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Status of Birkenhead River Chinook salmon (*Oncorhynchus tshawytscha*)

État du saumon quinnat de la rivière Birkenhead *(Oncorhynchus tshawytscha)*

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* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

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ABSTRACT

Birkenhead River Chinook (*Oncorhynchus tshawytscha*) is a Fraser spring run population that spawns in a tributary of the Harrison-Lillooet River system in southwestern BC. It is a genetically isolated population that possesses local adaptations (*e.g.,* far north marine distribution and very early spawner migration) that are an important component of the evolutionary legacy of the species.

Population status is assessed by evaluating spawner abundance and trends relative to potential benchmarks, fishery harvest and potential limiting factors and threats. This required the reconstruction of escapement and terminal fishery catch estimates based on a reevaluation of historic data and the inclusion of recent data. The spawner population has been trendless over a thirty year period when both enhancement was attempted and conservation actions were applied to the fisheries. The spawner population averaged 480, with an effective population size of about 300; both are below literature estimates for viable, genetically isolated populations. Potential benchmarks are discussed, with the lowest ($\hat{S}_{msy}$ = 1,700) over triple current abundances, suggesting that considerable population growth is required.

Small populations are especially vulnerable to threats such as those posed by fishery exploitation, climate change and habitat alteration. The Birkenhead has been harvested at about 50%, with three fisheries predominant: Alaska troll and the First Nations fisheries in the lower Fraser and Lillooet System. The impacts of climate change are already apparent in freshwater and are expected to increase in future decades, while the threat from habitat alteration, geomorphic processes and rapid human population growth remain significant. A comprehensive recovery plan is required.

RÉSUMÉ

Le saumon quinnat de la rivière Birkenhead (*Oncorhynchus tshawytscha*) est une population de remonte de printemps du Fraser qui fraye dans un tributaire du réseau Harrison-Lillooet, dans le sud-ouest de la C.-B. Il s'agit d'une population génétiquement isolée qui possède des caractéristiques d'adaptation locale (p. ex. une répartition marine vers le grand nord et une migration très hâtive des géniteurs) qui constituent une composante importante du patrimoine évolutif de l'espèce.

L'état de la population est déterminé par l'évaluation de l'abondance des géniteurs et des tendances relativement à des points de référence possibles, des résultats de la pêche, ainsi que de certains facteurs limitatifs et menaces possibles. Cette évaluation a nécessité la reconstitution de l'estimation de l'échappée et des captures de la pêche terminale à partir d'une réévaluation des données historiques et de l'inclusion de données récentes. La population de géniteurs a été stable pendant une période de trente ans, au cours de laquelle des activités de mise en valeur ont été tentées, tandis que des mesures de conservation étaient appliquées à la pêche. La population de géniteurs était en moyenne de 480, et la taille effective de la population, d'environ 300; ces deux totaux sont inférieurs aux estimations fournies dans la documentation pour des populations viables, génétiquement isolées. Les points de référence potentiels ont été examinés, le plus faible ($\hat{S}_{msy}$ = 1 700) de trois taux d'abondance actuels indiquant qu'il faudrait une croissance considérable de la population.

Les petites populations sont particulièrement vulnérables face aux menaces comme celles que posent la pêche, les changements climatiques et la modification de l'habitat. Le saumon de la Birkenhead a été exploité à environ 50 % dans le cadre de trois pêches particulièrement dominantes : la pêche aux lignes en Alaska et les pêches des Premières nations dans le bas-Fraser et le réseau de la Lillooet. Les conséquences des changements climatiques sont déjà manifestes en eau douce et devraient augmenter au cours des prochaines décennies, tandis que les menaces que représentent les modifications de l'habitat, les processus géomorphiques et la rapide croissance démographique demeurent importantes. Il faut un plan complet de rétablissement.

INTRODUCTION

Birkenhead Chinook salmon (*Oncorhynchus tshawytscha*) are one of a group of 64 Fraser River populations, termed the spring run, that migrate through the lower Fraser River before early July. The status of these populations has been a concern since the 1970s when declining returns to the river triggered the implementation of a suite of conservation measures in freshwater and marine fisheries. After almost three decades, many of these measures remain in place today.

The conservation plan for Birkenhead Chinook had enhancement and fishery management components. The feasibility of enhancement was explored in 1975-1976, and a pilot hatchery was established in 1977 (Berezay *et al.* 1988). The initial fishery reductions began in 1976, focusing on early season (January to June) fisheries in the lower Fraser River and the Harrison-Lillooet System: the Fraser River commercial gill net fishery opened a month later than normal, in late April, and was reduced from two to one day per week (and was completely eliminated in 1980); fishing time in the lower Fraser River First Nations fisheries was reduced from three to one day per week, and was closed until mid-March after 1992; the Lillooet System First Nations agreed to limit their harvest to 25 Chinook per year and, in 1986, fishing time before the June freshet was reduced from seven to one day per week; and the retention of Chinook adults in the freshwater recreational fisheries was not permitted until April 19 in the lower Fraser River (expanded to all year beginning in 1980), August 1 in the Harrison River and October 3 in the Lillooet System.

Conservation measures were extended to the marine fisheries with the 1985 signing of the Pacific Salmon Treaty (PST) between Canada and the United States. The Treaty objective was to halt the decline and restore the escapements of naturally spawning Chinook salmon to target levels by 1998. To achieve this objective, the Treaty established harvest ceilings in mixed stock ocean fisheries as well as harvest rate limits in more terminal fisheries to ensure that the fish that escape the former could pass through the latter and on to the spawning grounds (PSC 1987). An escapement goal for Fraser River spring run populations was established by policy as double the 1979-1982 average escapement. Because individual populations were not considered, a goal was not identified for Birkenhead Chinook.

In an evaluation of stock assessment information for selected Fraser River spring run Chinook populations (including Birkenhead), Bailey *et al.* (2001) concluded that, while the status of the populations was uncertain, there was weak evidence that escapements continued to decline. They noted that, while few Birkenhead Chinook are harvested in Canadian marine fisheries, they are present in significant numbers in Alaskan and early season freshwater fisheries. They cautioned that inadequate assessments limit our understanding of escapement trends and river fishery impacts and, consequently, the productive capacity of the populations. They recommended the completion of habitat-based capacity assessments for these Chinook populations.

This research document has been prepared in response to concerns expressed by the Lil'wat Nation regarding the Birkenhead Chinook population's apparent failure to recover despite almost 30 years of conservation actions (Jones 2004). Our objective was to describe the status of the population, considering its genetic character, abundance and habitats in the context of the Department's Wild Salmon Policy (DFO 2005). To do so, we updated and reinterpreted the 2001 assessment data (Bailey *et al.* 2001). Recognizing the limitations imposed by data availability and quality, we augmented the assessment with new data. We also reinterpreted the existing data by exploring assumptions (and their limitations) that would better permit the characterization of the population's status and productive potential.

We structured the research document in six general sections examining the: freshwater watersheds and watershed uses that may affect the population; life history of the species in general and Birkenhead Chinook in particular; abundance levels and trends on the spawning grounds and in the fisheries; history and effectiveness of enhancement; productivity and productive capacity of the population and its habitats; and limiting factors and threats to the population.

WATERSHED DESCRIPTION AND USE

LILLOOET RIVER SYSTEM

The Harrison-Lillooet System originates near the Lillooet Glacier south of Chilko Lake and flows southeast through a series of rivers and lakes before entering the Fraser River 102 km upstream from its estuary (Fig. 1). The system drains a mountainous and glaciated watershed of 7,900 km^2 that is located in the eastern part of the Coast Mountains in southwest British Columbia (BC). Its location at the border of the coast and interior geoclimatic zones results in heavy coastal rainfall as well as significant spring and summer snowmelt, producing an annual mean discharge (446 $m^3 \cdot sec^{-1}$) that is the second highest among the major Fraser drainage basins despite having the smallest drainage area (Northcote and Larkin 1989). In this section, we briefly describe the entire system to provide context for our assessment of a Chinook population that utilizes a broad range of freshwater habitats for rearing and migration. The Birkenhead River, one of the systems larger tributaries and the natal stream for the Chinook population, is described in the next section (see *Birkenhead River*).

The upper watershed is drained by the upper Lillooet and Birkenhead rivers, both of which flow into Lillooet Lake. The upper Lillooet River, with a mean daily discharge of 126 $m^3 \cdot sec^{-1}$, is about five times larger than the Birkenhead River (24 $m^3 \cdot sec^{-1}$) (Environment Canada 2006). It has a length of over 100 km and drains 3,150 km^2 of geologically active, glaciated, steep mountainous terrain; 16% of the watershed is covered by glaciers, and over 50% lies above the timberline. The hydrograph reflects a dominant summer snowmelt, with maximum and minimum mean daily discharges generally occurring in July (316 $m^3 \cdot sec^{-1}$) and February (30 $m^3 \cdot sec^{-1}$), respectively. Violent flow fluctuations occur in the fall and winter as a result of rainfall coupled with snowmelt at middle and low elevations. The watershed is geologically active due to the presence of the Mount Meager volcanic complex, located about 70 km northwest of Lillooet Lake (see *Limiting Factors and Threats*). The river is typically braided as it flows across a broad, terraced valley bottom bounded by steep bedrock slopes. There are two exceptions: in the 10 km above Meager Creek, the river flows in a single, confined channel cut through volcanic deposits; and in the lower 40 km, flood control structures confine it to a single channel flowing across flat agricultural land (see *Watershed Development*). The river carries a heavy sediment load from both glacial melt and sediment transport from Meagher Creek, the dominant coarse-sediment source in the system (Bovis and Jakob 2000). Its waters are turbid year-round, as are those of Lillooet Lake and the lower Lillooet River (Schaefer 1951).

With a length of 22 km and a surface area of 35 km^2, Lillooet Lake is small with mean and maximum depths of 62 m and 137 m, respectively (Shortreed *et al.* 2001; Desloges and Gilbert 1992). The lake is heavily influenced by the sediment-laden inflow water; it has a cool epilimnion (mean 12º C), a weak thermocline (39 m average depth) and a shallow euphotic zone (4.5 m). Phytoplankton productivity and biomass are high, especially considering the low water clarity. It supports a simple zooplankton community (*Leptodiaptomous* – 91%; *Epischura* – 7%) with a low average biomass (139 mg dry wt m^{-3}) that peaks in May, and a substantial population of sockeye (*O. nerka*) fry. Bailey *et al.* (1979) report a limnetic community that includes, in addition to Chinook and sockeye salmon fry, coho salmon (*O. kisutch*), kokanee (*O. nerka*), coastal cutthroat trout (*O. clarki clarki*), rainbow trout (*O. mykiss*), Dolly Varden char (*Salvelinus malma*), mountain whitefish (*Prosopium williamsoni*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), largescale sucker (*Catostomus macrocheilus*) and prickly sculpin (*C. asper*).

Lillooet Lake is drained by a short riverine channel before again widening into Tenas Lake, a small lake with a length of about 8 km. The lower Lillooet River then flows southeast for 55 km to Harrison Lake. The lower Lillooet Valley has steep side slopes and is narrow relative to the upper Lillooet, constraining the river to a single channel that is braided only in localized areas. Tributaries tend to flow directly into the river without any significant low gradient sections along the valley floor. The dominant feature is Skookumchuck Rapids, a constricted passage between bedrock walls located 31 km upstream from Harrison Lake (Schaefer 1951). While passable to salmon, it is a point of difficult passage and is a traditional fishing site of the In-SHUCK-ch people.

