Genetic evidence of substantial reproductive isolation</td><td colspan="3">------------------------?-------</td><td>-------</td><td>-------</td><td>--------</td><td>-------</td><td>-------</td></tr>
<tr><td>Non-genetic evidence of substantial reproductive isolation</td><td>--------</td><td>--------</td><td>-------</td><td>-------</td><td>-------</td><td>---------</td><td>-------</td><td>--------</td></tr>
<tr><td>Life history evidence of evolutionary legacy</td><td colspan="3">-------------------------------</td><td>--------</td><td colspan="2">-------------------</td><td>--------</td><td>--------</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Combined</td><td colspan="3">------------------------------</td><td>--------</td><td>--------?</td><td>?--------</td><td>--------</td><td>--------</td></tr>
</table>

Table 6.1.1 - Higher productivity populations with large lake systems upstream.

Spawning System	Large Lakes Upstream	Surface Area[1] (km^2)
Upper-mid Fraser/North Thompson		
Chilko	Chilko Lake	185
Cariboo-lower	Cariboo Lake	10
Clearwater	Azure Lake	31
	Clearwater Lake	33
	Murtle Lake	76
	Mahood Lake	33
Nechako	Nechako Reservoir	890
	Fraser Lake	54
	Francois Lake	250
North Thompson	Azure Lake	31
	Clearwater Lake	33
	Murtle Lake	76
	Mahood Lake	33
Portage	Anderson Lake	28
Quesnel	Quesnel Lake	270
	Horsefly Lake	58
Stuart	Takla Lake	246
	Trembleur Lake	116
	Stuart Lake	359
Taseko	Taseko Lake	31
South Thompson		
Adams-lower	Adams Lake	129
Little River	Shuswap Lake	305
	Mara Lake	20
	Adams Lake	129
	Mabel Lake	60
	Sugar Lake	21
Shuswap-mid	Sugar Lake	21
Shuswap-lower	Mabel Lake	60
	Sugar Lake	21
South Thompson	Adams Lake	129
	Little Shuswap Lake	18
	Shuswap Lake	305
	Mara Lake	20
	Mabel Lake	60
	Sugar Lake	21
Thompson	Kamloops Lake	55
	Adams Lake	129
	Little Shuswap Lake	18
	Shuswap Lake	305
	Mara Lake	20
	Mabel Lake	60
	Sugar Lake	21
	Azure Lake	31
	Clearwater Lake	33
	Murtle Lake	76
	Mahood Lake	33
Lower Fraser		
Harrison	Harrison Lake	220
	Lillooet Lake	35
Chilliwack	Chilliwack Lake	12

1. Lake surface area data were retrieved from the Fish Wizard (http://pisces.env.gov.bc.ca/).

Table 6.1.2 - Provisional CUs at tier 2 of the hierarchy that correspond to aggregates used for international management.

International Management Groupings	Provisional CUs at Tier 2
Fraser Late-run Harrison	Lower Fraser Fall Whites
Fraser Summer-run Age 0.3	Higher productivity South Thompson
Fraser Summer-run Age 1.3	Higher productivity Upper-mid Fraser/North Thompson
Fraser Spring-run Age 1.3	Lower productivity Upper-mid Fraser/North Thompson
	Lower productivity South Thompson
Fraser Spring-run Age 1.2	Lower productivity Lower Thompson

Table 6.2 - Marine recoveries patterns (frequency by recovery area) for Fraser chinook salmon CWT'ed populations. Shading indicates relative value, with the largest values shaded the darkest. Populations excluded where observed values < 10 recoveries. Table 2.2 provides the statistical areas for each of the recovery areas.

Productivity	Population	Northern	WCVI	Inside	JDF/Puget	Wash/Ore	ObsN	EstN
Higher	Stuart	0.27	0.49	0.09	0.13	0.01	109	412
	Chilko	0.19	0.35	0.21	0.23	0.01	59	276
	Quesnel	0.39	0.29	0.18	0.13	0.00	314	1,236
	L. Cariboo	0.64	0.07	0.09	0.20	0.00	13	49
	Clearwater	0.41	0.37	0.06	0.08	0.01	397	1464
	N.Thompson	0.67	0.20	0.03	0.10	0.00	81	327
Lower	Dome	0.10	0.10	0.19	0.50	0.02	86	356
	Slim	0.00	0.41	0.26	0.20	0.03	10	34
	Bowron	0.31	0.25	0.15	0.27	0.02	20	83
	West Road	0.09	0.17	0.15	0.43	0.15	30	144
	U. Cariboo	0.09	0.12	0.40	0.32	0.05	23	87
	Chilcotin	0.10	0.33	0.29	0.24	0.01	30	108
	Finn	0.30	0.26	0.29	0.10	0.03	38	153
	Raft	0.38	0.43	0.07	0.12	0.00	239	901
	Bridge	0.06	0.61	0.09	0.22	0.00	28	106
Higher	S.Thompson	0.71	0.07	0.21	0.00	0.00	21	78
	L. Shuswap	0.66	0.08	0.18	0.06	0.00	1,317	4,746
	M. Shuswap	0.61	0.12	0.18	0.09	0.00	532	1,973
Lower	Salmon R	0.44	0.11	0.38	0.04	0.02	43	170
	Eagle	0.50	0.18	0.19	0.13	0.01	367	1391
Lower	Bonaparte	0.08	0.27	0.34	0.29	0.03	108	398
	Deadman	0.15	0.13	0.42	0.26	0.04	40	217
	Nicola	0.13	0.19	0.26	0.4	0.03	413	1,946
	Coldwater	0.09	0.03	0.14	0.73	0.02	28	76
Lower	Birkenhead	0.57	0.03	0.31	0.07	0.02	44	333
Higher	Chilliwack	0.01	0.27	0.44	0.2	0.07	4,530	15,538
	Harrison/Cheh	0.05	0.31	0.50	0.11	0.03	5,969	22,708
	Stave	0.00	0.07	0.19	0.12	0.61	242	657

Table 6.3 - Counts of peak passage through Albion determined by maximum CPUE for a given year (2000 or 2001) and net type (8 inch or multi-panel)[1].

			Spring					Summer			Fall	
Provision ESU	**Productivity**		**April**	**May**	**June 1-15**	**June 16-30**	**July 1-15**	**July 16-31**	**Aug 1-15**	**Aug 16-31**	**Sept 1 - 15**	**Sept 15 ->**
UPFR/MDFR/NOTH	Higher	Stuart					1	3				
		Nechako				1		3				
		Chilko				1	3					
		Quesnel						2	1	1		
		Taseko				2	1	1				
		Portage						1		1		
		Clearwater						3	1			
		North Thompson						1	3			
	Lower	Fraser-TeteJaune				1	3					
		Fontoniko		1	1	1	1					
		Dome		2	1	1						
		Slim			1	2	1					
		Walker				2	1					
		Swift			1	1	2					
		Goat		2		2						
		Bowron			1		3					
		Torpy			2	2						
		Indianpoint			1		2	1				
		Holmes			1	1	2					
		Morkill				3	1					
		MacGregor				4						
		Westroad					2		1			
		Willow			2	1	1					
		Salmon-PG		1	1	2						
		Cariboo-Upper				1	3					
		Chilako	3		1							
		Chilcotin-Lower			2		2					
		Chilcotin-Upper	2	2								
		Cottonwood		4								
		Horsefly		1	1		2					
		Bridge	1			3						
		Elkin					4					
		Endako		1	1			2				
		Finn					2	2				
		Barriere						3	1			
		Raft						3	1			
SOTH	Higher	Thompson-Lower							1	3		
		South Thompson							1	3		
		Little							4			
		Shuswap-Lower						1	3			
		Shuswap-Mid					3		1			
		Adams-Lower						1	3			
	Lower	Adams-Upper						1	2	1		
		Bessette		1					1	2		
		Salmon-SA			1	1	1			1		
		Eagle				1	2		1			
		Duteau					1	2		1		
LWTH	Lower	Bonaparte				3	1					
		Coldwater	1	1	1			1				
		Coldwater-Upper	1	2	1							
		Deadman		1	2	1						
		Louis	2	1			1					
		Nicola		1		2	1					
		Spius			1		1	1				
		Spius-Upper					1		1			
LWFR Spring Reds	Lower	Birkenhead	3									
LWFR Summer Reds	Lower	Maria_Slough						2		2		
LWFR Fall Whites	Higher	Chilliwack								2	2	
		Harrison							1	1	1	1
		Stave								2	2	

[1] Numbers in each cell refer to the number of times that the peak count occurred of a particular year/net. For example, in the first row Stuart fish peaked during the first half of July in one net/year, and in the last half of July in three net/year combinations.

12. Figures

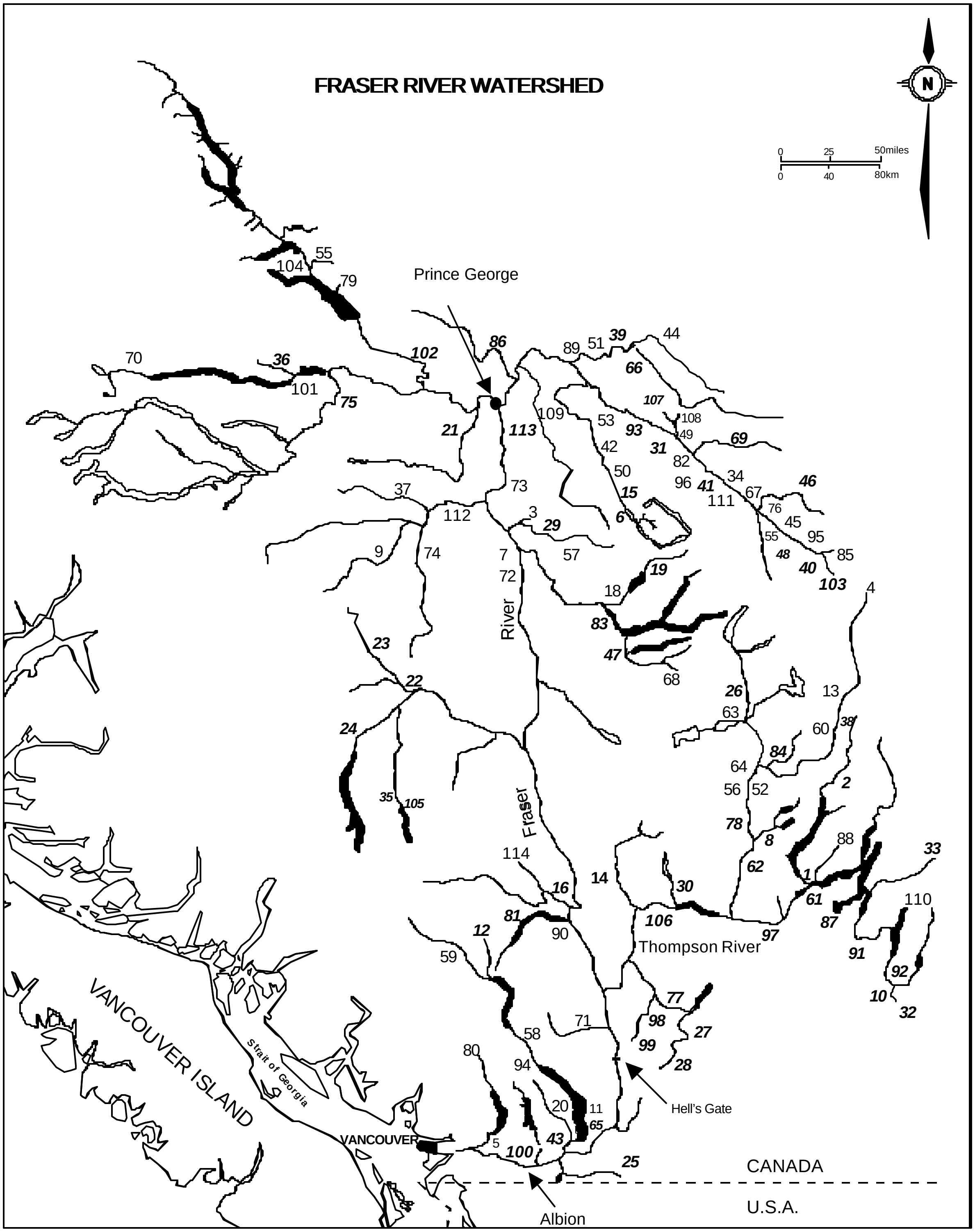


Figure 1 – Locations of 114 chinook spawning locations from the Fraser River. Sampling numbers correspond to Table 2.1 and Appendix 1. Numbers in bold and italics identify sampling locationswith more than 30 genetic samples.