Harrison is by far the largest lake in the system, with a length of 58 km, a surface area of 220 km^2, and mean and maximum depths of 151 m and 270 m, respectively (Shortreed *et al.* 2001). While turbid river water enters the upper end of the lake, its limnological impact is less than in Lillooet Lake because the latter traps a significant proportion of the sediments (Gilbert 1973). It too has a cool epilimnion (mean 13º C) and a weak but shallower thermocline (21 m average depth); however, the clear water results in a much deeper euphotic zone of 11 m. The zooplankton community is diverse, including the copepods *Diacyclops, Leptodiaptomous and Epischura,* as well as some *Daphnia*; its biomass (572 mg dry wt m^{-3}) is higher than in Lillooet Lake, but is low relative to other Fraser lakes. The limnetic community is complex. Sockeye fry, pygmy longfin smelt (*Spirinchus thaleichthys*), threespine stickleback (*Gasterosteus aculeatus*) and mysids (*Neomysis relicta*) dominate the limnetic areas, while Chinook and coho fry, prickly sculpin (*Cottus asper*) and mountain whitefish are abundant in the littoral zone (Hume *et al.* 2000). Chinook and coho are most abundant (especially in June) in bedrock, rubble and mudflat habitats. Other species include those reported in Lillooet Lake as well as chum salmon (*O. keta*), white sturgeon (*Acipenser transmontanus*), redside shiner (*Richardsonius balteatus*) and goldfish (*Carassius auratus*). The few detectable contaminants in lake sediments reflect long range atmospheric transport, an observation consistent with the relatively undeveloped drainage basin (Macdonald and Paton 1998). The lake is drained by the Harrison River which flows southwest for 29 km before entering the Fraser River near the town of Harrison Hot Springs.

BIRKENHEAD RIVER

The Birkenhead River arises in the Coast Mountains and flows south for 60 km, entering the north end of Lillooet Lake near the communities of Mount Currie and Pemberton (Fig. 2). It is the largest tributary of the Lillooet River, draining a mountainous watershed of 596 km^2. The hydrograph reflects a dominant spring snow melt and fall and spring precipitation. Daily discharge averages 24 m^3s^{-1} with mean daily maxima (71 m^3s^{-1}) and minima (7 m^3s^{-1}) in June and March, respectively (Environment Canada 2006). While the hydrograph is similar to the Lillooet River, the Birkenhead has much less glacial influence and its waters are relatively clear for most of the year. The river flows for much of its length through a narrow valley bounded by steep mountains. Tributary streams enter from steep side valleys and generally flow directly into the main river. As a result, Chinook spawning habitat is largely confined to mainstem and side channel areas, to short seepage-fed flood plain tributaries and to the deltaic portions of larger tributaries. While the river is passable to adult Chinook salmon as far upstream as Taillefer Creek (34 km) and Birkenhead Lake, a 2 m elevation change in a bedrock canyon located 28 km upstream is passable only at certain water levels. Below the canyon, the river is characterized by long rapids and riffles, frequent deep pools and isolated braided areas in a 19 km section that is the main Chinook spawning area. It flows from the mountain valley onto the Lillooet River flood plain 8 km upstream from Lillooet Lake, then flows to the lake in a meandering, dyked channel that parallels the upper Lillooet River.

The fish community in the Birkenhead system, in addition to Chinook salmon, includes significant populations of sockeye and coho salmon as well as chum salmon, kokanee, rainbow and coastal cutthroat trout, Dolly Varden char, bull trout (*Salvelinus confluentus*), mountain whitefish, northern pikeminnow, large-scale sucker sculpin and lamprey (*Lampetra sp.*) (Johnson and Sutherland 2004). Limited sampling suggests that water quality is generally good. Because there are no permitted point sources discharging into the river, the principle concern is from non-point source pollution from activities such as forest harvesting and the limited agricultural and urban developments.

WATERSHED DEVELOPMENT

This section focuses on activities in the Lillooet and Birkenhead watersheds, an area where watershed uses are likely to have a direct impact on Birkenhead Chinook adults or juveniles. Both watersheds are isolated and have supported small human populations until comparatively recently. Settlements are scattered, with Pemberton and Mount Currie the principle population centres. Forestry and farming have been the predominant activities; the latter occurs in a 30 km section of the floodplain upstream from Lillooet Lake (Pemberton Meadows) and has had the largest impact on the fish resource. Urban development and tourism have recently become the dominant watershed uses and continued growth is expected. The following description draws heavily from the local resource management plan (Nicol and Sunderman 2005).

Human Settlements

The people of the Lil'wat and In-SHUCK-ch nations have occupied the Lillooet and Birkenhead valleys for centuries. The Lil'wat Nation, part of the St'atl'imx group, is centered in the Birkenhead watershed at the community of Mount Currie and includes a number of smaller reserves along Lillooet Lake and the upper Lillooet and Birkenhead rivers. It is a rapidly growing community with a population of about 1,800. Public administration and the resource sectors are the leading employers; the recently formed Land and Resources Department handles the Band's environmental assessment and development initiatives.

The In-SHUCK-ch Nation, closely related to the St'atl'imx, is centered along the lower Lillooet River in the communities of Douglas, Skatin (Skookumchuck) and Samahquam as well as a number of smaller reserves. The current population is about 1,000, with the largest community at Skatin. Like Mount Currie, public administration and the resource sectors are the leading employers.

The first substantial European presence in the watershed came with the fur trade and expanded in 1858-1863 when the valley was the principle route to the Cariboo gold fields. In the 1880's, settlement began near Pemberton with agriculture and forestry becoming the mainstay of the economy. In the last 25 years, it has been one of the fastest growing communities in Canada, increasing from 300 residents in 1981 to 2,200 in 2004. Economic change has accompanied population growth. Agriculture and forestry declined from 34% of the economy in 1981 to only 3% today, while tourism has increased to 57%. Population growth and tourism are expected to accelerate as the transportation infrastructure is improved in advance of the 2010 Winter Olympics and as affordable housing attracts residents who commute to the Whistler resort community.

The only settlement in the Birkenhead watershed other than Mount Currie is Birkenhead Lake Estates, a 100 lot subdivision on Birkenhead Lake and its outflow stream, Taillefer Creek.

Forestry

There is a long history of logging the Lillooet watershed, especially in valley bottom and other accessible areas. As a result, mature stands are limited to inaccessible sites while the valley bottom supports immature (< 40 years) timber. The annual cut has been reduced since the early 1990's, and recent harvests have been lower than allowable levels due to low demand and the location of stands in economically inaccessible areas. Timber rights were recently transferred to the Lil'wat and In-SHUCK-ch nations and the N'Quatqua (D'arcy) First Nation under the Forestry Revitalization Plan, a reallocation process intended to diversify the forest economy by engaging First Nations and other communities. Timber processing in the watersheds is limited to small facilities at Mount Currie and Pemberton (post and pole plant, log house construction). Future harvests are predicted to continue to decline due to public pressure to preserve the environmental attributes on which the emerging tourism and recreational sectors rely.

In the Birkenhead system, forest harvesting has been most intensive along the upper river and its tributaries, especially Tenquille Creek. A new road to the extreme upper reaches of Tenas Creek, constructed in 2000, provides access to undisturbed areas that were previously inaccessible by vehicle (Johnson and Sutherland 2004).

Agriculture

There is about 6,900 hectares of arable land in the Lillooet River watershed, mostly in a broad, flat bottomed section of the Lillooet River flood plain known as Pemberton Meadows. While best known for the production of seed potatoes, alfalfa, hay and cattle ranching are also common and there has been a recent diversification into vegetables and berries to supply the emerging local and Whistler markets. Seed potatoes, grown according to the measures of the BC *Seed Potato Act,* are certified virus and disease-free and command high prices in Canadian and export markets. Agriculture is expected to continue to play a role in the watershed in view of the protection conferred by the Indian reserves and the Agricultural Land Reserve. It has significantly impacted fish habitat as a result of flood control measures intended to reclaim and protect arable land on the low-lying and often swampy floodplain (see *Flood Control*). Further growth in the sector is not expected, however, due to competing land uses from the growing population as well as the protections conferred to the seed potato sector.

Agriculture in the Birkenhead watershed is limited to the lowlands around Phelix Creek, a small tributary of Birkenhead Lake. Agricultural impacts (removal of riparian vegetation, loss of wetlands, sedimentation) have been associated with the decline in kokanee and bull trout populations (Johnson and Sutherland 2004).

Flood Control

Over the last century, Pemberton Meadows and Mount Currie have been subject to regular fall and winter floods that result from rain-induced freshets in local tributaries such as Birkenhead, Green and Ryan rivers, Miller and Pemberton creeks. Flood control measures have dramatically changed the river and lake morphology and impacted salmon habitat on the Birkenhead and Lillooet river floodplains, in their tributaries and in Lillooet Lake. In 1946-1952, 14 km of meanders were cut off and 38 km of dykes were constructed in the Lillooet River upstream from the lake, reducing the channel length by over 5 km (Kerr Wood Leidal Associates 2002). At the same time, several tributaries were either dredged and dyked or diverted into new dyked channels that enter the river several kilometers downstream from their original confluences; the Birkenhead was diverted to its current channel from one that drained into the upper Lillooet River 4.5 km above Lillooet Lake. In 1949, the outlets of Lillooet and Tenas lakes were dredged, lowering lake levels by 2.5 m and draining a large marsh on the upper Lillooet River delta. Since then, sections of the Birkenhead River and much of the lower 40 km of the upper Lillooet River have been dyked, and much of the floodplain has been ditched or filled. Kerr Wood Leidal Associates (2002) identified a number of impacts that likely degraded or destroyed salmon habitat: the formation of wider, shallower river channels with steeper gradients; channel degradation in the lower 13 km of Lillooet River; the isolation of cutoff meanders; a loss of wetlands; and a rapid increase in the rate of advance of the river delta. Because the length of channels or the area of wetlands that were lost have not been estimated, it is difficult to quantify the loss of salmon habitat. The impact on Birkenhead Chinook, which may have utilized only a portion of the affected area, is even more nebulous. It seems clear, though, that the diversion of the Birkenhead River away from the wetlands and floodplains that formerly existed upstream from Lillooet Lake eliminated important rearing habitats for Birkenhead Chinook.

Linear Developments

Railway: The Vancouver-Prince George rail line, constructed in 1914 and recently acquired by Canadian National Railway (CNR), runs northeast along the Green River, crosses the upper Lillooet River near Pemberton, and then crosses and parallels the Birkenhead River for about 21 km as it runs east to Lillooet. Past derailments have caused spills of sulfur, diesel fuel and wood chips (Berezay *et al.* 1988). While fish kills have not been reported, their habitats are vulnerable where the rail corridor parallels or crosses the rivers. This is a topical concern in view of the 12 derailments that have occurred in the CNR’s first year operating the line, including a caustic soda spill that caused a massive fish kill in the Cheakamus River (Korman 2006).

Roads: The northern portion of Highway 99, completed in 1975, is the primary two-lane paved road running from Vancouver to Whistler, Pemberton and Mount Currie and continuing to Lillooet; it crosses the Lillooet River near Pemberton and the Birkenhead River near Lillooet Lake. Highway upgrades associated with the 2010 Winter Olympics are expected to improve access to the Lillooet River watershed. To the northeast, along the Birkenhead River, there is a paved highway from Mount Curie to D’Arcy and to Birkenhead Lake Provincial Park; bridges cross the Birkenhead River near Mount Currie and above Owl Creek. The remainder of the watershed is serviced by industrial grade roads. North of Pemberton, a paved road through Pemberton Meadows changes to a logging road that continues to the Upper Lillooet Provincial Park boundary. To the south, a Forest Service road between Lillooet and Harrison lakes continues along the west side of Harrison Lake to Harrison Hot Springs. There is interest by the In-SHUCK-ch Nation in upgrading the road to highway standards to facilitate tourism and economic development in the lower Lillooet Valley.

Electrical transmission lines: Four electrical transmission lines run adjacent to the Birkenhead River for 13 km; they are maintained by physically clearing trees and shrubs and the application of herbicides (Berezay *et al.* 1988). The Birkenhead Valley is also being considered for a new transmission line from the planned Meager Creek geothermal development (see *Energy*); public consultations are underway.

Mining

Despite extensive exploration of the Lillooet watershed, the only activity is a pumice and aggregate mine near Mt. Meager. While future trends are uncertain, recent higher metal prices and the new mineral exploration tax credit are likely to increase exploration and development. As well, the substantial sand and gravel resources along the Lillooet River may be considered for exploitation given the regional demand driven by the active construction industry.

Energy

The Lillooet River watershed has a high potential for geothermal and run-of-the-river electric power generation. Mount Meager, the most promising geothermal site in BC, has a capacity to meet the electrical needs of a population of 200,000. A feasibility study is underway; test wells have been drilled and generation is expected to begin in 2007.

The watershed topography is well suited to small scale run-of-the-river power generation. Plans are well advanced for several facilities in the lower Lillooet Valley, including a new substation near Harrison Lake. Facilities are already operating or in final planning stages in the upper Lillooet Valley (Miller Creek, Green River). The large number of water licenses on file or in the application stage indicates continued growth in this sector.

Parks and Recreation

There are three Class A provincial parks in the watershed: Upper Lillooet; Birkenhead Lake; and Garibaldi. Upper Lillooet (20,000 ha), established as a wilderness park in 1997 in the headwaters of the Lillooet River, comprises valley bottom old growth forest and wetlands as well as high alpine areas (BC Parks 1999a). Birkenhead Lake, a 9,800 ha park that includes the lake (but not its outflow, Taillefer Creek) and its main tributaries, was established as a summer recreation-oriented park in 1963 and accommodates about 25,000 visits per year (BC Parks 1999b). Garibaldi, established in 1920, is a large park (195,000 ha) that lies along the western boundary of the lower Lillooet River and Lillooet Lake watersheds; it is virtually inaccessible from the east and there are few park use activities in the Lillooet watershed.

Tourism is the most important economic activity in the watershed, reflecting the viewscapes and wilderness settings as well as a variety of recreational activities that include ski touring, snowmobiling, heli-skiing and biking, hiking and mountaineering, kayaking and river rafting, angling, wildlife viewing, paragliding, and all terrain vehicle and mountain bike riding. The demand for outdoor recreation is expected to grow.

SPECIES AND POPULATION DESCRIPTION

SPECIES CLASSIFICATION AND DESCRIPTION

We synthesized the following species descriptions from Hart (1973), Scott and Crossman (1973) and Healey (1991). The scientific name for Chinook salmon, *Oncorhynchus tshawytscha* (Walbaum 1792), derives from the Greek roots *onchos* (hook) and *rynchos* (snout), and *tshawytscha*, a common name for the species in Alaska and Kamchatka. Other common names are spring, king, quinnat, tule, blackmouth and tyee. As one of seven species of the genus native to North America, they are most closely related to coho.

Chinook juveniles have variable traits, but usually have wide parr marks that extend well below the lateral line. Adults have robust, deep bodies with iridescent bluish-green backs that fade to silvery sides and white ventral surfaces. They can be distinguished from other members of the family *Salmonidae* by their large size, black spotting on both lobes of the caudal fin, black pigmented gums and more than 100 pyloric cacae. At an average weight at maturity of 6-9 kg, they are the largest Pacific salmon; they commonly exceed 15 kg and sometimes reach 45 kg. During maturation, they undergo a sex-specific transformation of colour and body shape that is typical of Pacific salmon. Males change in colour to olive-brown or purple, the body becomes more compressed, and they develop hooked snouts and large teeth (termed a kype). Females largely retain their marine body shape and undergo less pronounced changes in colour.

SPECIES DISTRIBUTION

Like other species of Pacific salmon, Chinook populations in their natural marine habitats are generally distributed in the temperate and sub-arctic waters (north of 40° N latitude) of the North Pacific Ocean and the Bering Sea, Sea of Japan and the Sea of Okhotsk. Their spawning distributions range in northeast Asia from northern Hokkaido in Japan to the Anadyr River in Siberia, and in North America from central California to the Chukchi Sea in Alaska (Healey 1991). There are in excess of a thousand spawning populations in North America, with the largest rivers (Sacramento, Columbia, Fraser, Yukon) supporting the largest number of populations and the largest individual populations. The Birkenhead population spawns about 270 km upstream from Fraser estuary, and the juveniles are distributed in downstream habitats.

LIFE HISTORY

General

Like other Pacific salmon, Chinook is primarily an anadromous species that utilizes freshwater habitats for spawning, egg incubation, juvenile rearing and smoltification, and marine habitats for growth and maturation. The species exhibits a range of variability in its utilization of freshwater, estuarine and marine habitats, ocean distributions, age at maturity and spawning season that is more pronounced than in any other Pacific salmon species. While individual populations can return to freshwater almost every month of the year, there are typically one to three peak migration periods depending on the river system. Run timing tends to be earlier in the north (June peak) and becomes progressively later for more southern populations. While many Fraser populations peak in late June or early July, there are also distinct peaks in August and September. Spawning can occur from May to January, with northern populations spawning earlier (May to June) than in southern BC (August to November). While Chinook can spawn in coastal rivers, they are powerful swimmers capable of long migrations to the headwaters of major river systems. For example, headwater populations in the Fraser and Yukon rivers undertake freshwater migrations of 1,300 km and 3,200 km, respectively. Females construct nests (termed *redds*) at a variety of water depths and velocities located in habitats ranging from small tributaries to the mainstems of large rivers. The main selection criterion is the presence of strong sub-surface flows, a general requirement of species with large eggs (Chinook eggs are the largest among Pacific salmon). Some populations prefer to spawn at the outflow of pools where the tail spill mound induces sub-gravel water to percolate through the redd; others construct large, permanent dunes which similarly induce sub-gravel flows. The fry emerge from the gravel from March to June and migrate passively downstream at night. After the initial downstream dispersal, individual populations follow one of two distinct life history patterns that Healey (1991) termed the *stream-type* and *ocean-type* races.

Ocean-type Chinook are typical of most southern North American populations. After the initial downstream dispersal, the fry may take up residence in the stream for up to three months before a second migration takes them to sea, they may continue on a protracted rearing migration, or they may migrate immediately to sea. Those that take up residence initially rear in marginal, shallow areas where the substrate size is small, then progressively move offshore into deeper, faster water with boulder or cobble substrates. They feed in the water column and on the surface, with insect larvae and adults predominant, although small crustaceans such as *Cladocera* are seasonally important. They are preyed on by piscivores such as sculpins (as small (< 55 mm) fry), char, and trout. Because they occupy shallow edge habitats, they tend to be segregated from rainbow and cutthroat trout except when migrating downstream. Fingerlings (50-120 mm) reach the estuary after the freshet in late June to August and rear for a few weeks. Their marine distribution is not extensive and is typically closely associated with the coast; southern populations remain in coastal waters off BC and Alaska. Chinook populations generally mature at ages three to five, with a younger age at maturity among males. Ocean-type Chinook return to their natal streams predominantly in the late summer and fall of their fourth year and spawn without significant delays in freshwater. A variant of this racial type, the immediate migrant, occurs in some southern rivers such as the Harrison. They migrate immediately to the estuary as fry (30-45 mm), rear for several weeks (the longest period of estuarine residence among Pacific salmon), disperse as smolts to near shore rearing areas off the coast of southern BC and Washington, and return to their natal stream later in the fall than most ocean-type populations. Like other Pacific salmon species, they die and decompose after spawning.

Stream-type Chinook are typical of Asian populations and most northern (>56° N) and headwater tributary populations in North America. The fry take up residence in the stream and associated over-wintering habitats for a year or more before resuming their migration to the estuary. They utilize the same freshwater habitats as ocean-type Chinook, the main difference being that, following their initial downstream dispersal, a second migration redistributes them to more favourable summer rearing habitats within the river system rather than to sea. There also may be a third late fall redistribution to more suitable over wintering habitats in deep pools or boulder/cobble interstices in mainstem channels. The smolt migration brings them to the estuary with the freshet in late spring and they reside there briefly, if at all. By early summer, they have moved from near shore waters and have begun extensive migrations to both coastal and offshore rearing areas in the eastern North Pacific Ocean. Like other Chinook populations, their diet at sea is heavily dependent on a variety of fishes (herring, sand lance, pilchards) as well as other species such as squid and euphausiids. Stream-type Chinook return to their natal stream predominantly in the spring or summer of their fifth year and may delay in freshwater for several months before spawning.

Lakes can serve as rearing areas for both ocean-type (Brown and Winchell 2004; Tabor *et al.*

2004) and stream-type (Levings *et al.* 1985) Chinook fry. They initially occupy the shallow littoral zone (< 1 m) in areas of low bottom slope and small substrates, moving onshore at night and off shore during the day; they sometimes move to limnetic habitats later in the spring. They feed primarily on chironomids, although mayflies, sockeye fry and zooplankton can be important. Glacial lakes can be productive Chinook rearing areas due to their rich nutrient load, especially in lake edge habitats during the rising hydrograph when the rising water is warmed as it floods the sun-heated shoreline (T.G. Brown, pers. comm.).

Harrison-Lillooet Chinook Populations

The Harrison-Lillooet system supports a number of Chinook populations (Appendix 1) with immediate, ocean and stream-type juvenile life histories and spring, summer and fall adult spawning migrations. The most abundant is a fall run population that spawns in the Harrison River in October and November. Harrison Chinook adults are white-fleshed and their fry exhibit a unique immediate migrant-type life history; they mature predominantly at ages three and four.

The Harrison Lake tributaries support three small populations (Big Silver, Cogburn, Douglas), none of which were consistently assessed until 2002. The most significant of these is Big Silver, a stream-type summer run population that matures at ages four and five and spawns in early September to early October (mid September peak); spawner abundance ranges from 100 to 300. While the timing of its maturation migration is not documented, an absence of reports of early arrival in the river or off the mouth suggests a migration that is much later than that of Birkenhead Chinook. Tissue samples show a population that clusters with Birkenhead, but that is sufficiently distinct to be recognizable in mixed population samples (see *Population Genetics*). Douglas Creek supports a second Harrison Lake population that spawns in a creek that flows into Little Harrison Lake and eventually into the northern tip of Harrison Lake. Chinook have been observed only twice and in small numbers since 2002, and were reported to be holding rather than spawning.