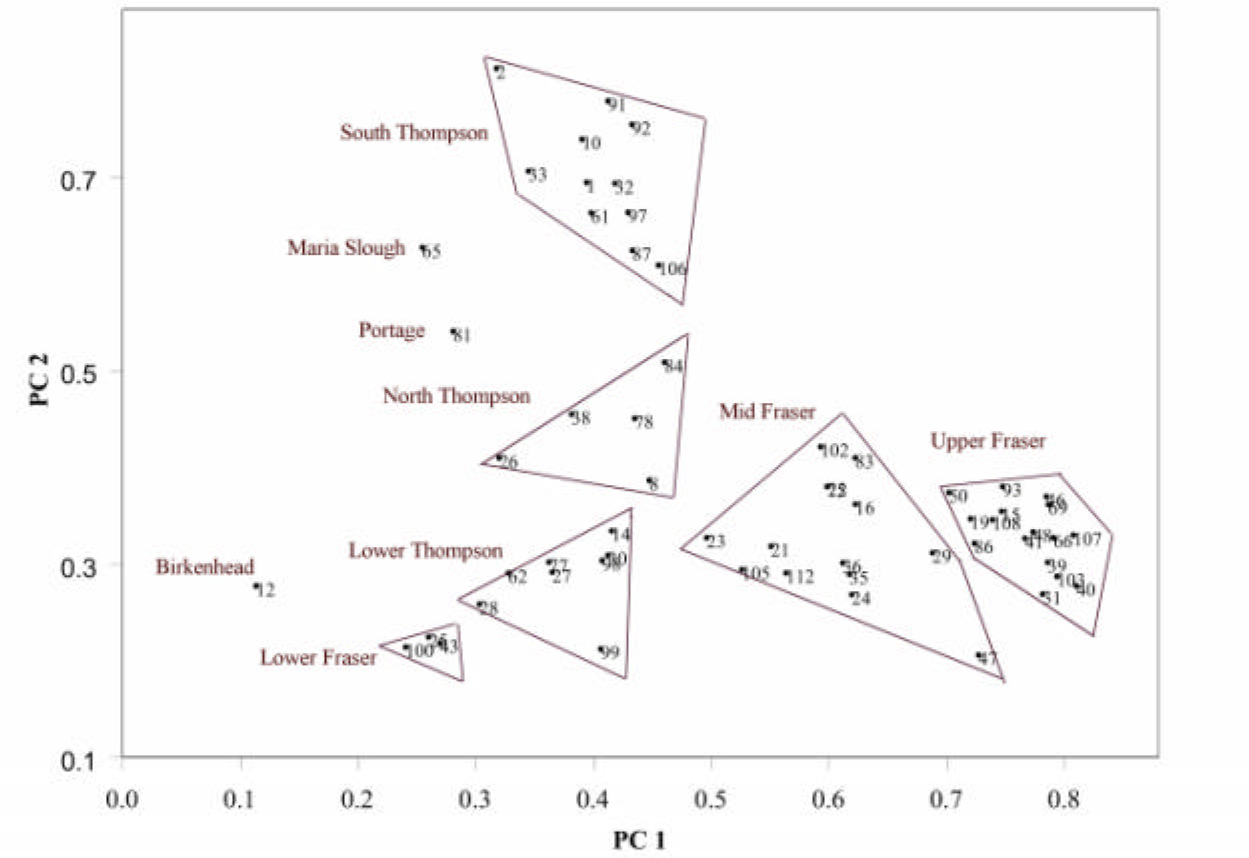


Figure 5.2.1 – Scatterplot of scores along the first two principal components (PCA) for 61 chinook salmon populations from the Fraser River. Stock names are given in Table 2.1 and Appendix 1. Populations forming regional grouping are identified with polygons.

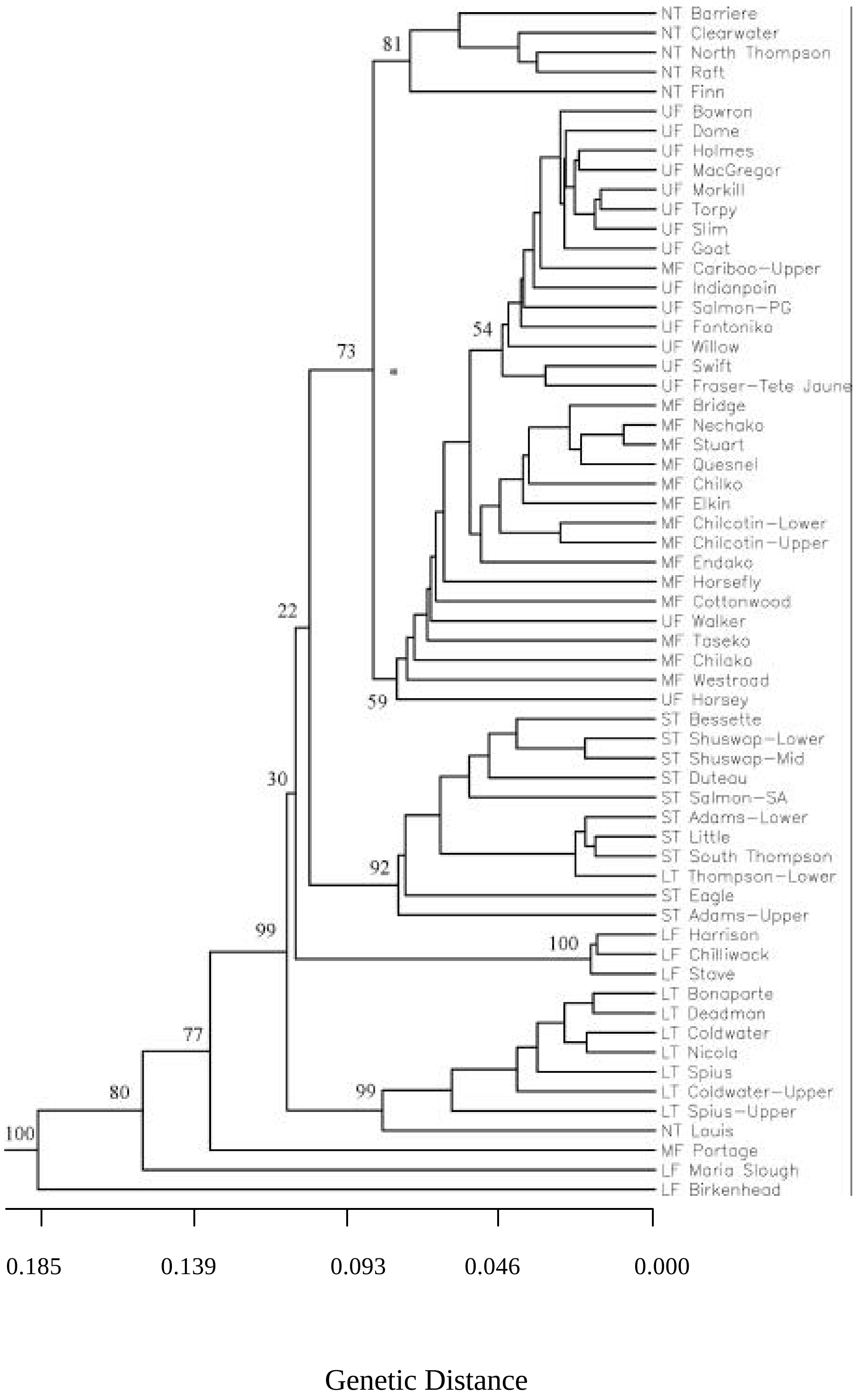


Figure 5.2.2 – Dendrogram of Cavalli-Sforza and Edwards (1967) chord distances (13 loci) among 61 chinook salmon populations in the Fraser River. Geographic regions are upper Fraser (UF), mid Fraser (MF), lower Fraser (LF), South Thompson (ST), lower Thompson (LT), North Thompson (NT). Values along the branches indcate consensus values in percent for 1000 bootstrap allele frequency datasets. "*" indicates demarkation point in Figure 5.2.3.

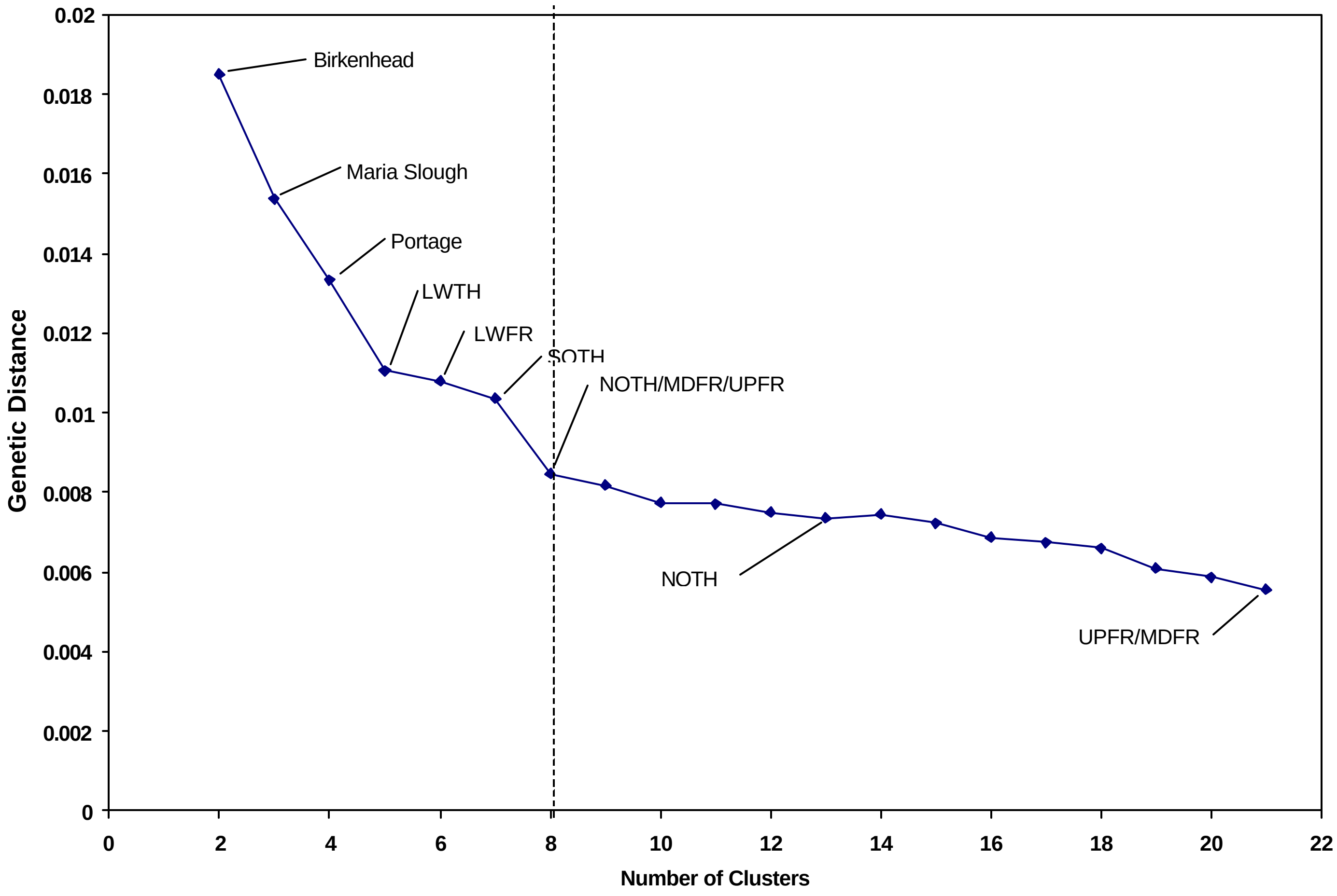


Figure 5.2.3 – Scree plot of genetic distance and number of clusters associated with branch nodes (seen in Figure 5.2.2) showing the genetic distance to the separation of major regional groups. Dash line indicates last major change in genetic distance with the inclusion of additional nodes.

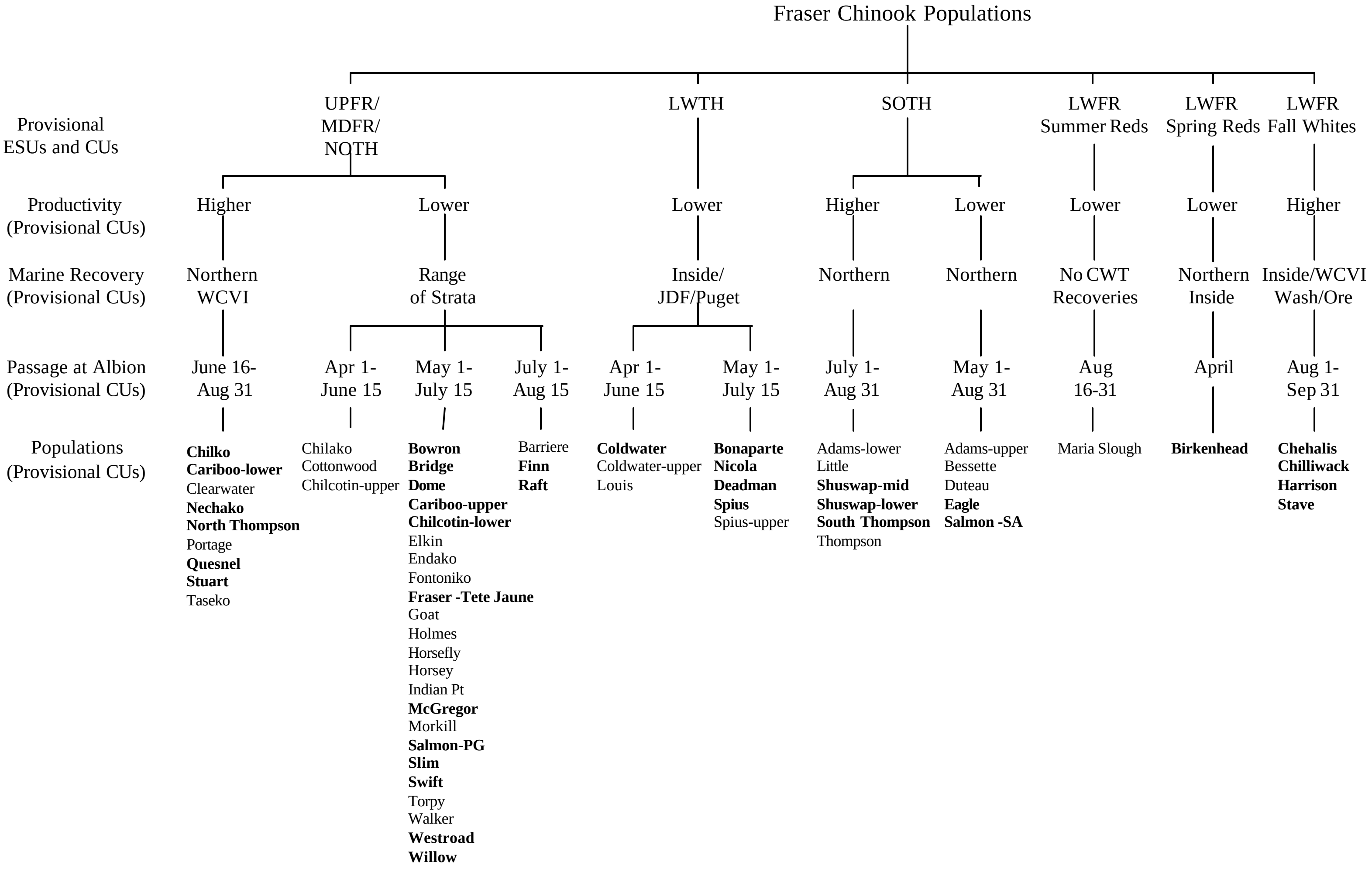


Figure 5.5 – One possible hierachical classification of Fraser chinook salmon based on provisional Evolutionarily Significant Units (ESUs) and Conservation Units (CUs). Chinook from streams in bold have been coded-wire tagged. Note that the LWFR summer red provisional ESU is highly questionable due to our difficulty in concluding that these fish are evolutionarily significant. Portage is not included in this figure. See Appendix 3 for other possible classifications.

Appendices

Appendix 1. List of Fraser River chinook spawning populations, estimates juvenile life history, basin sizes, juvenile life history, peak spawning, age at return, and recent enhancement..

Stream Name	Stock Code	Basin Area Km^2	Juvenile Life History	2001 Peak Spawning (week)	Most Common Age at Return	Recently Enhanced
Adams River (lower)	1	3323	Ocean	10/2-10/9	4	N
Adams River (upper)	2	3087	Stream	9/20-9/27	***5***	N
Ahbau Creek	3	505	***Stream***	8/21-8/28	***5***	N
Albreda River	4	406	***Stream***	8/20-8/27	***5***	N
Alouette River	5	332	NA	NA	NA	Y
Antler Creek	6	359	Stream	8/24-8/31	5	N
Baker Creek	7	1570	Stream	8/25-9/1	***5***	Y
Barriere River	8	1151	***Stream***	9/12-9/19	***5***	N
Bazeko River	9	1980	Stream	8/26-9/2	5	N
Bessette Creek	10	795	Stream	9/23-9/30	4	N
Big Silver Creek	11	495	Stream	NA	NA	N
Birkenhead River	12	593	Stream	9/9-9/16	5	Y
Blue River	13	275	Stream	8/25-9/1	5	N
Bonaparte River	14	5390	Stream	9/5-9/12	4	N
Bowron River	15	3600	Stream	8/24-8/31	5	N
Bridge River	16	4637	Stream	8/24-8/31	4	Y
Captain Creek	17	135	Stream	8/15-8/22	5	N
Cariboo River (lower)	18	3253	Stream	9/18-9/25	5	N
Cariboo River (upper)	19	NA	Stream	8/11-8/18	5	N
Chehalis River	20	392	NA	NA	NA	Y
Chilako River	21	3578	***Stream***	8/19-8/26	***5***	Y
Chilcotin River (lower)	22	6220	Stream	8/30-9/6	5	N
Chilcotin River (upper)	23	NA	***Stream***	8/14-8/21	***5***	N
Chilko River	24	6940	Stream	9/8-9/15	5	N
Chilliwack River	25	1230	Stream	oct 23- nov 5	4	Y
Clearwater River	26	10551	Stream	9/25-10/2	5	N
Coldwater River	27	915	Stream	8/27-9/3	4	Y
Coldwater River (upper)	28	NA	Stream	8/27-9/3	4	Y
Cottonwood River	29	2460	Stream	8/21-8/28	5	N
Deadman River	30	1497	Stream	9/9-9/16	4	Y
Dome Creek	31	273	Stream	8/12-8/19	5	Y
Duteau Creek	32	217	Stream	9/23-9/30	4	N
Eagle River	33	1246	Stream	9/14-9/21	5	Y
East Twin Creek	34	128	***Stream***	8/10-8/17	***5***	N
Elkin Creek	35	210	Stream	9/8-9/15	5	N
Endako River	36	2033	***Stream***	8/28-9/4	***5***	N
Euchiniko River	37	1370	***Stream***	8/26-9/2	***5***	N
Finn Creek	38	134	Stream	8/10-8/17	5	N
Fontiniko Creek	39	321	Stream	8/15-8/22	5	N
Fraser River (Tete Jaune)	40	NA	Stream	8/31-9/7	5	N
Goat River	41	661	***Stream***	8/17-8/24	***5***	N

Appendix 1 – continued.

Stream Name	**Stock Code**	**Basin Area km^2**	**Juvenile Life History**	**2001 Peak Spawning (week)**	**Most Common Age at Return**	**Recently Enhanced**
Haggen Creek	42	649	Stream	8/24-8/31	5	N
Harrison River	43	8324	Ocean	Nov 6-12	4	Y
Herrick Creek	44	2058	Stream	8/15-8/22	5	N
Holliday Creek	45	NA	***Stream***	8/18-8/25	***5***	N
Holmes River	46	785	Stream	8/20-8/27	5	N
Horsefly River	47	2860	Stream	8/29-9/5	5	N
Horsey Creek	48	201	***Stream***	8/23-8/30	***5***	N
Humbug Creek	49	NA	***Stream***	8/15-8/22	***5***	N
Indian Point Creek	50	396	Stream	8/24-8/31	5	N
James Creek	51	116	***Stream***	8/15-8/22	***5***	N
Joseph (Dunn&McTaggart)	52	259	***Stream***	NA	***5***	N
Kenneth Creek	53	216	***Stream***	8/18-8/25	***5***	N
Kiwa Creek	54	NA	***Stream***	8/20-8/27	***5***	N
Kuzkwa River	55	NA	***Stream***	9/2-9/9	***5***	N
Lemieux Creek	56	454	Stream	10/3-10/10	4	N
Lightning Creek	57	243	***Stream***	8/21-8/28	***5***	N
Lillooet River (lower)	58	6109	NA	9/25-10/2	NA	N
Lillooet River (upper)	59	3675	NA	NA	NA	N
Lion Creek	60	46	***Stream***	8/17-8/24	***5***	N
Little River	61	NA	Ocean	10/15-10/22	4	N
Louis Creek	62	526	Stream	8/25-9/1	4	N
Mahood River	63	4915	***Stream***	9/25-10/2	***5***	N
Mann Creek	64	295	***Stream***	9/11-918	***5***	N
Maria Slough	65	33	Ocean	10/7	4	Y
McGregor River	66	5550	***Stream***	8/15-8/22	***5***	N
McKale River	67	280	Stream	8/10-8/17	5	N
McKinley Creek	68	450	Stream	8/29-9/5	5	N
Morkill River	69	1333	***Stream***	8/25-9/1	***5***	N
Nadina River	70	1093	***Stream***	NA	***5***	N
Nahatlatch River	71	1256	NA	8/24-8/31	5	N
Narcosli Creek	72	1700	***Stream***	8/22-8/29	***5***	N
Naver Creek	73	900	***Stream***	8/19-8/26	***5***	N
Nazko River	74	4150	***Stream***	8/26-9/2	***5***	N
Nechako River	75	51900	Stream	9/11-9/18	5	N
Nevin Creek	76	137	***Stream***	8/8-8/15	***5***	N
Nicola River	77	7227	Stream	9/11-9/18	4	Y
North Thompson River	78	20742	Stream	9/12-9/19	5	N
Pinchi Creek	79	NA	***Stream***	NA	***5***	N
Pitt River	80	1660	Stream	late Aug/Sep	5	N
Portage Creek	81	728	Stream	10/19-10/26	5	N
Ptarmigan Creek	82	183	Stream	8/12-8/19	5	N
Quesnel River	83	11730	Stream	9/25-10/2	5	Y
Raft River	84	764	Stream	9/9-9/16	5	N
Robson River	85	NA	Stream	9/2-9/9	5	N

Appendix 1 – continued.