The Lillooet System supports at least two other Chinook populations in addition to the Birkenhead. Sloquet Creek, which flows into the Lillooet River just north of Harrison Lake, was assessed in 2002-2005 by the Douglas Band through funding provided by the Aboriginal Fisheries Strategy. It supports a small summer run population (escapements of 68-221) that arrives in the river in early August and spawns through mid September; as with Big Silver, there have been no reports of early arrival in the area or prolonged holding periods. The second population, which spawns in the lower Lillooet River, has not been assessed in recent years and little information on timing and distribution of the spawning population is available. It is believed the population enters the river in September and spawning likely occurs in October and November. There are some areas in the lower Lillooet River mainstem that provide suitable spawning habitat that are likely used by this population, although direct observations of spawning Chinook in these areas have not been reported in recent years. Escapements averaged 480 in the 1980s; however, the assessments terminated in 1989.

In addition to the above, the watershed may support other small populations that have not been detected due to the turbid water or late spawning time. Bailey *et al.* (1979) report large, unspawned Chinook caught in the upper end of Lillooet Lake in October and November, and below Tenas Lake in October. They also speculate that the magnitude of the terminal harvest indicates the presence of other populations. It seems unlikely, however, that other populations contribute substantially to the harvest. Any unknown populations are unlikely to be abundant, and the known populations appear spatially and temporally segregated from Birkenhead; consequently, they are unlikely to confound our terminal fishery analyses.

Birkenhead Chinook

The balance of this document focuses on Birkenhead Chinook, a stream-type population that spawns in a headwater tributary of the Lillooet River system. Its marine distribution and maturation migration timing has been assessed by the application and recovery of coded wire tags and through genetic analyses (see *Fisheries*); the following description is summarized from Bailey *et al.* (2001). Like many stream-type populations, Birkenhead Chinook migrate far to the north where they feed for three or four years off the coast of northern BC and Alaska. They generally mature at age five (with a significant age four component) and are known for their large body size (see *Biological Characteristics*). They migrate from the north Pacific Ocean in early winter, entering the Strait of Georgia from the north through Johnstone Strait. Their migration through the lower Fraser River is the earliest of any Fraser Chinook population; it begins as early as January and is essentially complete by early May. They enter the Harrison-Lillooet System and migrate through the lower Lillooet River as early as January and into Lillooet Lake as early as March. They likely mature in both Lillooet Lake and the deeper pools of the Birkenhead River. Greenbank (2006) reports two distinct groups entering the river in late May to late July and late August to mid-September (Fig. 3) (although this may in part reflect improved post-freshet viewing conditions). They spawn from late August through September (a September 12 peak is assumed for assessment purposes) in the middle sections of the Birkenhead River, between kilometers 17 and 26, an area known as *the flats* that provides habitats suitable for spawning and holding. In some years, they migrate further upstream through a steep bedrock canyon to spawn in Taillefer Creek at the outlet of Birkenhead Lake, and possibly in the upper Birkenhead River upstream from the Taillefer confluence.

Their juvenile life history is complex and not completely understood. Trapping studies in the 1970s (Bailey *et al.* 1979; Berezay *et al.* 1988) document fry emergence beginning in March followed by an immediate emigration (peaking in early-mid April and extending to June) from the Birkenhead River (Fig. 4); very few juveniles have been reported in potential rearing or over-wintering areas in that river. The fry then either continue on an uninterrupted migration through Lillooet Lake (there is a second peak at the lake outlet about a week after the Birkenhead peak; Fig. 4) into the lower Lillooet River and downstream habitats, or they delay to rear in Lillooet Lake. The latter either continue their migration as larger fry after two to three months, or over-winter in the lake and emigrate in the spring as smolts (Fig. 4). While the extent of utilization of the lower Lillooet River and Harrison Lake has not been documented (although Hume *et al.* (2000) report Chinook fry of unknown origin in Harrison Lake), most of the population remains in fresh water for one year before migrating to sea. The emigration through the lower Fraser River likely occurs coincident with that of other stream-type Fraser populations in May (Rosberg and Millar 1987).

POPULATION GENETICS

REPRODUCTIVE ISOLATION

The Birkenhead and other Fraser Chinook populations have been screened at 12 microsatellite loci: *Ots101, Ots102, Ots104, Ots107, Ots2, Ots9, Ogo2, Ogo4, Oke4, Oki100, Omy325*, and *Ssa197*. The analysis uses fish that scored at eight or more loci; it uses a Cavalli-Sforza and Edwards (1967) cord distance calculated in PHYLIP (Felsenstein 1993) and depicted in a neighbor-joining plot (NJPlot; Perrière and Gouy 1996). Genetic variation at the microsatellite loci (Beacham *et al.* 2003; Candy *et al.* 2002; Nelson *et al.* 2001) and for allozyme data (Teel *et al.* 2000) show that the 70 Fraser Chinook populations are structured geographically (Fig. 5).

The Birkenhead clusters with two other spring or summer run lower Fraser populations, Big Silver and upper Pitt, and more distantly with the fall run Harrison population. The Birkenhead, Big Silver and Pitt populations show large genetic distances between one another (long branch lengths) and are well differentiated from other Fraser populations.

F_{st} provides a relative measure of genetic differentiation using the allelic variance within and between samples. Pair wise F_{st} values for lower Fraser samples (determined using FSTAT (Goudet 2001)) range from 0.0 to 0.13 (Table 1), indicating that the populations are significantly different from one another ($p<0.05$). Birkenhead is most similar to the Harrison and Pitt and least similar to Maria Slough, which clusters with South Thompson populations (Fig. 5).

Allelic richness, the average number of alleles per loci for a population, and gene diversity (expected heterozygosity) was also estimated by FSTAT. Because allelic richness depends on sample size, FSTAT was used because it standardized to a common sample size of 42 fish. Other than Maria Slough and Yakoun, Birkenhead has the lowest average number of alleles per loci of all populations sampled in BC; it also has low levels of heterozygosity compared to the more abundant Harrison population (Table 2).

Candy *et al.* (2002) concluded that the low levels of heterozygosity at allozyme and microsatellite loci indicate a small effective population size and very low gene flow from other populations. We estimate the effective population size (N_e) and the effective number of breeders per year (N_b) using two methods that consider the variation in allelic frequencies between two samplings: the temporal method (Waples 1990); and the maximum likelihood method (Wang and Whitlock 2003). We consider the following:

- Only genetic drift is involved in allele frequency change (Wang and Whitlock, 2003);
- An estimate of the number of generations elapsed between the two samplings (*b*) is calculated with a constant age structure method of Tajima (1992), assuming a population with 5%, 29%, 61% and 5% at ages three, four, five and six, respectively;
- The estimates of N_b can be converted to approximate estimates of N_e by multiplying by the mean age of maturity of 4.7 years; and
- Although sample sizes are small, we use five samples (1993, 1996, 1998, 2000, 2003) that exceed 25 fish (Table 3) to calculate estimates of N_b and N_e , that are then averaged.

The temporal estimator provides slightly lower estimates of N_e and N_b (296 and 63) compared to the maximum likelihood estimator (338 and 72) (Table 3). Waples *et al.* (1993) report a ratio of N_b to actual census size (*i.e.,* the escapement estimate) of 0.2 – 0.3 for Pacific salmon; the ratio for Birkenhead since 1975, based on an average escapement of 480, is 0.13 – 0.15. N_e is a measure of the rate of genetic drift and is directly related to the rate of loss of genetic diversity and the rate of increase in inbreeding in a population (Rieman and Allendorf 2001). In general, a population with a N_e less than about 50 is vulnerable to the immediate effects of inbreeding depression, while a N_e of greater than 500 is required to maintain adaptive genetic variation over long periods of time. The Birkenhead N_e estimates (296 and 338) are well below the latter, suggesting concerns regarding the long term viability of the population.

We also use a maximum likelihood method to identify potential full siblings and parent-offspring combinations by analyzing individual samples for shared alleles using COLONY (Wang 2004). The Birkenhead sample has more family structure compared to Harrison (Fig. 6). The percent of groups containing either three or four individuals per kin group is 17% for Harrison, 20% for Chilliwack and 36% for Birkenhead. We recognize, however, that multi-year sampling and within year sample sizes can influence the number of kin groups in a sample.

In summary, the genetic data provides clear evidence of reproductive isolation of Birkenhead from other Fraser Chinook populations; Birkenhead has the lowest level of heterozygosity at allozyme loci of all populations sampled in BC (Candy *et al.* 2002; Teel *et al.* 2000). Such low levels of allelic richness and heterozygosity indicate the Birkenhead receives limited gene flow (less than three migrants per generation) from other populations. Greater family structure indicates a smaller effective population size compared to other more abundant populations such as Harrison. The small effective population size may be detrimental to the long term viability of the population.

LOCAL ADAPTATION

Every salmon population is adapted to some degree to the stream beds, flows, velocities, water temperatures, predators and prey in the waters that support them. Where a salmon population is isolated from other similar populations, these differences can become pronounced and can lead to the evolution of unique new species. Just where the line is drawn between a new species and a unique and genetically isolated sub-species is open to debate, but the presence of unique local adaptations in conjunction with evidence of reproductive isolation is indicative of a distinct population that is important to the evolutionary legacy of the species.

The Birkenhead Chinook population possesses a number of attributes that make it distinctive:

- Spatial isolation from other major Fraser Chinook populations (they are separated by 150 km of complex river and lake habitats);
- Very early entry into the Fraser and Lillooet rivers. The Birkenhead is the first Chinook population to enter the Fraser River and complete their migration before most other populations have arrived. We can speculate that this behaviour is an adaptation that allows them to take advantage of higher spring flows to gain access to otherwise inaccessible spawning areas in the upper system, or to take refuge in cool lake waters through the heat of summer. The important point is that it is a behaviour unique among all the Chinook salmon that spawn in the upper Lillooet drainage or elsewhere in the Fraser River system;
- A marine distribution that extends further north than any other Fraser Chinook population (Candy *et al.* 2002);
- A large body size at age and older age at maturity among males; and
- A utilization of lake habitats while rearing as fry.

SUMMARY

Canada's *Species at Risk Act* (*SARA*) defines a wildlife species as a species, subspecies, variety, or geographically or genetically distinct population. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) interprets such populations to be Nationally Significant Populations. In the United States, the application of the *Endangered Species Act* to Pacific salmon uses the criteria of Evolutionarily Significant Units (ESU) (Waples 1991), *i.e.,* a population that: a) shows substantial reproductive isolation, where the degree of isolation is sufficient to allow important differences to accrue to individual populations; and b) is an important component of the evolutionary legacy of the species, *i.e.,* its phenotypic life history traits reflect local adaptations of evolutionary importance (Waples 1991). As a genetically isolated population with attributes that likely have evolutionary importance, the Birkenhead population conforms to these criteria and is likely to be designated by COSEWIC as a Nationally Significant Population.

SPAWNER POPULATION

ABUNDANCE

Assessment History

Surveys of salmon spawners began in the Birkenhead River following the construction of the Pemberton Hatchery in 1905 (Bolton 1976). Chinook spawner abundance has been estimated annually since the 1940s (unpublished DFO files), and compiled estimates are available for 1951- 2005 (Farwell *et al.* 1987; DFO files; Bailey *et al.* 2001; Greenbank 2005, 2006).

In 1940-1990, fishery officers estimated escapement using a variety of methods that are generally neither well documented nor easily assessed. The early estimates are based on interviews with local residents and spawner counts from foot surveys that were then expanded to account for fish visibility, the proportion of the spawning area surveyed or the timing of the survey in relation to the date of peak spawning. There is little documentation of the frequency or extent of the surveys or the method used to calculate the estimates; consequently, changes in fishery officers can result in large changes in the estimates that may not reflect real changes in abundance because observational and analytic techniques may differ. This occurred in the early 1970s when there was an abrupt change in the estimates following a long period of unrealistic consistency that only rarely fluctuated from 750 (Fig. 7; Appendices 1,2). The subsequent increased variability reflects both the replacement of a long-term officer and, beginning in 1975, the availability of aerial counts by hatchery staff that informed the fishery officer process. Helicopter flights at the time of peak spawning (typically on September 12, but ranging from September 6 to 20) (Appendix 3) introduced greater rigor to the estimation process. When fishery officers and hatchery staff were asked to evaluate the accuracy of their estimates, however, they concluded that their observational effectiveness remained limited due to fast flows, boulders, undercut banks and log jams, and glacial siltation from Poole Creek during warm weather (Fielden and Slaney 1991). These issues make uncertain the interpretation of both the magnitude of historic populations and trends in abundance.

In 1991-2005, ground surveys conducted in partnership by the Pemberton Wildlife Association (PWA) and DFO recorded live and dead Chinook by river section at the assumed time of peak spawning (on or near September 12; H. Naylor, pers. comm.) (Appendix 3). The counts are not expanded to account for survey conditions (recorded in some but not all years) or the proportion of the spawning grounds that was surveyed (although efficiency (70-77%) and coverage (90-100%) were recorded in some years); consequently, they serve as an index of abundance trends rather than an estimate of the total abundance.

In 2002-2005, more intensive assessments and alternate estimation techniques were investigated in a project funded by the Aboriginal Fisheries Strategy and conducted in partnership by the Lil'wat Nation and DFO (Greenbank 2006). The project reestablished helicopter flights (5-8 per year) and complete ground surveys (weekly through the spawning period). A comparison of simultaneous ground and aerial counts at the time of peak spawning showed that Birkenhead Chinook spawners are more visible from the ground (Mean = 2.02; St. Dev. = 0.95; Range: 1.12 to 3.03) (Appendix 3), an important finding given that both aerial and ground surveys have been used since 1975. This result is similar to but larger than that reported in the Chilcotin and Blackwater rivers by Dickson (1996) (republished in Farwell *et al.* 1999). That the magnitude of the difference is larger in the Birkenhead River likely reflects site-specific physical factors such as river size and the frequency of cut banks, large woody debris or deep pools, seasonal factors such as water quality or discharge patterns, and biological factors such as the abundance and distribution of Chinook and sockeye spawners. The variability of the estimates likely reflects annual differences in water clarity, which makes spawner more difficult to see from the air. The study generated spawner-day estimates and considered the use of the area-under-the-curve (AUC) escapement estimation technique (English *et al.* 1992); unfortunately, direct estimates of redd residence time were unavailable.

Reevaluation of Spawner Abundance Estimates

Total Spawners: Our objectives in re-evaluating the spawner abundance data are to extend the 1991-2000 time series reported by Bailey *et al.* (2001) and to replace the index with estimates of total spawner abundance. The latter permits the estimation of the number of spawners with adipose fin clips (AFCs) and coded-wire tags (CWTs) and, consequently, exploitation rate and survival. We reject the Bailey *et al.* (2001) approach (the PWA spawner count expanded by a constant (1.54) plus the brood stock removal) because the constant actually relates observer efficiency between simultaneous ground and helicopter observations (Dickson 1996, cited in Farwell *et al.* 1999) rather than peak count to total population size; consequently, its use to adjust ground counts to estimate total escapement is not appropriate. Furthermore, the exclusive use of ground counts ignores 12 years of aerial counts since 1975 that could be informative in the evaluation of abundance trends.

We use a two step process to estimate annual spawner abundance. First, we calibrate the older aerial counts (1975-1988, 1999) based on the average ratio of ground-to-aerial counts in 2002-2005 (2.02) (Appendix 3), producing an index of peak live counts over a longer time series. Second, we expand the index by a constant (1.71, the average ratio between peak live counts and total abundance in Nechako Chinook) (NFCP Technical Committee 2005). Total escapement is then the sum of the expanded index plus the hatchery brood stock (brood stock is removed before the live count occurs). We use Nechako data because direct estimates of escapement (*e.g.,* from enumeration fences or mark-recapture and AUC studies) are unavailable for Birkenhead Chinook. Nechako has a long time series of data and its physical environment and the biological characteristics of its Chinook population are more similar to Birkenhead than other potential surrogates such as Nicola or Shuswap.

The result is estimates that are about 12% larger than those of Bailey *et al.* (2001) for the same years, and are similarly trendless over a longer time series (a slightly negative trend disappears with the addition of the 2005 record count) (Fig. 7; Appendix 3). Annual abundance averages 480 and ranges from 130 to 1,491. Interestingly, the 2005 escapement is the largest in the time series and over double those reported in recent years. This increase is inconsistent with the sharp decline reported among other spring run Fraser Chinook populations (R. Bailey, pers. comm.), suggesting that the factors controlling survival to escapement may differ for the Birkenhead relative to the other Chinook populations with which it is aggregated.

Overall, we believe the revised estimates are generally closer to true abundances than the index estimates and serve as reasonable indicators of gross trends in abundance. We acknowledge, however, that our assumptions could introduce significant errors in specific years. The use of averages to both calibrate the aerial observations and convert the peak live count into an escapement estimate has certainly resulted in an underestimate of the true variability of annual population size. Similarly, the use of Nechako data introduces a myriad of assumptions (*e.g.*, little variability in date of peak spawning, similar temporal pattern in the start, peak and end of spawning, similar observer efficiency, *etc.*) that could introduce substantial error. While we are comfortable that the current data allow the gross characterization of population abundance and trends, we are unable to generate the rigorous annual estimates that we believe are necessary for a scientifically defensible characterization of population status. We recommend restructured assessments that include the periodic foot surveys required to estimate total spawner-days (as occurred in 2005) as well as direct estimates of spawner residence time and observer efficiency, with periodic verification using more accurate techniques.

Spawners with Adipose Fin Clips and Coded-wire Tags: We estimate the number of CWTs in the escapement from the total escapement, the AFC incidence in the carcass and brood stock samples, and the tags dissected from the snouts of spawners with AFCs: the number of AFCs in the river escapement is the product of the escapement estimate (Appendix 3) and the AFC incidence (Appendix 4); and the CWT code-specific escapement is the sum of the river escapement (the product of the AFC escapement and the ratio of recovered CWT codes) and the CWTs recovered in the brood stock sample. We then expand the code-specific estimates based on the proportion of the associated brood year production that was released with tags (Appendix 5). Our calculation of the code-specific estimates, which is the product of the ratio of the observed codes and the AFC estimate, assumes equal long term tag loss each year. We do not use the code-specific estimate of short term tag loss because data from other systems (*e.g.,* Salmon River coho) show little relationship between short and long term tag loss.

The reliability of the code-specific estimates is constrained by uncertainties in the total escapement estimate (see the previous section) and the small samples available to estimate the AFC incidence and to recover CWTs. We combine the brood stock and carcass recoveries to maximize sample sizes; however, even the combined samples are generally insufficient to permit stratification by sex. Sample size averaged 55 adults each year, with an average recovery of only five AFCs; none were detected in seven of the 23 years in which they were expected to return (Appendix 4). Although sampling was constrained by a lack of resources to survey the river (spawning ground samples are available in only seven of the 23 years), the small escapements resulted in brood stock capture efforts that were temporally and spatially extensive (17% of the population was retained for brood stock and examined for AFCs); consequently, despite the small sample sizes, sampling occurred in a reasonably representative manner.

TIMING

Time of entry into Birkenhead River is near the end of May with a large proportion of the run in the river by July (Berezay *et al.* 1988). These findings were confirmed in 2005 when a number of ground surveys were completed through this time period. The first survey was completed on April 4 and the first holding Chinook were observed on May 26. The period of spawning has been well defined over the years as beginning in the last week of August with the peak spawn observed during the survey completed nearest to September 12. The last fish are generally observed in the last few days of September.

BIOLOGICAL CHARACTERISTICS

Age

Spawner age has been estimated from scale samples collected from spawning ground carcasses and brood stock samples (some verified against coded-wire tags) since 1975. Birkenhead Chinook have a predominately stream-type life history, with a small ocean-type component (about 6%) in earlier samples that may be an artifact of different ageing criteria being employed at that time. They mature predominantly at ages five (61%) and four (29%), with a small proportion maturing at ages three (4%) and six (7%) (Appendix 6a). As with most Chinook populations (Healey 1991), males mature at a younger age than females (Appendices 6b, 6c). While both males (69%) and females (73%) are predominately 5-year-olds, males have a larger 4 year-old component (25% versus 15%) while females have a significant 6 year-old component (10%).

Body Size

Postorbital-hyperal length (POHL) is a standard measure of body size in salmonids recovered on the spawning grounds. We compiled POHL data for Birkenhead Chinook from three sources: ageing cards on file at DFOs regional scale laboratory (1975-1989); Birkenhead Hatchery records (1983-2001); and stock assessment projects funded through DFO's Aboriginal Fisheries Strategy (2002-2004). Data were rejected if incomplete (*i.e.,* sex, length and age recorded) or if contradictory data exists from different sources.

The mean POHL of Birkenhead Chinook was 705 mm (SD=79; n=252), with males and females averaging 680 mm and 716 mm, respectively (Appendix 7). This is near the upper end of the size range reported for interior Fraser Chinook populations (NFCP Technical Committee 2005), likely reflecting two factors. First, Birkenhead Chinook are somewhat older than is typical for Fraser Chinook salmon. Healey (1991) reports that male and female Fraser Chinook (both ocean and stream-type) are typically ages four and five, respectively. While Birkenhead females conform to this pattern (although there is also a significant 6 year-old component), the males are also predominantly the larger 5 year-olds. Second, the spawner sex ratio is skewed toward females (1.7:1) that tend to return at older ages and larger sizes.

FISHERIES

Much of our knowledge regarding the marine distribution and freshwater migration of Birkenhead Chinook is inferred from fishery sampling for tissues and for the CWTs that had been applied to the 1977-1992 and 1995 brood year hatchery releases; Bailey *et al.* (2001) describe the basic sampling procedures and analytic processes involved. In this section, we update the fishery descriptions and sampling results and review the terminal area fishery assessment data in an attempt to better characterize the impacts of those fisheries. We rely on three information sources: hatchery production data (numbers released by CWT code, release strategies and associated release without CWTs) (Appendix 5) from Oceans, Habitat and Enhancement Branch's (OHEB) Information Management System; recoveries in marine fisheries (expanded to represent associated production) (Appendix 8) from the Pacific Biological Station Mark Recovery data base; observed escapement CWT codes from the OHEB escapement data base; and CWTs in freshwater fisheries and the escapement (expanded to represent associated production) (Appendix 8) using procedures described in this research document.