Stream Name	**Stock Code**	**Basin Area km^2**	**Juvenile Life History**	**2001 Peak Spawning (week)**	**Most Common Age at Return**	**Recently Enhanced**
Salmon River (PG)	86	4437	Stream	8/23-8/30	5	Y
Salmon River (SA)	87	1501	Stream	9/11-9/18	5	Y
Scotch Creek	88	611	**Stream**	10/2-10/9	***5***	N
Seebach Creek	89	421	Stream	8/15-8/22	5	N
Seton River	90	1920	Stream	10/19-10/26	5	N
Shuswap River (Lower)	91	5415	Ocean	10/6-10/13	4	Y
Shuswap River (Middle)	92	NA	Ocean	9/24-10/1	4	Y
Slim Creek	93	856	Stream	8/26-9/2	5	N
Sloquet Creek	94	206	Stream	late Aug/Sep	NA	N
Small Creek	95	NA	Stream	8/23-8/30	5	N
Snowshoe Creek	96	100	Stream	8/14-8/21	5	N
South Thompson River	97	17311	Ocean	10/10-10/17	4	N
Spius Creek	98	780	Stream	8/27-9/3	4	Y
Spius Creek (upper)	99	NA	Stream	8/27-9/3	4	Y
Stave River	100	1003	Stream	late Aug/Sep	4	Y
Stellako River	101	3600	***Stream***	8/28-9/4	***5***	N
Stuart River	102	NA	Stream	9/10-9/17	5	N
Swift Creek	103	135	Stream	8/16-8/23	5	N
Tachie River	104	NA	***Stream***	NA	***5***	N
Taseko River	105	2730	Stream	9/8-9/15	5	N
Thompson River (lower)	106	55665	Ocean	9/28-10/5	4	N
Torpy River	107	1285	Stream	8/13-8/20	5	N
Walker Creek	108	364	Stream	8/13-8/20	5	N
Wansa Creek	109	293	Stream	8/24-8/31	5	N
Wap Creek	110	354	***Stream***	9/14-9/21	***5***	N
West Twin Creek	111	174	***Stream***	8/8-8/15	***5***	N
Westroad River	112	12400	Stream	8/26-9/2	5	N
Willow River	113	2875	Stream	8/24-8/31	5	N
Yalakom River	114	676	Stream	8/24-8/31	4?	N

NA indicates systems with no data.

1. Bold and italics were used for systems with no scale samples, although juvenile life history and most common age at return were assumed to be similar to nearby spawning systems.

Appendix 2. Contribution estimates of chinook salmon to 61 Fraser River populations for the Albion test fishery 2000 and 2001. Standard deviations in brackets.