FRESHWATER FISHERIES

Lillooet System First Nations

The First Nations of the Lillooet System use set gill nets at various locations in the lower Lillooet River (In-SHUCK-ch reserves at Douglas, Skatin, Peters and Baptiste-Smith, with the highest effort at the bridge near Douglas) and along the foreshore at the upper end of Lillooet Lake (Lil'wat Nation) (Fig. 2). There are about 15 fishing sites, with only five occupied at any time. Since 1991, angling with bait or lure has been frequent in the lower Lillooet River and upper

Lillooet Lake and, less so, in the lower Birkenhead River. Historically, the fishery was managed through permits issued to individual band members. It was open seven days per week but, in response to concerns regarding the status of Birkenhead Chinook, DFO requested that First Nations limit their annual harvest to 25 Chinook in 1976 and subsequent years. Beginning in 1986, the early season pre-freshet fishery was reduced to one day per week. Since 1991, the fishery again expanded to seven days per week as a result of the *Sparrow* decision.[1]

Fishing can occur every month of the year, but typically peaks in March to May with the arrival of Chinook, declines in June and July during the freshet, then again peaks in August to October with the arrival of sockeye, late run Chinook and coho (Fig. 8). Before the freshet, effort peaks at 4-6 nets in both the river and lake fisheries and, after the freshet, at 8-10 nets. In the lower Lillooet River, the Chinook fishery begins in January, catch per net peaks in April and May, then declines to almost nothing during the freshet; there is a smaller peak in October (Fig. 8). The Lillooet Lake Chinook fishery is later, beginning in February, peaking in May to early June and continuing through the freshet; it also shows a smaller peak in October.

Fishery officers assessed these fisheries in 1951-1991 (Appendix 2) by observing fishing activity and interviewing the fishers. The estimated harvest averages 132 Chinook per year (range: 6-396), with about half taken in each of the Lillooet River and Lillooet Lake fisheries. Harvest declines over that period, reflecting low catches in the late 1970s and late 1980s. There are a number of deficiencies in the assessment of these fisheries: a) Assessment procedures are poorly documented, with only annual estimates of harvest by species available in most years; consequently, there are few records of the temporal pattern of survey effort. This is an important issue because temporally extensive assessments are required for populations with extended migrations such as the Birkenhead. The failure to assess components of the fishery would result in an underestimate of harvest; b) Although there are other Chinook populations in the watershed (see *Harrison-Lillooet Chinook Populations*), stock composition samples have not been obtained from the fishery. The harvest estimates, therefore, likely include non-Birkenhead Chinook; and c) Because fishery assessments terminated after 1991, we have no direct estimates of subsequent fishery impacts.

We evaluated the temporal pattern of the assessments and the potential catch of late run Chinook by examining the weekly data that are available in 1983-1991 (Appendix 9). An assessment is adequate if it encompasses the full Chinook migratory period (excluding May-July freshet) or, if breaks in coverage occur, low catches in subsequent weeks indicate the fishery had been inactive. Survey coverage appears adequate in only five of the nine years (1983, 1985, 1987, 1988-89), suggesting that harvest may be underestimated for a substantial part of the 1951-1991 time series. We further examined the years with adequate coverage to identify and exclude non-Birkenhead harvest, thus permitting the estimation of harvest rate. The most obvious is the late season harvest that extends well after the Birkenhead's spawning peak (Fig. 8); an average 22% and 3% of the river and lake harvest, respectively, occurred after September 12 (Appendix 9). Sloquet is the only other population that might contribute to the Lillooet River fishery; however, its small apparent size in the early 1980s (Appendix 1), later arrival timing and limited exposure to the fishery (Sloquet Creek enters the Lillooet River downstream from almost all fishing) suggests that its contribution was minor.

We use the adjusted harvest estimates in the years with adequate assessments to estimate the Birkenhead Chinook harvest rates in the Lillooet System First Nations fisheries (Table 4).

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[1] The 1990 Supreme Court of Canada ruling that Aboriginal groups have a right to fish for food, social and ceremonial purposes and established governments' obligation to consult when these rights are affected.

Harvest rates average 23%, but vary over a large range from 2% in 1988 to 63% in 1985. These highly variable harvest rates reflect in part annual differences in discharge and debris loads that affect the ability of fishers to operate in the river. While a 30-fold range might suggest assessment error, we have independent verification of the 1985 extreme estimate that suggests this is not the case. In that year, hatchery staff offered a reward for the voluntary return of heads from fish with AFCs. First Nations fishers returned 32 heads with AFCs and CWTs (Dixon 1985). The AFC incidence in the catch (8.7%) is very similar to that in the escapement (9.6%). This suggests that the harvest estimate, the highest on record, is reasonable and tends to support the assumption that estimates in years when survey coverage is extensive represent a reasonable assessment of the fishery.

Our assessment of the impact of the Lillooet System First Nations fisheries relative to other fisheries is constrained by the quality of the assessments; harvest rate estimates are available in only 5 of the 21 years when Chinook with CWTs were expected to return. One approach to roughly approximate the catch by CWT code is to apply the mean harvest rate reported above to years when the survey coverage was inadequate or unknown (1979-1982, 1984, 1986, 1990-1991) or when the fishery was not assessed (1992-2001). As would be expected if the fisheries were inadequately assessed, the estimates from this approach are generally higher than the fishery officer's estimates for the same year. The AFC catch (Table 5) and catch by CWT code (Appendix 8) can then be estimated by applying the AFC incidence and code-specific CWT recoveries in the escapement to the total catch estimate. We recognize that the utility of these estimates is limited. Certainly, they do not properly represent the natural variability that results from annual differences in river discharges and debris loads that influence fishing effort, or systematic changes in effort that may result from demographic changes to the First Nations populations. We present them as reasonable approximations of the balance between freshwater and marine exploitation on a long term basis; however, we caution that they are not accurate estimates of catch in any year.

Clearly, a defensible characterization of population status requires the assessment of fisheries that are unrestricted in fishing time and seem capable of harvesting at rates that exceed 60%. We recommend the joint development with First Nations of a project to monitor the fisheries for effort and catch and sample for stock composition. A pilot project began this work in 2005-2006; improved data is expected as the project gains acceptance in the communities.

Lower Fraser River First Nations

The First Nations fish with drifted and set gill nets in the lower Fraser River. Birkenhead Chinook are vulnerable to the fisheries from the mouth to the Harrison River (and probably for a few kilometers further upstream) from the onset of the fishery until the end of April (termed *the early season fishery*). Historically, the fishery used only set nets and opened for three days per week throughout the year. Beginning in 1977, the weekly openings were progressively restricted to reduce the harvest of Fraser spring run Chinook: to 1.25 days per week in 1977-1981 (typically from early March to mid April); to 1.0 day per week over an expanded period in 1982-1992 (typically from late February through June); and since 1993, the fisheries have been closed until mid-March except for limited ceremonial or steelhead directed fisheries (Appendix 10). Over that period, openings in the three fishing areas (lower – Steveston; middle – Deas Island to Mission; upper – Mission to Harrison River) declined from an average 109 to 45 days. At the same time, though, drifted gill net fisheries were established in areas where set nets had been relatively ineffective: in the estuary area near Steveston beginning in 1981; in the fisheries below Mission beginning in 1993; and, more recently, in other areas by special permit.

Fishing effort has been highly variable in the early season, ranging from a few to almost 100 nets in a given week. In general, effort and Chinook harvest is lower in January and February than in March and April (*e.g.,* Schubert 1983). The fishery also varies among areas; the most intensive and effective fishery is in the upper area where faster flows make set gill nets more effective. In contrast, the lower and middle areas are tidal and set gill nets are relatively ineffective; consequently, these fisheries attracted little effort and were relatively ineffective until drifted gill nets were permitted in 1981 and 1993, respectively.

Fishery assessment records are available since 1951; annual catch estimates are available for 1951-2005, and weekly effort and catch estimates are available since 1969. Fishery officers assessed the fisheries until 1997 using a variety of techniques, including boat and aerial patrols, net inspections and interviews with fishers (see reports cited in Macdonald (1992)); their analytic techniques have been documented since the early 1980s. Temporally, the allocation of survey effort differed among areas and years. The early season upper area fishery was assessed in most weeks except in 1969-1972, 1983 and 1989-1991; the middle area was similarly assessed in the 1980s and since the mid-1990s; and the lower area since 1987 (Appendix 10). In other years, substantial periods of non-assessment (no surveys at all in some years) result in underestimates of effort and Chinook catch. Since 1998, structured assessments have been conducted by DFO and First Nations technicians in all of the fisheries and time periods (*e.g.,* Alexander (2001)).

We can investigate potential fishery impacts on Birkenhead Chinook only since 1969 when weekly estimates became available. Effort and Chinook catch in the early season fishery averages 645 net days and 246 Chinook, respectively; while catch increased since 1969, effort decreased in the early 1980s when the fishery openings were consistently reduced and especially since 1993 when the early season fisheries were closed (Appendix 10). To better evaluate trends, we eliminate years with poor assessments (more than five non-assessed weeks) then compare the Chinook catch and effort before and after early season closures were implemented in 1993. The average effort in the upper area decreases from about 1,000 to only 137 net-days while, in the lower and middle areas, effort changes from about 200 set net-days to 110 drift net-days. The average catch in the upper area decreases from 196 to 148 Chinook, while catch in the lower (33 to 56) and middle (from 50 to 140) areas increases, likely reflecting the change to a more effective gear.

DNA stock composition estimates are available from tissue samples collected from the lower Fraser First Nations fisheries in 1997-2001 and 2003. Birkenhead are present in abundance through the end of April (average 14%; range 9-21%), with very few in May and none in June (Appendix 11). We stratify the stock composition and total catch estimates in roughly 10-day time blocks to estimate the Birkenhead catch; annual catch averages 74 Chinook (range 28-172). To roughly quantify the impact of the fisheries on the Birkenhead population, we use the escapement and terminal fishery harvest estimates discussed above (see *Spawner Population* and *Lillooet System First Nations*) to estimate annual abundance and harvest rates in the lower Fraser fisheries. Harvest rates average 10.4% (range: 3.4-17.4%) (Table 6) and are closely related to fishing effort ($y = 0.0006\,x - 0.0514$; $R^2 = 0.7263$), indicating that these fisheries are capable of significant impacts on the Birkenhead population even under the current restrictive management regime where they remain closed until mid March.

Because harvest rate estimates are available largely in years following the last return of CWTs, it is difficult to assess the impact of the lower Fraser fisheries relative to other fisheries. It would be useful, therefore, to reconstruct harvest rates in earlier years. We considered two approaches: applying the relationship between harvest rate and fishing effort noted above; and simply applying the average harvest rate to earlier years. The use of either is constrained by three changes in the nature of the fishery over the last 35 years: the shift to more effective gear in the lower and middle areas; the perception since protracted early season closures were first implemented that every opportunity needs to be maximized, resulting in a more intensive set-net fishery with more active tending of the gear; and the shift in effort to later in the year when there are more populations in the river and the proportion of Birkenhead is lower. The use of the regression addresses annual variability in the fishery and likely provides realistic harvest rate estimates since the nature of the fishery changed in about 1993; however, it would likely overestimate harvest rates in earlier years. The application of the recent average fails to address annual variability and likely underestimates harvest rates in earlier years, especially in years with significant fishing effort in January through March. Regardless, we choose the latter approach to estimate Birkenhead catch (Table 5) and catch by CWT code (Table 7, Appendix 8) for the years when tagged Chinook were expected to return because we were unable to bound harvest rates during an era when effort was considerably higher but the nature of the fishery was much different. We acknowledge the limitations of this approach and echo our comments in the *Lillooet Systems First Nations* fishery discussion.