			2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
			8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	8 inch	8 inch
Provisional ESU	Prdductivity		April	April	May	May	June1-15	June1-15	June16-30	June16-30	July1-15	July1-15	July16-31	July16-31	Aug1-15	Aug1-15	Aug16-31	Aug16-31	Sep1-15	Sep16-30	Oct2-18
			20	28	47	27	37	24	131	82	143	217	163	136	83	139	87	97	102	89	42
UPFR/MDFR/NOTH	Higher	Stuart	0.0(4.5)	0.0(3.2)	0.0(1.2)	0.0(3.4)	0.0(2.1)	0.0(4.4)	1.6(2.3)	1.6(1.7)	1.8(2.0)	8.1(3.2)	7.2(4.3)	2.0(4.1)	0.0(2.5)	0.0(1.6)	0.8(2.2)	0.0(0.6)	0.0(0.0)	0.0(0.4)	2.4(2.1)
		Nechako	0.0(8.0)	0.0(2.1)	0.0(1.6)	0.0(2.4)	0.0(3.8)	4.8(6.1)	1.5(2.0)	1.3(2.2)	0.0(1.8)	1.4(3.3)	9.5(4.0)	8.9(5.2)	7.7(3.9)	5.2(2.5)	0.0(0.3)	0.0(0.0)	0.0(1.0)	0.9(1.8)	0.0(2.7)
		Chilko	0.0(0.0)	0.0(2.3)	4.1(3.1)	0.0(2.8)	11.8(5.4)	0.0(0.0)	11.9(3.0)	7.3(3.0)	9.0(3.2)	13.2(2.6)	3.2(1.4)	6.4(2.7)	4.8(2.0)	3.1(1.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Quesnel	0.0(0.0)	3.2(2.7)	0.0(1.7)	3.0(8.2)	0.0(0.0)	0.0(4.0)	2.7(2.8)	0.0(1.3)	1.0(2.1)	0.0(1.5)	2.9(3.2)	3.0(3.2)	1.4(1.9)	3.2(2.3)	6.3(2.5)	0.0(0.9)	0.0(0.5)	2.2(1.4)	0.0(0.0)
		Taseko	0.0(0.0)	0.0(0.6)	0.0(1.2)	0.0(3.0)	0.0(0.3)	2.7(3.4)	2.0(1.0)	1.4(1.4)	0.0(0.4)	0.0(0.3)	0.0(0.0)	0.8(0.8)	0.0(0.0)	0.0(0.0)	0.0(0.1)	1.0(1.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Portage	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.6(0.5)	0.0(0.0)	0.0(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)
		Clearwater	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	2.0(2.6)	0.0(0.0)	1.2(1.1)	3.9(2.4)	9.4(2.6)	4.6(1.9)	8.5(2.8)	15.2(3.6)	7.9(3.7)	10.6(3.3)	0.0(1.0)	2.2(1.8)	0.0(0.0)	0.0(0.5)	0.0(1.4)
		North Thompson	0.0(0.0)	0.0(1.0)	0.0(0.5)	0.0(0.4)	0.0(2.5)	0.0(0.0)	0.1(2.4)	0.4(1.8)	0.0(0.6)	3.6(2.2)	15.2(4.3)	6.5(3.2)	11.5(3.7)	10.5(3.7)	0.0(1.3)	2.9(2.1)	0.0(1.0)	0.0(0.0)	0.0(0.0)
	Lower	Fraser-TeteJaune	0.0(0.1)	0.0(0.0)	0.0(2.2)	0.0(1.6)	8.6(6.9)	0.0(0.0)	8.1(3.1)	2.3(2.4)	5.8(2.5)	6.3(1.9)	1.8(1.2)	1.2(1.0)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.5)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Fontoniko	0.0(0.5)	0.0(0.3)	0.8(1.4)	5.0(3.8)	0.0(1.4)	0.0(3.5)	1.5(1.6)	1.6(1.9)	4.4(2.0)	0.3(0.5)	0.0(0.0)	0.6(0.8)	0.0(0.1)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Dome	0.0(0.0)	2.2(2.7)	6.4(5.8)	0.0(1.9)	3.0(6.2)	10.1(8.2)	0.7(1.4)	2.5(3.2)	0.0(0.4)	0.5(0.8)	0.0(0.3)	0.0(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Slim	0.0(0.1)	0.0(0.0)	1.1(4.6)	0.0(1.3)	13.6(9.5)	0.0(1.4)	0.4(2.9)	5.2(4.6)	3.0(3.0)	2.5(2.1)	1.6(1.4)	0.8(0.8)	0.0(0.3)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.0)
		Walker	0.0(1.6)	0.0(0.8)	0.0(2.3)	0.0(0.3)	0.0(0.1)	0.0(2.2)	0.8(1.4)	0.0(1.4)	0.1(0.6)	0.0(0.2)	0.0(0.2)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Swift	0.0(0.0)	0.0(0.9)	1.1(1.9)	0.0(0.0)	5.3(4.6)	0.0(0.0)	0.0(1.1)	0.0(0.0)	0.0(0.8)	0.6(0.7)	0.6(1.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Goat	0.0(0.0)	0.0(4.1)	0.0(2.5)	1.1(5.7)	0.0(1.9)	0.0(1.8)	2.6(1.6)	0.0(1.7)	0.0(0.8)	0.0(0.6)	0.0(0.5)	0.0(0.3)	0.0(0.3)	0.0(0.5)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.4)
		Bowron	0.0(1.4)	0.0(0.0)	0.0(4.3)	0.1(5.0)	5.0(5.4)	0.0(2.7)	0.0(2.9)	2.4(3.3)	0.0(1.2)	1.7(1.5)	0.0(0.6)	0.0(0.3)	0.0(0.3)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.1)
		Torpy	0.0(0.1)	0.0(1.3)	21.5(9.2)	0.0(1.1)	7.0(8.2)	0.0(2.9)	20.2(5.9)	11.3(5.5)	4.3(3.4)	3.3(2.4)	0.0(0.7)	0.0(0.7)	0.0(0.1)	0.0(0.2)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Indianpoint	3.6(3.7)	0.0(0.0)	0.0(2.6)	0.0(0.7)	0.0(2.5)	0.0(2.6)	0.7(0.8)	0.0(0.8)	2.4(1.4)	2.9(1.2)	0.0(0.2)	0.0(0.3)	0.0(0.3)	0.0(0.2)	0.0(0.0)	0.0(0.1)	0.0(0.3)	0.0(0.0)	0.0(0.0)
		Holmes	0.0(0.0)	0.0(2.4)	1.1(3.3)	0.0(3.0)	0.7(5.7)	0.0(0.4)	0.2(2.9)	3.8(3.4)	6.3(3.0)	0.0(0.1)	0.0(0.3)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Morkill	0.0(0.0)	0.0(0.0)	0.0(5.2)	11.0(7.4)	0.1(3.3)	0.0(0.6)	7.1(4.5)	0.1(3.8)	1.8(3.2)	4.2(2.5)	0.7(1.1)	0.0(0.1)	0.0(0.1)	0.0(0.0)	0.0(0.5)	0.2(0.8)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		MacGregor	0.0(2.0)	0.0(0.0)	5.8(4.1)	0.0(1.5)	7.1(5.7)	8.2(6.7)	10.5(3.8)	5.3(3.8)	0.0(3.1)	0.6(1.2)	0.0(0.3)	0.9(1.3)	0.0(0.0)	0.0(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Westroad	0.8(2.8)	0.0(1.0)	4.8(2.7)	0.0(0.4)	2.0(2.6)	0.0(0.0)	0.0(0.5)	0.0(0.1)	0.7(0.5)	0.8(0.5)	0.0(0.0)	0.0(0.4)	1.2(1.2)	0.0(0.4)	0.0(0.0)	1.0(1.1)	0.0(0.3)	0.0(0.6)	0.0(0.0)
		Willow	0.0(1.5)	0.0(0.7)	0.0(1.6)	0.0(0.1)	0.0(3.5)	6.8(5.6)	1.1(2.0)	1.4(1.8)	0.0(0.5)	0.0(0.7)	0.0(0.3)	0.0(0.3)	0.0(0.0)	0.0(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Salmon-PG	0.0(0.0)	5.0(8.2)	0.0(2.0)	6.8(6.9)	5.3(4.2)	0.1(8.0)	0.8(1.8)	0.0(0.8)	0.0(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.1)	0.0(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Cariboo-Upper	0.0(1.1)	0.0(0.9)	0.0(4.5)	0.0(6.0)	0.0(2.3)	0.0(3.2)	3.3(3.0)	0.2(1.3)	7.6(3.6)	3.7(1.8)	2.4(1.6)	0.0(0.9)	0.0(0.1)	0.5(1.2)	0.0(0.0)	0.3(1.5)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Chilako	13.3(7.2)	12.7(6.6)	3.3(3.2)	3.9(4.5)	0.9(2.6)	0.0(2.0)	0.0(0.9)	0.2(0.8)	0.0(0.4)	0.0(0.6)	0.0(0.3)	0.8(0.5)	0.0(0.8)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Chilcotin-Lower	0.3(5.5)	0.0(0.4)	6.8(5.9)	6.7(7.2)	9.6(5.8)	5.4(5.6)	2.5(2.1)	0.0(1.9)	7.8(2.9)	3.2(2.2)	2.5(2.2)	3.3(2.6)	0.0(0.1)	0.0(0.4)	1.4(1.4)	1.5(1.5)	0.0(0.0)	0.0(0.4)	0.0(0.2)
		Chilcotin-Upper	19.6(13.5)	29.4(9.9)	2.5(5.7)	8.1(5.9)	0.0(1.8)	8.9(5.3)	0.0(0.5)	0.0(0.4)	0.0(0.1)	0.0(0.8)	0.7(0.9)	1.1(1.0)	0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Cottonwood	0.0(0.0)	10.6(6.3)	6.7(4.1)	13.6(7.3)	5.9(4.9)	0.0(0.7)	1.0(1.0)	4.2(2.6)	0.0(0.1)	0.0(0.1)	0.0(0.3)	0.8(0.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Horsefly	0.0(1.0)	0.0(1.6)	2.3(2.0)	0.0(1.1)	0.0(1.8)	0.0(0.0)	0.0(0.5)	0.0(0.3)	0.0(0.6)	1.1(0.7)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.5(0.3)	0.0(0.0)	0.0(0.0)	0.6(0.7)	0.0(0.0)	0.0(0.0)
		Bridge	21.8(11.0)	1.2(3.2)	0.0(2.2)	0.0(0.9)	0.0(1.3)	0.0(0.6)	1.5(1.8)	3.5(2.5)	1.2(2.2)	1.1(1.3)	0.0(1.2)	1.5(2.6)	0.0(0.8)	1.0(1.1)	0.0(0.0)	0.0(0.2)	1.1(0.8)	0.0(0.3)	0.0(0.0)
		Elkin	0.0(0.0)	0.0(0.0)	0.0(0.9)	0.0(0.0)	0.0(0.0)	0.0(3.0)	0.0(1.0)	0.0(0.4)	3.0(2.3)	0.2(1.4)	0.0(0.8)	0.0(0.2)	0.0(0.4)	0.1(1.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.5)	0.0(0.0)
		Endako	0.0(0.5)	0.0(0.9)	10.5(4.9)	3.5(2.7)	1.3(3.2)	10.6(6.3)	0.0(0.4)	0.0(0.5)	0.3(1.5)	0.0(0.1)	0.0(0.0)	0.0(0.6)	0.0(0.1)	0.0(0.7)	0.0(0.0)	0.0(0.0)	0.0(0.3)	0.0(0.0)	0.0(0.0)
		Finn	0.2(4.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	2.5(1.4)	2.5(1.8)	5.6(2.0)	2.5(1.2)	1.3(1.0)	4.0(2.0)	1.8(1.4)	1.5(1.7)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Barriere	0.0(1.4)	0.0(1.6)	0.0(0.1)	0.0(0.1)	0.0(1.6)	2.0(3.1)	4.7(1.9)	1.3(1.1)	1.1(1.0)	0.0(0.6)	6.0(2.9)	0.7(1.3)	0.0(0.5)	1.0(1.2)	1.2(0.6)	0.1(0.8)	0.0(0.0)	0.0(0.0)	0.0(0.2)
		Raft	5.2(3.5)	0.0(0.0)	0.0(0.5)	0.0(0.0)	0.0(0.7)	0.0(1.3)	1.2(1.2)	1.9(2.0)	0.0(1.5)	3.0(1.6)	2.2(3.1)	4.8(3.3)	0.0(1.7)	0.4(2.1)	0.0(0.7)	0.0(2.3)	2.0(1.8)	0.0(0.1)	0.0(0.0)
		Horsey	0.0(0.0)	0.0(0.7)	0.0(0.0)	0.0(1.2)	0.0(0.5)	0.0(2.1)	0.0(0.1)	0.0(0.0)	0.0(0.2)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
SOTH	Higher	Thompson-Lower	0.0(0.0)	0.0(0.0)	0.0(0.8)	0.0(3.0)	0.0(2.1)	0.0(0.0)	0.0(0.6)	0.0(1.0)	1.0(0.9)	1.3(1.1)	2.4(1.7)	0.5(1.9)	8.5(5.3)	14.8(4.7)	20.4(8.3)	24.4(7.0)	0.6(4.4)	0.0(0.3)	0.0(0.0)
		South Thompson	0.0(0.0)	0.0(0.0)	0.0(0.0)	4.3(2.8)	0.0(0.4)	0.0(0.5)	0.0(0.2)	0.0(0.6)	0.0(0.6)	0.4(1.6)	2.4(2.2)	0.0(1.7)	5.3(6.1)	12.4(5.6)	32.5(8.4)	30.5(7.6)	19.1(5.8)	0.0(0.5)	0.0(0.0)
		Little	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(1.5)	0.0(1.9)	0.0(0.0)	0.7(0.6)	0.0(0.7)	0.0(0.8)	1.4(1.1)	0.0(1.2)	1.4(1.6)	13.9(6.6)	8.9(5.3)	21.6(7.5)	7.6(6.2)	5.1(3.0)	0.0(0.0)	0.0(0.0)
		Shuswap-Lower	0.0(0.0)	0.0(0.0)	0.0(2.7)	0.0(0.0)	2.8(3.1)	0.0(0.4)	0.9(1.2)	2.5(1.9)	7.5(2.8)	12.3(2.9)	12.9(3.5)	21.0(4.1)	15.4(6.1)	16.4(3.6)	3.1(3.4)	8.4(5.4)	0.0(1.4)	0.0(0.0)	0.0(0.0)
		Shuswap-Mid	0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.5)	0.0(0.0)	0.0(0.2)	6.1(3.1)	7.0(2.9)	5.5(2.5)	5.8(3.3)	5.4(3.2)	8.4(5.6)	5.7(2.5)	1.0(1.6)	1.1(3.3)	0.0(0.4)	0.0(0.0)	0.0(0.0)
		Adams-Lower	0.0(0.0)	0.0(0.0)	0.0(0.8)	0.0(0.0)	0.0(0.0)	0.0(0.3)	0.0(0.0)	0.0(0.7)	0.0(0.7)	0.0(0.9)	0.0(0.7)	1.6(2.0)	8.2(5.0)	0.0(1.7)	1.0(4.3)	2.1(4.2)	2.3(2.9)	0.0(0.0)	0.0(0.0)
	Lower	Adams-Upper	0.0(0.0)	0.0(0.0)	1.2(1.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.8(0.7)	1.3(1.4)	0.0(0.3)	0.1(0.3)	1.2(0.9)	0.7(0.8)	0.0(0.7)	0.0(0.1)	0.3(1.0)	2.6(1.4)	0.0(0.5)	0.0(0.0)	0.0(0.0)
		Bessette	0.0(0.0)	0.0(0.0)	3.1(1.9)	0.0(0.0)	0.0(0.0)	0.0(0.9)	0.0(0.2)	0.0(0.2)	0.0(0.2)	0.0(0.6)	0.0(0.7)	0.0(0.8)	0.3(1.7)	0.0(0.6)	0.0(0.9)	1.4(1.4)	0.0(0.4)	0.0(0.0)	0.0(0.0)
		Salmon-SA	0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.0)	4.2(3.3)	0.0(0.1)	1.5(1.4)	0.0(0.6)	0.0(0.5)	0.0(0.4)	0.0(0.6)	0.0(0.7)	0.0(1.4)	1.9(1.7)	0.0(0.3)	0.0(0.6)	0.0(0.0)	0.0(0.0)
		Eagle	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.9(0.9)	0.4(0.6)	0.0(0.0)	0.0(0.3)	0.0(0.4)	0.0(0.1)	0.0(0.5)	0.4(1.0)	0.0(0.0)	0.0(0.3)	0.0(0.0)
		Duteau	0.0(2.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.9)	0.0(0.0)	0.0(0.0)	0.0(0.4)	1.5(1.2)	1.7(0.9)	3.1(1.3)	0.0(0.1)	0.0(0.0)	1.1(1.1)	0.0(0.8)	0.0(0.8)	0.0(0.5)	0.0(0.0)	0.0(0.0)
LWTH	Lower	Bonaparte	0.0(0.0)	4.5(4.1)	0.0(0.9)	0.0(0.2)	4.2(3.6)	7.1(5.7)	1.9(1.2)	6.0(4.6)	0.0(0.6)	2.1(1.3)	0.0(0.4)	0.0(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.9)
		Coldwater	0.0(1.4)	6.9(5.0)	10.8(6.3)	0.0(3.5)	0.0(0.5)	0.0(3.7)	0.0(0.2)	0.6(1.8)	0.3(1.3)	0.0(0.1)	0.8(1.4)	3.7(2.1)	0.0(0.0)	0.0(0.5)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Coldwater-Upper	5.1(3.9)	0.0(2.7)	0.7(2.8)	18.0(8.4)	0.0(0.0)	0.0(3.8)	0.0(0.0)	0.0(1.1)	0.0(1.5)	0.0(0.2)	0.0(0.6)	0.0(0.4)	0.0(0.0)	0.8(0.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.3)	0.0(0.0)
		Deadman	0.0(1.6)	2.8(3.3)	5.4(3.6)	4.0(5.9)	3.8(4.3)	2.9(6.3)	0.0(1.4)	5.0(3.4)	0.0(0.6)	0.6(1.1)	0.0(0.6)	0.8(0.9)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.3)	0.0(0.0)	0.0(0.0)
		Louis	5.1(4.8)	0.0(0.0)	0.0(0.0)	7.6(6.5)	0.0(0.6)	5.9(5.8)	0.0(0.0)	0.0(1.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Nicola	0.0(0.0)	2.6(5.5)	0.1(4.9)	0.1(5.1)	0.0(0.1)	12.9(9.5)	3.4(1.9)	11.5(4.2)	4.6(2.6)	5.2(2.0)	2.0(1.5)	1.0(1.4)	0.0(0.1)	0.0(0.5)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Spius	0.0(0.0)	4.7(3.7)	0.0(1.2)	0.0(3.0)	0.0(0.9)	7.5(7.1)	0.0(0.4)	0.0(1.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.1(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Spius-Upper	0.0(0.0)	0.0(1.7)	0.0(0.5)	0.0(0.8)	0.0(0.0)	0.0(3.7)	0.0(0.0)	0.0(0.2)	0.0(0.1)	0.0(0.0)	0.0(0.1)	0.0(0.4)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)
LWFR Spring Reds	Lower	Birkenhead	25.0(10.7)	14.3(6.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.5)	0.0(0.1)	0.0(0.0)	0.0(0.0)
LWFR Summer Reds	Lower	Maria_Slough	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	1.4(0.9)	0.0(0.0)	1.3(1.2)	0.4(0.6)	1.2(1.0)	1.0(0.9)	0.0(0.0)	0.0(0.0)	0.0(0.0)
LWFR Fall Whites	Higher	Chilliwack	0.0(3.1)	0.0(0.0)	0.0(0.0)	0.0(1.5)	0.0(0.0)	0.0(0.5)	0.0(0.0)	0.0(0.0)	0.0(0.3)	0.0(0.1)	0.0(0.6)	0.0(0.3)	2.6(1.9)	0.8(0.9)	0.0(0.8)	4.1(2.3)	17.8(8.3)	15.1(8.5)	14.7(11.2)
		Harrison	0.0(1.3)	0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.5)	0.0(0.4)	0.0(0.7)	0.0(0.0)	0.0(1.5)	1.4(1.1)	6.2(3.9)	1.1(3.3)	19.9(9.2)	46.9(9.0)	53.3(13.6)
		Stave	0.0(2.5)	0.0(0.0)	0.0(0.0)	3.2(2.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.7(0.7)	0.0(0.0)	1.2(1.0)	0.9(1.0)	0.0(1.2)	0.0(0.2)	1.3(3.0)	6.4(3.7)	31.5(9.3)	35.0(9.1)	29.6(11.2)

Appendix 2 continued

			2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001
Provisional ESU	Prdductivity		8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	multi-panel	8 inch	Multi-panel	8 inch	multi-panel	8 inch	Multi-panel	8 inch	8 inch
			April	April	May	May	June1-15	June1-15	June16-30	June16-30	July1-15	July1-15	July16-31	July16-31	Aug1-15	Aug1-15	Aug16-31	Aug16-31	Sep1-15	Sep16-30
		N	No samples	53	45	64	133	71	204	254	158	194	233	153	222	243	191	181	162	69
UPFR/MDFR/NOTH	Higher	Stuart		0.0(0.2)	0.0(0.0)	0.0(3.1)	0.0(0.7)	0.0(1.5)	0.2(1.8)	2.4(2.0)	2.4(3.1)	4.6(2.9)	6.8(3.4)	11.5(4.9)	1.7(1.6)	2.9(1.8)	0.0(0.3)	1.2(1.7)	0.1(0.6)	0.0(1.3)
		Nechako		0.0(4.0)	0.0(0.6)	4.4(4.6)	0.1(1.5)	0.0(2.4)	5.2(2.7)	4.7(2.0)	5.9(3.2)	0.0(1.4)	9.9(4.0)	5.8(5.9)	0.9(1.6)	2.0(1.8)	0.6(0.9)	0.0(0.4)	0.1(0.8)	0.0(1.1)
		Chilko		0.0(0.0)	0.0(0.0)	0.0(0.0)	1.6(1.4)	2.3(1.8)	9.8(2.6)	4.4(1.4)	15.3(3.4)	8.7(2.0)	9.1(2.4)	9.4(3.1)	0.9(1.0)	3.1(1.3)	1.1(0.7)	0.0(0.2)	0.3(0.6)	0.0(0.0)
		Quesnel		0.0(2.3)	0.0(3.0)	0.0(2.2)	0.0(0.2)	0.0(2.8)	0.1(1.7)	0.0(0.3)	0.0(1.7)	1.5(2.4)	6.5(2.9)	1.4(2.8)	1.4(1.7)	4.0(1.6)	0.5(0.9)	2.7(1.4)	1.5(1.0)	0.0(0.0)
		Taseko		0.0(0.4)	0.0(1.1)	0.0(0.0)	0.7(0.9)	0.0(0.0)	0.0(0.6)	0.0(0.4)	0.7(0.7)	0.2(1.0)	0.6(1.2)	0.4(0.9)	0.0(0.2)	0.0(0.1)	0.0(0.1)	0.0(0.4)	0.0(0.0)	0.0(0.0)
		Portage		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.1)	0.4(0.4)	0.0(0.1)	0.0(0.0)
		Clearwater		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	2.2(2.2)	1.1(0.9)	1.5(0.8)	4.8(2.1)	2.4(1.9)	6.6(2.1)	4.9(2.7)	2.1(1.6)	5.3(1.7)	0.0(0.2)	0.0(0.2)	0.0(0.2)	0.0(0.0)
		North Thompson		0.0(0.3)	0.0(1.3)	0.0(0.6)	0.0(0.6)	0.0(1.3)	2.0(1.3)	0.0(0.6)	1.3(1.8)	3.4(2.2)	6.3(2.6)	0.5(2.2)	6.3(1.9)	5.4(2.0)	1.6(1.2)	0.7(0.8)	0.0(0.1)	0.0(0.0)
		Fraser-TeteJaune		0.0(0.0)	2.6(2.5)	0.0(0.2)	1.4(2.4)	5.0(3.3)	9.8(3.1)	3.5(1.7)	7.9(2.5)	7.4(2.3)	1.6(0.9)	2.0(1.5)	0.0(0.3)	0.9(0.6)	0.0(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Fontoniko		0.0(0.0)	1.6(2.7)	0.0(0.3)	6.0(2.8)	1.4(2.1)	0.1(0.8)	2.1(1.0)	2.0(1.2)	0.5(0.9)	0.0(0.1)	0.0(0.4)	0.0(0.2)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Dome		0.0(0.3)	7.1(5.3)	7.6(6.2)	0.0(0.6)	0.0(2.8)	2.1(1.5)	2.5(2.1)	1.5(1.5)	0.0(0.1)	1.8(1.1)	2.4(2.1)	0.0(0.0)	0.0(0.0)	0.0(0.3)	0.0(0.2)	0.0(0.0)	0.0(0.0)
		Slim		0.0(0.3)	0.0(2.6)	0.0(2.8)	5.7(5.2)	0.8(5.9)	6.5(3.5)	3.9(2.4)	4.6(2.8)	1.4(2.7)	1.7(1.2)	0.4(2.4)	0.0(0.1)	0.0(0.1)	0.0(0.2)	0.0(0.2)	0.0(0.1)	0.0(0.1)
		Walker		0.0(0.2)	0.0(0.4)	1.1(1.4)	0.0(0.7)	0.0(1.3)	0.0(0.4)	1.9(0.9)	2.8(1.5)	0.3(0.5)	0.0(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Swift		0.0(0.6)	3.0(3.1)	0.0(1.2)	2.1(1.7)	0.0(1.3)	2.7(1.9)	0.8(0.6)	0.0(0.3)	1.5(1.2)	0.0(0.3)	0.0(0.4)	0.0(0.0)	0.2(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Goat		0.0(0.8)	1.3(2.7)	0.0(2.6)	0.0(2.7)	0.0(1.5)	0.2(1.3)	5.1(2.2)	0.0(1.3)	0.0(0.2)	0.0(0.2)	1.3(1.1)	0.0(0.2)	0.0(0.2)	0.0(0.0)	0.7(0.7)	0.0(0.0)	0.0(0.0)
		Bowron		0.0(1.3)	0.5(3.0)	0.0(0.3)	0.0(2.2)	0.9(2.2)	0.0(1.5)	1.4(1.7)	3.7(2.8)	3.2(2.0)	0.0(0.4)	0.0(1.6)	0.0(0.0)	0.0(0.2)	0.0(0.2)	0.0(0.6)	0.0(0.1)	0.0(0.0)
		Torpy		0.0(0.2)	3.7(4.4)	15.9(7.3)	25.3(6.7)	15.2(6.9)	9.1(4.2)	3.5(4.1)	4.0(3.6)	2.9(3.8)	1.9(1.5)	0.0(1.0)	0.4(0.4)	0.0(0.0)	0.0(0.2)	0.0(0.2)	0.0(0.4)	0.0(0.0)
		Indianpoint		0.0(0.2)	0.0(2.5)	0.0(0.8)	5.4(2.3)	0.0(1.3)	0.0(0.9)	1.9(1.4)	1.4(0.8)	0.8(1.3)	0.0(0.5)	5.0(2.0)	0.0(0.1)	0.0(0.3)	0.0(0.1)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Holmes		0.0(1.3)	5.4(5.1)	4.1(3.8)	2.7(4.0)	1.2(3.6)	0.0(1.2)	1.8(1.6)	0.0(1.3)	4.5(2.8)	0.0(0.4)	0.0(1.3)	0.0(0.1)	0.0(0.2)	0.0(0.2)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Morkill		0.0(0.1)	0.0(4.5)	2.3(3.8)	7.2(5.9)	7.3(5.7)	9.6(3.8)	9.3(3.2)	1.2(3.1)	8.1(4.0)	1.4(1.2)	2.8(3.0)	0.0(0.6)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		MacGregor		0.0(0.0)	8.1(5.6)	0.0(2.5)	1.7(4.9)	0.0(1.0)	6.3(3.0)	6.4(2.7)	0.0(2.4)	2.4(2.4)	0.0(0.1)	0.0(0.5)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Westroad		1.8(1.5)	0.0(0.5)	1.8(1.1)	0.0(0.3)	0.0(0.8)	0.0(0.5)	0.0(0.2)	0.0(0.2)	0.9(0.9)	0.0(0.4)	0.0(0.3)	0.0(0.1)	0.4(0.3)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)
		Willow		0.0(0.1)	5.4(4.5)	0.0(1.9)	1.8(1.6)	6.8(3.7)	0.0(0.6)	0.8(1.0)	1.5(1.2)	0.0(1.1)	0.0(0.5)	0.0(0.0)	0.4(0.4)	0.0(0.1)	0.0(0.0)	0.8(1.1)	0.0(0.0)	0.0(0.0)
		Salmon-PG		1.7(2.6)	4.8(4.9)	6.3(3.3)	1.2(1.9)	0.7(2.7)	2.8(2.1)	2.9(1.9)	0.0(0.0)	0.0(0.6)	0.0(0.5)	0.0(0.6)	0.0(0.3)	0.0(0.4)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Cariboo-Upper		3.1(3.2)	9.5(6.0)	1.7(2.1)	2.1(3.3)	6.3(4.5)	3.5(2.7)	4.3(2.2)	4.5(3.0)	3.2(2.0)	1.6(1.4)	0.3(2.0)	0.8(0.8)	0.3(0.5)	0.6(0.7)	0.0(0.5)	0.0(0.2)	0.0(0.0)
		Chilako		14.14.5)	3.6(2.7)	0.2(1.7)	2.5(1.4)	7.0(2.6)	0.2(0.5)	0.0(0.5)	0.0(0.4)	0.0(0.6)	0.0(0.5)	1.0(0.7)	0.0(0.1)	0.0(0.2)	0.0(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Chilcotin-Lower		3.6(4.5)	4.4(4.8)	2.4(2.7)	8.9(3.2)	14.0(6.0)	6.2(2.6)	4.4(2.0)	3.3(2.4)	3.2(1.9)	1.6(1.7)	2.7(2.3)	1.3(1.1)	1.2(1.4)	0.0(0.1)	0.0(0.3)	0.9(0.9)	0.0(0.0)
		Chilcotin-Upper		12.4(5.9)	8.1(4.9)	19.7(5.1)	0.0(1.5)	0.0(2.4)	0.0(0.4)	0.5(0.7)	0.0(0.3)	2.2(1.6)	1.4(1.0)	0.0(1.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Cottonwood		2.0(2.6)	3.3(2.7)	3.4(2.5)	0.2(0.9)	1.4(1.6)	0.0(0.2)	0.0(0.4)	0.0(0.1)	0.0(0.6)	0.3(0.5)	0.0(0.5)	0.0(0.1)	0.0(0.1)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Horsefly		0.0(1.2)	0.0(0.9)	0.0(0.6)	1.6(1.3)	0.0(1.0)	0.0(0.2)	0.6(0.5)	0.0(0.3)	1.8(0.9)	0.0(0.2)	0.0(0.5)	0.0(0.2)	0.0(0.1)	0.0(0.0)	0.0(0.3)	0.0(0.3)	0.0(0.0)
		Bridge		0.0(0.5)	3.7(3.4)	0.5(1.6)	0.0(1.1)	0.0(0.9)	1.8(1.6)	1.5(1.5)	0.0(1.4)	1.6(1.9)	1.0(1.8)	0.0(1.0)	0.0(0.3)	0.0(0.4)	0.0(0.9)	0.0(0.3)	0.0(0.2)	0.0(0.0)
		Elkin		0.0(1.6)	0.1(2.7)	0.1(1.4)	1.0(1.4)	0.3(3.1)	0.0(0.9)	0.0(0.6)	5.8(2.3)	2.7(1.5)	0.0(0.5)	0.0(0.9)	0.0(0.3)	0.0(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Endako		0.0(2.0)	0.0(0.5)	0.0(0.0)	0.3(1.3)	2.9(4.0)	0.0(0.5)	0.0(0.4)	0.0(0.0)	0.0(0.4)	2.4(1.2)	2.1(1.5)	0.0(0.2)	0.0(0.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Finn		0.0(0.0)	0.0(0.0)	0.0(0.6)	0.4(0.6)	1.4(1.8)	1.2(1.0)	1.8(0.8)	2.2(1.7)	2.7(1.2)	1.6(1.1)	3.5(2.0)	0.0(0.2)	0.8(0.7)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.0)
		Barriere		0.0(0.0)	0.0(0.6)	0.0(0.1)	0.0(0.1)	2.6(1.5)	0.0(0.8)	0.0(0.1)	3.0(1.6)	0.0(0.6)	3.6(1.3)	2.7(1.4)	0.2(0.6)	0.0(1.0)	0.0(0.1)	0.0(0.2)	0.1(0.4)	0.0(0.0)
		Raft		0.8(1.7)	0.0(2.5)	0.4(1.1)	0.0(0.5)	0.0(1.5)	0.5(0.9)	1.4(1.0)	1.6(1.9)	2.2(1.9)	0.2(1.8)	9.3(3.0)	1.3(1.3)	2.5(2.0)	0.0(0.4)	1.1(1.1)	0.0(0.5)	0.0(0.0)
		Horsey		0.0(0.5)	0.0(0.0)	0.0(0.2)	0.0(0.2)	0.0(0.3)	0.0(0.1)	0.0(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.3)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
SOTH	Higher	Thompson-Lower		0.0(0.0)	2.2(1.8)	0.0(0.3)	0.0(0.2)	0.0(0.2)	0.0(0.6)	0.0(0.1)	0.0(1.2)	0.0(0.4)	5.4(2.1)	3.8(2.5)	9.1(3.6)	7.5(3.3)	26.3(5.0)	18.6(5.3)	11.0(3.8)	4.8(2.7)
		South Thompson		0.0(0.0)	0.0(1.8)	0.0(0.0)	0.0(0.2)	0.0(0.2)	0.0(0.0)	0.0(0.3)	0.0(1.4)	0.0(0.7)	3.2(2.7)	0.0(1.6)	30.7(6.3)	19.2(4.1)	41.9(6.9)	42.3(6.3)	8.1(3.6)	0.0(2.1)
		Little		0.0(0.0)	0.0(0.6)	0.0(0.0)	0.7(1.1)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.9(2.0)	0.0(0.7)	1.6(2.0)	1.6(1.7)	17.9(5.7)	16.5(3.7)	11.2(4.4)	14.8(5.0)	11.1(3.8)	2.0(1.7)
		Shuswap-Lower		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.5)	0.0(0.0)	0.6(1.0)	0.1(0.7)	6.1(2.7)	4.9(2.0)	10.9(3.3)	6.5(3.1)	10.0(3.4)	14.4(3.4)	1.8(2.2)	3.1(1.9)	0.0(0.2)	0.0(0.5)
		Shuswap-Mid		0.0(0.0)	0.0(1.1)	0.0(0.0)	2.6(1.6)	0.0(0.0)	3.9(1.5)	5.7(1.6)	2.5(2.9)	7.7(2.8)	2.7(2.0)	9.3(3.0)	0.5(2.0)	4.8(2.8)	0.0(0.8)	0.3(2.4)	0.0(0.9)	0.0(0.0)
		Adams-Lower		0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.1)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.8(1.3)	0.8(0.9)	0.9(1.2)	2.7(2.6)	8.0(3.8)	4.2(3.3)	8.3(4.6)	2.4(4.4)	3.8(2.6)	0.0(0.7)
	Lower	Adams-Upper		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.4)	0.0(0.0)	0.0(0.3)	0.5(0.3)	2.7(1.2)	0.8(0.5)	0.0(0.3)	0.9(1.2)	1.9(0.7)	1.1(0.6)	1.7(0.8)	1.1(0.8)	0.0(0.2)	0.0(0.0)
		Bessette		0.0(0.0)	0.0(0.0)	0.0(0.0)	1.2(0.8)	0.0(0.0)	0.0(0.3)	0.0(0.4)	0.0(0.1)	0.0(0.0)	0.8(0.6)	0.0(0.6)	1.6(0.7)	0.0(0.3)	0.3(0.5)	0.4(0.8)	0.0(0.2)	0.0(0.0)
		Salmon-SA		0.0(0.0)	2.6(2.1)	0.0(0.0)	0.6(0.9)	0.0(0.2)	0.8(1.0)	1.8(1.4)	0.8(0.7)	1.4(0.9)	0.9(0.7)	0.0(0.6)	0.0(0.5)	0.0(0.4)	0.0(0.5)	0.4(0.5)	0.0(0.0)	0.0(0.0)
		Eagle		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.8(0.7)	0.0(0.0)	2.2(1.0)	1.1(0.7)	0.7(0.6)	0.0(0.0)	0.0(0.3)	0.0(0.1)	0.0(0.2)	1.5(0.9)	0.0(0.1)	0.0(0.5)	0.0(0.0)	0.0(0.0)
		Duteau		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.5)	0.0(0.0)	0.0(0.3)	0.2(0.4)	0.4(1.3)	1.0(0.7)	1.7(1.0)	0.0(0.5)	0.8(0.6)	0.7(0.6)	0.2(0.3)	1.4(0.9)	0.6(0.5)	0.0(0.1)
		Bonaparte		7.4(5.2)	0.0(1.8)	4.7(3.1)	1.9(1.4)	4.4(3.4)	2.1(1.4)	2.6(1.6)	1.2(1.0)	0.0(0.5)	0.8(0.8)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)
		Coldwater		10.1(8.2)	4.0(4.7)	6.9(5.9)	3.9(2.7)	0.0(2.3)	1.8(1.8)	0.3(1.6)	1.2(1.0)	0.0(0.0)	0.5(0.8)	0.7(1.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Coldwater-Upper		9.06.2)	0.0(0.3)	9.0(5.1)	3.8(2.0)	0.0(0.6)	0.6(0.6)	0.3(0.7)	0.3(0.7)	1.1(1.3)	0.2(0.4)	0.1(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Deadman		8.9(4.7)	0.0(0.4)	0.0(1.4)	2.9(2.0)	8.3(5.4)	2.8(1.5)	1.9(1.5)	0.1(0.7)	1.3(1.1)	1.1(0.8)	0.4(0.5)	0.0(0.0)	0.0(0.1)	0.0(0.4)	0.3(0.4)	0.0(0.0)	0.0(0.0)
		Louis		3.6(2.9)	0.0(0.0)	1.7(1.9)	0.8(0.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.7(0.7)	0.0(0.0)	0.0(0.2)	0.5(0.7)	0.0(0.0)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Nicola		0.0(3.6)	15.3(6.2)	4.0(5.7)	0.0(1.5)	7.2(4.2)	4.2(2.2)	9.4(2.0)	0.4(0.9)	3.9(2.3)	0.0(0.6)	0.5(1.1)	0.0(0.1)	0.0(0.3)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Spius		2.6(2.6)	0.0(0.0)	0.5(1.6)	0.0(0.0)	0.0(0.2)	0.0(0.3)	0.0(0.4)	0.1(0.8)	1.9(1.0)	0.0(0.3)	2.6(1.4)	0.0(0.0)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)
		Spius-Upper		0.0(0.8)	0.0(1.0)	0.0(0.6)	0.0(0.0)	0.4(1.1)	0.2(0.3)	0.7(0.8)	0.0(0.0)	1.1(0.8)	0.0(0.3)	0.0(0.2)	0.4(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
LWFR Spring Reds	Lower	Birkenhead		18.9(5.2)	0.0(0.0)	1.6(1.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
LWFR Summer Reds	Lower	Maria Slough		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.8(0.6)	0.0(0.0)	0.0(0.1)	0.3(0.3)	0.0(0.1)	0.5(0.7)	0.0(0.3)	0.0(0.0)
LWFR Fall Whites	Higher	Chilliwack		0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.1)	1.1(0.7)	0.0(0.7)	1.5(1.0)	0.5(0.6)	0.7(0.8)	3.8(1.9)	24.6(5.6)	30.2(9.4)
		Harrison		0.0(0.3)	0.0(0.0)	0.0(0.0)	0.8(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.1)	0.0(0.0)	0.0(0.1)	0.0(0.4)	0.0(0.2)	0.0(0.5)	0.3(0.6)	2.5(1.5)	2.1(1.8)	24.6(5.7)	29.7(10.7)
		Stave		0.0(0.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.2)	0.0(0.0)	0.0(0.2)	0.9(0.7)	0.1(0.7)	0.0(0.6)	1.0(1.1)	1.0(1.2)	13.04.2)	33.3(12.3)