Albion Test Fishery

The Albion test fishery operates from April to November in the lower Fraser River near Fort Langley. It uses standardized fishing times, locations and gear to index Chinook abundance and collect biological samples (Schubert *et al.* 1988; Dempson *et al.* 1998). DNA analyses of tissue samples taken in 2000-2001 and 2005 confirm that Birkenhead Chinook are abundant in April and are through the area by mid May (Appendix 11). The 2000-2001 analyses show a similar Birkenhead composition in the Albion and First Nations fisheries samples through April 19, but a generally higher Birkenhead composition in subsequent samples. The Birkenhead component of the test fishery catch, estimated from DNA samples, was 9 and 14 in 2000 and 2001, respectively, a harvest rate of 1.4% (Table 6). In addition to DNA sampling, three Birkenhead CWTs have been recovered in the test fishery, all in April (Table 5). This likely under-estimates their true abundance because a high proportion of the early season Chinook lose their heads to seals when entangled in the net. This reflects the predation by a large seal population on the small numbers of salmon present in the river at the only site where fishing occurs daily at that time of year (A. Baker, pers. comm.).

Fraser River Commercial

Effort and harvest records are available for the commercial drifted gill net fishery for 1951-2005. Until 1980, the fishery was open for up to five days per week beginning as early as February; average Chinook harvests through April declined from 6,500 in the 1950s to 4,200 in the late 1970s (Fraser *et al.* 1982). While these fisheries likely harvested substantial numbers of Birkenhead Chinook, stock composition estimates are not available. The closure of the early season fishery (before the arrival of sockeye in late June) in 1981 and subsequent years eliminated the harvest of Birkenhead Chinook in this fishery.

Recreational

Lower Fraser River*:* In 1980-97, the retention of Chinook adults was prohibited in response to concerns regarding the status of the Fraser spring run. While harvest estimates are available in previous years (average 1,500; Fraser *et al.* 1982), monthly catch and stock composition estimates are not available and catch locations are vague.

Since the recreational fishery reopened in 1998, total Chinook harvest from the mouth to the Harrison River in May averaged 102 and ranged from 35 to 220 in the years with full assessments (1998, 2002-2005) (J. Mahoney, pers. comm.). Based on the stock composition estimates from the Albion test fishery (Appendix 11), the Birkenhead component of the May recreational fishery catch is less than 1% (Table 6).

Lillooet River System: Until catch and release regulations were implemented in 1976, Lillooet River and Lake supported a Chinook fishery that attracted about 20 anglers and peaked on the May long weekend (Bailey *et al.* 1979). Catch, estimated only in 1974-1975, totaled 91 and 64 Chinook (Appendix 2), representing a harvest rate of 15-18%. A weekend derby in late April, 1967-1975, attracted 25-30 anglers and harvested 2-20 Chinook. Currently, the catch and release fishery is open year round; although it is not assessed, anecdotal information from fishery officers and Lil'wat Nation staff indicate that effort is unchanged.

Birkenhead River: The Birkenhead River also supports an active recreational fishery. Chinook spawners are protected by the August 1 to September 15 salmon closure and bait ban. The Lillooet Sport Fish Advisory Committee also promotes fly fishing from August 1 to September 15 to protect Birkenhead Chinook; they have developed posters and flyers and have placed advertisements in newspapers to educate anglers on the population's status and to promote compliance with this voluntary measure.

MARINE FISHERIES

The 1985 PST between Canada and the US recognized that many Chinook populations were severely depressed. To improve returns, ocean fisheries were managed to catch ceilings; however, by 1998 it was evident that fixed catch ceilings had not been effective for many populations. Consequently, the 1999 bilateral agreement stipulated that the three major Chinook mixed stock fisheries (all fisheries in southeast Alaska (SEAK), northern BC troll and Queen Charlotte Islands sport (NBC), and the troll and outside sport fisheries off the west coast of Vancouver Island (WCVI)) would be managed under an abundance-based management (AABM) approach. Annual catch limits were set based on forecasted abundance and negotiated harvest rate reductions. All other fisheries were to be managed to negotiated exploitation rates on individual Canadian and southern US populations (ISBM fisheries).

In the mid-1990s, conservation concerns for interior Skeena and Fraser coho and WCVI Chinook led to severe restrictions on ocean fisheries until 2000. More recently, the improved status of some populations and better fisheries management tools have led to increased allowable catches in Canadian AABM fisheries. In general, the new management regimes have led, at least in part, to improved Chinook abundance in both countries; between 1999 and 2004, Chinook abundance in the two Canadian AABM fishery areas increased by over 60%. A number of populations in Canada and the southern US remain depressed, however, including WCVI natural spawners, Fraser springs and lower Strait of Georgia populations. Consequently, despite the increase in overall Chinook abundance, Canada's AABM fisheries continue to be managed to address conservation concerns for both coho and Chinook populations.

The PSC Chinook model is used to forecast abundance for the major Canadian and US population aggregates. The Birkenhead is aggregated in the *Fraser Early* group with other spring and summer-run populations. Little CWT information was available for this group when the model was developed in the late 1980s (marine distributions were estimated from CWT recoveries for Chilko and lower Shuswap, both summer-run populations); consequently, the model probably does not accurately represent early-run populations such as Birkenhead. As a result, we did no consider the model output useful in providing insights into Birkenhead abundance, exploitation or survival trends. Instead, our evaluation of fishery impacts relies on the limited CWT recoveries and fishery DNA analyses specific to the Birkenhead population.

Individual Fishery Impacts

CWTs were applied to 1977-1995 brood year Birkenhead Chinook and recovered in 1979-2000. The ocean fisheries were consistently sampled for CWTs in this entire period. Despite harvesting significant numbers of Birkenhead Chinook, however, the freshwater First Nations fisheries were not sampled in an *ad hoc* project in the Lillooet System in 1985. To estimate the impacts of these fisheries over this period, we calculate pseudo-recoveries using procedures described previously (see *Freshwater Fisheries*). Combined with ocean recoveries, this allows us to assess the annual mortality distributions to the end of the CWT assessment period in 2000. To estimate more current fishery impacts, we use average historical CWT distributions scaled to annual catch through 2000, assuming that: post-1995 brood year survivals are similar to the historical average; Birkenhead Chinook densities in each fishery are similar to the historical average (*i.e.,* the abundance of Birkenhead and all other populations co-varies in each fisheries); and current and historic ocean fisheries are conducted in a similar manner.

The ocean catch data used to scale recoveries are from CTC (2005), while First Nations catch is from Table 5. Commercial and recreational CWT recoveries are obtained from the Regional Mark Information System (RMIS), while estimated First Nations recoveries are from Appendix 8. Once recoveries are generated for each fishery for years 2001-2005, the percent mortality across fisheries is calculated for each fishery and year (Appendix 12). Not included are recoveries taken as by-catch in Alaskan high seas and groundfish fisheries. Typically, recoveries in such fisheries are not included in mortality distribution tables because they are opportunistic rather than the result of comprehensive and representative sampling programs. We recognize, however, that Birkenhead Chinook are intercepted in such fisheries even though quantifying the impacts of these fisheries on this population is problematic; consequently, there is an inherent slightly negative bias in our estimates of total fishery impacts.

SEAK Troll: This is the single largest ocean harvester of Birkenhead Chinook, with most impacts from the troll fishery (CWT recoveries in the sport and net fisheries suggest a relatively small impact). Historically, this fishery accounted for 39% of all fishing mortality; since 2000, we estimate a decrease to about 35% (Appendix 12).

Strait of Georgia Recreational: While this fishery historically accounted for up to 25% of annual Birkenhead fishing mortality, due to a large reduction in catch starting in the early 1990's (largely reflecting lower Chinook abundance in general), it currently accounts for less than 2%.

Other Ocean Fisheries: The Northern BC and WCVI troll, WCVI/Juan de Fuca sport, and Georgia Strait and Fraser River commercial net fisheries historically intercepted Birkenhead Chinook. Since 2000, however, they have accounted for no more than 18% (average 10%) of total mortalities. A recent shift in the WCVI troll fishery from a summer to a spring/fall fishery may have increased impacts on spring run populations like Birkenhead; however, without CWTs, these impacts cannot be quantified. While the Birkenhead population is genetically distinct, its small size makes detection in mixed stock samples unlikely given the low sampling rates typically employed by genetic stock identification projects (1-2% of the landed catch). Consequently, our assessment of impacts in this fishery will not be possible unless CWT marking is reimplemented or sampling rates are substantially increased.

Fraser First Nations Fisheries: As described earlier, the lower Fraser and Lillooet System First Nations fisheries have approximately equal annual impacts on Birkenhead Chinook. They historically accounted for about 36% of fishing mortality while, more recently, they may account for over 50% of all fishery harvest. This change reflects declines in Canadian ocean harvest and a possible increase in First Nations catch. We note, however, that the latter is estimated from average historical harvest rates applied to escapement over the last five years and may not accurately reflect true levels (see *Freshwater Fisheries*). For example, this approach produces an estimate of 421 fish in the 2005 Lillooet System First Nations fisheries, while anecdotal reports suggest the actual catch was much less. There is little question, however, that First Nations fisheries are now the largest single harvester of this population. There is also little question that improved fishery assessments are required.

SUMMARY

Birkenhead Chinook are harvested over a migratory pathway that extends from southeast Alaska to the spawning grounds (Appendix 8). CWT recoveries in 1979-2000 show significant impacts in fisheries in Alaska, the Strait of Georgia and in freshwater, with exploitation rates that have averaged 53% and ranged from 26% to 85% (Table 7). Our evaluation of current impacts suggests that only the Alaska and freshwater fisheries remain significant; others are minor either because the early migration of maturing Birkenhead adults reduces their vulnerability or because conservation actions for other populations and species have reduced harvest rates. We note, however, that current assessments are constrained by the need to rely on genetic stock identification techniques that employ sample sizes that are not intended to detect small populations such as Birkenhead.

Marine and freshwater exploitation rates on the 1977-1995 brood years were similar, averaging about 34% and 29%, respectively. Again, we emphasize that our evaluation of freshwater impacts and, indeed, of overall survival and exploitation rates, is severely constrained by uncertainties in the escapement estimates and either inadequate stock composition estimates or the complete lack of assessment of freshwater First Nations fisheries. While our estimates of returns to freshwater show a relatively trendless pattern (Table 5), this likely reflects our reliance on averages in estimating escapement (aerial survey bias, expansion of peak live to total population) and harvest in both major First Nations fisheries.