Appendix 3. Alternate hierarchical groupings of Fraser chinook populations.

Hierarchical groupings of Fraser chinook populations can be developed by re-ordering the criteria tiers or by relying on different criteria. For examples, we provide one alternate hierarchical grouping based on re-ordering of the criteria tiers and two groupings based on different productivity criteria.

Example 1 (Appendix Figure 3a).

This hierarchical grouping is based on the same criteria used in Fig. 5.5 described in the main body of this report except that we have considered the criteria in a different sequence.

Example 2 (Appendix Figure 3b)

Here we use juvenile life history and age information (Appendix 1) to identify populations of relatively similar productivity.

Example 3 (Appendix Figure 3c)

In the context of productivity, trends in spawning escapement may identify populations of relatively more similar productivity. However, factors other than productivity could influence spawning escapements and their trends. For example, different escapement methods may have been used in various portions of the watershed and over time. Also, spatial and temporal variations in terminal fisheries management and exploitation can result in non-correlated escapement trends among spawning systems. Furthermore, anthropogenic effects such as hatchery supplementation, habitat enhancement, and habitat deterioration can result in spatial and temporal variation.

To assess whether chinook spawning escapements varied in a consistent manner among spawning systems within a provisional ESU, common factor analysis of the escapement estimates was used for the period 1975-2001. Correlations among escapement time series' and the factor scores provide an estimate of the degree to which the variation in survival and productivity of a particular spawning system is similar to the common source of variability estimated for all spawning systems (Bradford 1994). Common factor analysis weights each spawning system by its relative variability such that factor scores were not necessarily dominated by spawning systems with large escapements. The first factor from the analysis described the major trend common to all spawning systems, and scores from the first factor were used as an index of abundance for the aggregate. Spawning systems were categorized according to the correlation of their escapement time series with the provisional ESU's index of abundance (Appendix Table 3).

We used the escapement estimates in the chinook escapement database maintained by BC Interior, DFO, Kamloops. For some spawning systems the escapement time series was log transformed to achieve univariate normality and improve the overall multivariate normality of the data set. Some rivers and years of data were excluded because of missing values, which are identified in Appendix Figure 3c. The lower Fraser summer reds and spring reds provisional

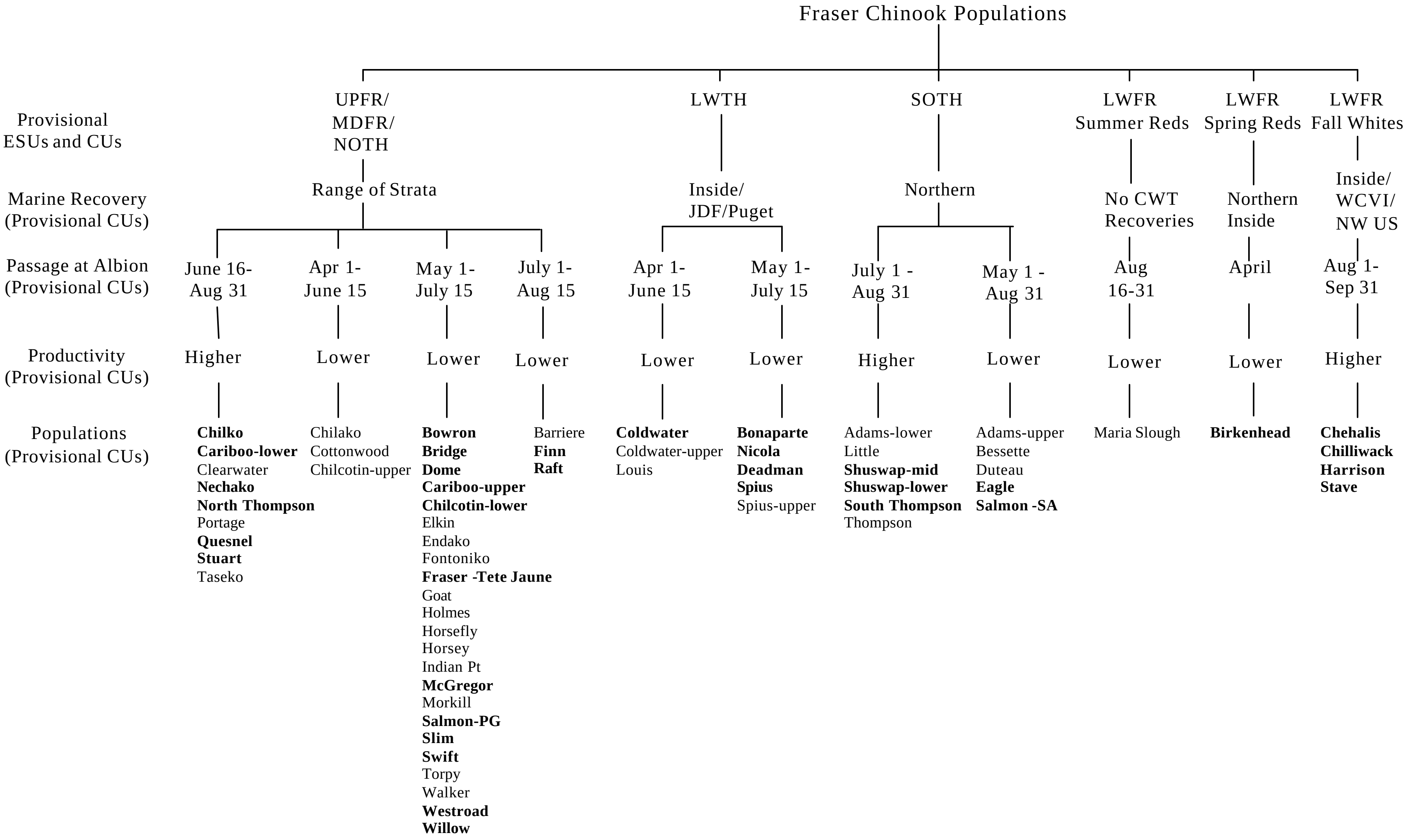
ESUs were excluded from the analysis because each consisted of a single spawning system. Also, the lower Fraser fall whites were excluded because the time series of escapement estimates was too short.

Inferences about the relative productivity of populations partitioned several of the provisional ESUs into subgroups (Appendix Figure 3c) based on their association with the provisional ESU's abundance index (Appendix Figure 3d). The upper-mid Fraser/North Thompson was partitioned into five groups based on 27 years of escapement data. The lower Thompson provisional ESU was partitioned into four groups whereas the south Thompson provisional ESU was partitioned into three groups based on 25 and 23 years of escapement data, respectively.

Appendix Table 3. Categories used to describe the association of each spawning system's escapement trend with provisional ESU's index of abundance (first factor) based on the rules suggested by Tabachnik and Fidell (1996).

Category	Percentage of overlapping variance with the abundance index	Association with the abundance index
Type 1	$\geq$ 50%	Excellent
Type 2	40 - 49%	Very good
Type 3	30 - 39%	Good
TYPE 4	20 - 29%	Fair
TYPE 5	10 - 19%	Poor
TYPE 6	< 10%	Very poor

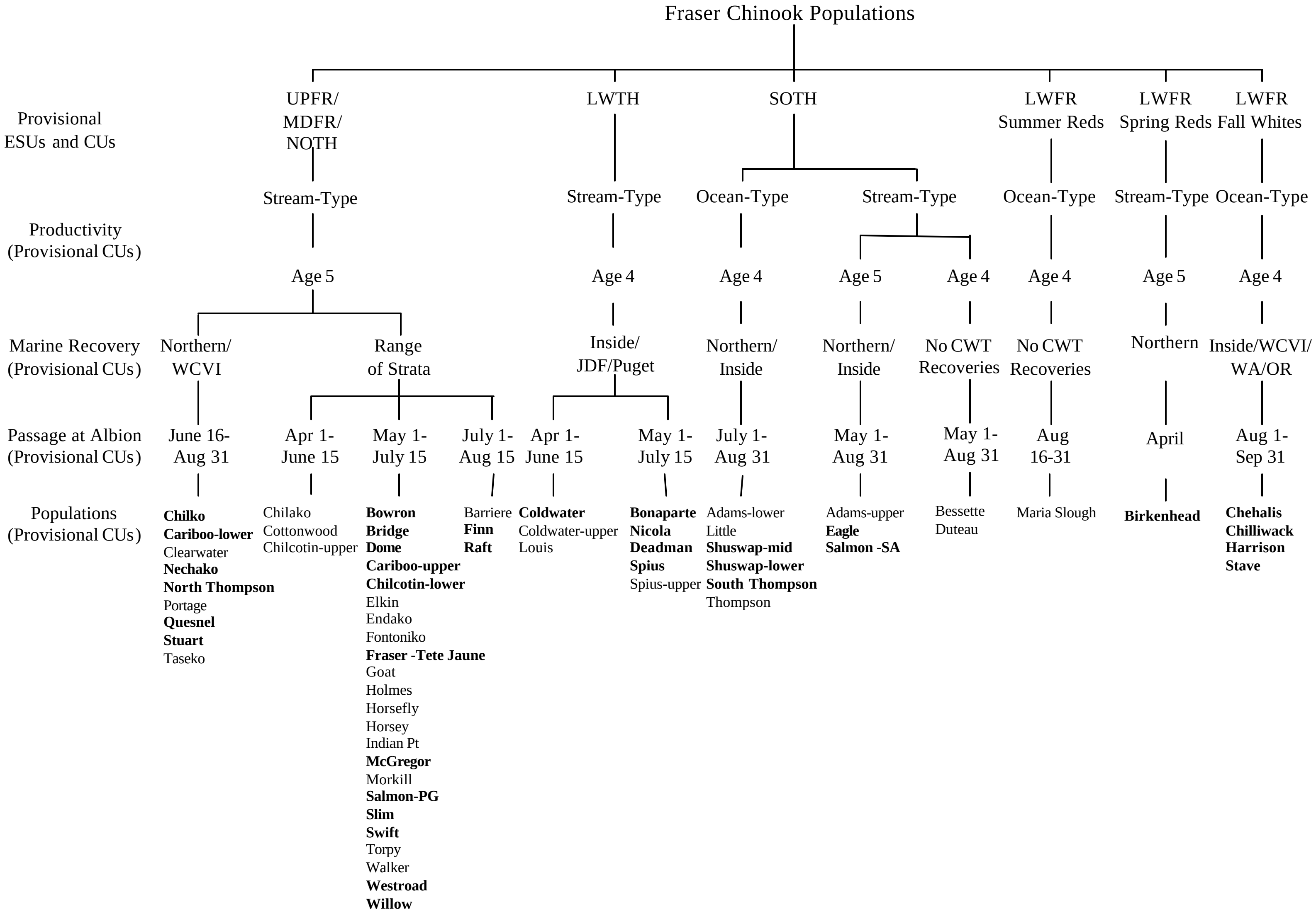
Appendix Figure 3a. Alternate hierarchical groupings of Fraser chinook populations based on genetic structure, marine recovery patterns, life history characteristics, and lower river run timing.



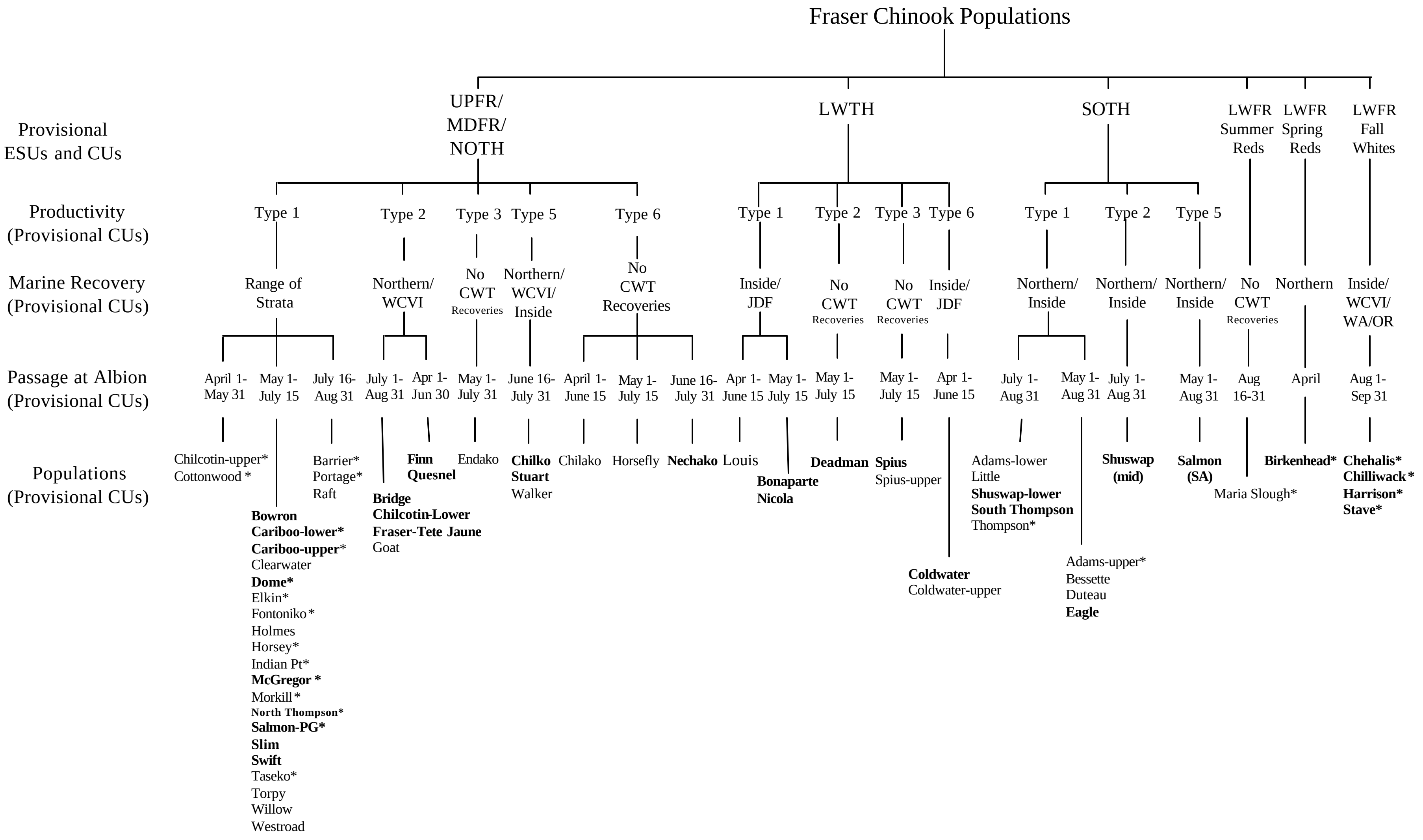
Fraser Chinook Populations

Provisional ESUs and CUs	Marine Recovery (Provisional CUs)	Passage at Albion (Provisional CUs)	Productivity (Provisional CUs)	Populations (Provisional CUs)
UPFR/ MDFR/ NOTH	Range of Strata	June 16-Aug 31	Higher	**Chilko** **Cariboo-lower** Clearwater **Nechako** **North Thompson** Portage **Quesnel** **Stuart** Taseko
		Apr 1-June 15	Lower	Chilako Cottonwood Chilcotin-upper
		May 1-July 15	Lower	**Bowron** **Bridge** **Dome** **Cariboo-upper** **Chilcotin-lower** Elkin Endako Fontoniko **Fraser -Tete Jaune** Goat Holmes Horsefly Horsey Indian Pt **McGregor** Morkill **Salmon-PG** **Slim** **Swift** Torpy Walker **Westroad** **Willow**
		July 1-Aug 15	Lower	Barriere **Finn** **Raft**
LWTH	Inside/ JDF/Puget	Apr 1-June 15	Lower	**Coldwater** Coldwater-upper Louis
		May 1-July 15	Lower	**Bonaparte** **Nicola** **Deadman** **Spius** Spius-upper
SOTH	Northern	July 1 - Aug 31	Higher	Adams-lower Little **Shuswap-mid** **Shuswap-lower** **South Thompson** Thompson
		May 1 - Aug 31	Lower	Adams-upper Bessette Duteau **Eagle** **Salmon -SA**
LWFR Summer Reds	No CWT Recoveries	Aug 16-31	Lower	Maria Slough
LWFR Spring Reds	Northern Inside	April	Lower	**Birkenhead**
LWFR Fall Whites	Inside/ WCVI/ NW US	Aug 1-Sep 31	Higher	**Chehalis** **Chilliwack** **Harrison** **Stave**

Appendix Figure 3b. Alternate hierarchical groupings of Fraser chinook populations based on juvenile life history and age structure instead of lake moderating influence as a surrogate for productivity.



Appendix Figure 3c. Alternate hierarchical groupings of Fraser chinook populations based on trends in spawning escapements instead of lake moderating influence as a surrogate for productivity. An * indicates systems excluded from the escapement trend analysis due to sample size requirements.



Appendix Figure 3d. Abundance indices for upper-mid Fraser/North Thompson, lower Thompson, and south Thompson provisional ESUs.