ENHANCEMENT

HISTORY

The Birkenhead River Hatchery, constructed in 1976 in response to escapement declines (see *Spawner Population*), was located on the east bank of the Birkenhead River 11 km upstream from Lillooet Lake and 1.5 km from Mount Currie (Fig. 1). The site was selected for its high quality surface and ground water; however, the temperature (7.5º C) was about 3º C lower than what was considered at the time to be ideal for Chinook incubation and rearing. It operated as a DFO hatchery until 1992, then closed following a review that concluded it had not contributed to the recovery of the population. Subsequently, the PWA operated the hatchery under contract from DFO until 2003, when it again closed because the deterioration of the site had made it a safety concern.

The hatchery production strategy changed as assessment information became available. Initially, the strategy employed for stream-type Chinook was the release of accelerated *super-smolts* (4-7 g) in April or May (Appendix 5). It was assumed that the enhanced smolts would immediately migrate to the estuary, thereby minimizing interactions with wild salmonids in freshwater habitats. Operationally, brood stock was captured by angling while holding in the river before spawning; the target was to collect 250,000 eggs to permit the subsequent release of 212,000 fry at 7 g. Release to adult survivals were poor (Table 7), likely because 0+ smolts were released too large and too late and at too large a size. In 1991-1995, a new strategy developed at Spius Creek Hatchery was adopted that entailed the release by mid-April of large 1+ smolts (up to 20 g) that had been reared for 12 months. The final strategy, adopted in 1995, was the release of 0+ fry into natural areas in the upper watershed or semi-artificial rearing areas such as Fee Creek.

CWTs that were applied to the 1977-1992 and 1995 releases are the basis for our evaluation of the various production strategies. Our analyses are constrained in two ways: because survivals were low and CWT groups and escapement samples small, there are several years when returns were expected but there were no recoveries in either the fisheries or the escapement; and when the terminal First Nations fisheries were not directly assessed, we use average harvest rates to estimate CWT recoveries (see *Freshwater Fisheries*). The latter limits the accuracy of estimates for individual years; however, because each brood year returns over multiple years, we consider the estimates to be reasonable (if rough) indicators of long term patterns in survival and the balance between marine and freshwater exploitation.

The under-yearling releases are grouped into four strategies with different times or sizes at release: *fed fry* (spring-summer release at a wild fry size); *0+ accelerated* (same release time but at a larger size, but not large enough to smolt in the first year); *0+ smolt* (spring-early summer release at a smolt size) and *fall release* (Table 7). The average survival for the fed fry and 0+ accelerated groups was 0.21% and 0.13%, respectively; while survival was variable, the fed fry strategy showed the highest average survival. In contrast, the average survival for the 0+ smolt and fall fry groups was only 0.01%, with the highest survival of only 0.06%. Similarly, 0+ smolts released from Spius Creek Hatchery survived at only 0.0% - 0.2% range. Sampling programs conducted in the tidal areas of the lower Fraser revealed that these juveniles did immediately emigrate after release. Their low survival suggests that, while they exhibited the migratory behaviour of smolts, the majority did not possess the physiological attributes necessary to make a successful transition between the freshwater and saltwater environments.

The survival of the yearling releases ranged from 0.01% to 0.37%. The highest value was for the 1995 brood group that was released into Fee Creek, with voluntary migration out of the system at some later date. As a comparison, the survival of yearling releases from Spius Creek Hatchery average 0.5% to 1.0%, and have been as high as 3.0%.

Ultimately, the success of enhancement as a recovery tool is measured in terms of its cost (*i.e.,* the number of spawners that are removed from the population in a given year) relative to its contribution to the spawner population in that year (*i.e.,* from previous years' enhancement). In the Birkenhead, the annual contribution per removal averaged 1.0, *i.e.*, the hatchery production only replaced the number of fish removed for brood stock each year (Table 9; Fig. 9). At the level of exploitation experienced by these brood years, therefore, the survivals of hatchery fish were insufficient to allow enhancement to contribute to the recovery of the Birkenhead population.

POTENTIAL ROLE

While enhancement did not contribute to the recovery of the Birkenhead population, experience gained both in the Birkenhead and with other stream-type Chinook populations suggests that it could play a role in future recovery plans. Certainly, experience at Spius Creek Hatchery demonstrates the potential for much higher survivals than occurred at Birkenhead, and lower marine exploitation rates (see *Marine Fisheries*) may increase the numbers that return to freshwater. It remains uncertain, however, whether the Spius results could be achieved at Birkenhead because there have been few assessments of similar populations; the direct assessment of Birkenhead is required. There is also uncertainty in the selection of an optimal release time in populations such as Birkenhead where large lakes can influence arrival time at the estuary.

There are two strategies that have potential as recovery tools. First, yearling smolt releases are an option provided: the rearing and river water temperatures are identical at the time of release, thereby facilitating their immediate emigration from the system; and they are released in late March to early April to allow the smolts to arrive at the Fraser estuary before the freshet. Given uncertainties about migration rates through Lillooet and Harrison lakes, experimentation would be required to identify the optimal timing window. Second, a fed fry strategy is an option given that rearing habitat is likely underutilized at current population sizes. Such a strategy has the advantage of allowing larger numbers of fish to be released at lower costs, and it permits the juveniles to move to preferred habitats during their year of freshwater residency. It requires: the release into vacant habitat or into Fee Creek for further rearing; the limitation of release size so as not to promote early emigration or the selection of unnatural rearing habitats; and post-freshet releases to avoid the depressed survivals caused by the freshet. Each strategy requires the marking of at least 100,000 fish; 275,000 eggs would be required to produce two 100,000 release groups, which equates to about 100 adults for brood stock. The usual DFO policy for populations of conservation concern is to take no more than 30% of the escapement for brood stock, which may result in an inability to meet the target in some years.

If enhancement is adopted as a recovery tool, the fish could be cultured at either the Birkenhead or another facility. The Birkenhead site requires major renovations and the addition of a surface water supply. The use of other facilities depends on numbers to be raised, the amount of space and water available, the risk of straying and the ability to imprint the fish on Birkenhead River water.

PRODUCTIVITY

The productivity of salmon populations is commonly estimated as an output parameter from a stock-recruitment relationship using, for example, a Ricker or Beverton-Holt model. We considered fitting the reconstructed Birkenhead Chinook data to a stock-recruitment model to estimate the productivity and capacity of the population. We decided against doing so for two reasons. First, of the 17 brood years for which CWT marking occurred, the estimated recoveries in fisheries and the escapement exceeded 100 in only six return years, leading to imprecise estimates of fishery exploitation. Furthermore, five different release strategies were used over these 17 broods. Such inconsistency in release type would contribute to between-brood variability in survival unrelated to natural sources of variability in stock productivity. Second, for every recovery year, estimates of CWT recoveries in one or more terminal fisheries had to be derived from data from other years. This lack of independence in terminal harvest estimates has likely led to an underestimation of the variability in these rates between years. Since terminal fisheries appear to represent one of the largest components of total harvest, particularly in recent years, this would lead to great uncertainty in the exploitation rate calculated from these data. This, coupled with the high degree of uncertainty associated with annual estimates of escapement, leads us to conclude that any stock-recruit relationship developed from such data would be highly questionable and likely uninformative. Consequently, we do not report estimates of population productivity.

PRODUCTIVE CAPACITY

Little information exists about the productive capacity of the Lillooet watershed for Chinook salmon. Capacity is defined as the average spawner abundance that produces an equivalent average number of mature adult spawners in the absence of fishing when the environment is stable. Also, it is the equilibrium point where the Ricker stock-recruitment function crosses the one-to-one replacement line. Hilborn and Walters (1992) suggested that productivities would be relatively similar within a species, yet capacity would be related to the area of the habitat and would vary among populations. Until recently, however, insufficient studies were available for salmon species to demonstrate these suggestions.

The productive capacity of watersheds for Chinook salmon increases with the freshwater habitat area, indicated by watershed area, and the same general relationship exists for the spawning abundance that produces the maximum sustained yield on average (Parken *et al.* 2006). Watershed area is an index of the habitat area that limits a Chinook salmon population and is the drainage area contributing to a particular channel or set of channels downstream of migration barriers. Watershed area explains about 91% of the variation in productive capacity and about 89% of the variation in the spawning abundance producing maximum sustained yield for populations with a stream-type life history.

For data-limited Chinook populations that do not have valid stock-recruit data, the watershed area habitat model can be used to estimate escapement targets (Parken *et al.* 2006). The habitat model predicts in units of total spawners; therefore, for populations with spawner indices, additional information is needed to adjust the indices to total escapement. The Birkenhead River watershed area is 547 km^2, which excludes 132 km^2 of inaccessible habitat upstream of its confluence with Taillefer Creek. For a population with a stream-type life history, a watershed of this size is expected to have a capacity of 4,400 fish; a spawner abundance of 1,700 fish would on average produce maximum sustained yield (Table 10).

ABORIGINAL TRADITIONAL KNOWLEDGE

Birkenhead Chinook are important to the First Nations that have occupied the Harrison-Lillooet and lower Fraser watersheds for thousands of years. The Lillooet, In-SHUCK-ch and, to some degree the Sto:lo, Musqueam and Tsawwassen people, have coexisted for centuries, depending, to one degree or another, on Birkenhead spring Chinook for food, social and ceremonial purposes. The health, identity and even the existence of these First Nations as distinct people depends on the survival and health of the salmon upon which they rely. Aboriginal traditional knowledge should be a necessary consideration for every assessment of the status of Pacific salmon stocks. Traditional knowledge can provide important information when considering the current status of a fish population because it often refers to a period prior to modern fisheries management. The Lil'wat and In-SHUCK-ch Nations have relied on Birkenhead Chinook for thousands of years. Consequently, it is likely that much useful information on the population dynamics of Birkenhead Chinook has been gleaned by these First Nations over many generations.

Through discussions with Lil'wat fisheries technicians and resource managers, we have initiated a process to compile the type of information that would be valuable to current fisheries management and assessments. Through consultation with community members, the Lil'wat fisheries technicians are collecting traditional information regarding historical distribution, timing and abundance of Birkenhead Chinook and other populations in the upper Lillooet River watershed. Although no specific information is reported here, we are confident that community members are considering this issue and will report on what they feel should be passed along as the information becomes available. It is hoped that the issue of traditional knowledge will be considered in upcoming treaty negotiations with the In-SHUCK-ch Nation.

ASSESSMENT AGAINST THE WILD SALMON POLICY

The Wild Salmon Policy (WSP; DFO 2005) requires the identification of conservation units (CU) and the establishment of processes to monitor the status of their populations, habitats and ecosystems. We have no guidance regarding the status of the Birkenhead population as a CU because the process to identify CUs is currently underway. On the basis of information presented in this research document, however, it is likely that Birkenhead will either form a CU itself or will be one of a small group of populations in a CU. If the latter, Birkenhead will certainly be the most data-rich population and will likely serve as the indicator of population, habitat and ecosystem status. Consequently, we provide brief comments on is use for this purpose.

POPULATION

The WSP identifies two benchmarks for spawning abundance and distribution that delineate red, amber and green zones, with changes between zones expected to initiate different levels of management intervention. The lower benchmark is intended to provide a substantial buffer from the level at which COSEWIC would consider the CU to be at risk of extinction. The upper benchmark is intended to identify a level that can be expected to maximize the annual catch for the CU.

Although our assessment data do not support a sophisticated analytic approach, we can identify four levels of population abundance that might be considered as benchmarks: a minimum effective population size (N_e) of 500, representing a minimum viable population size based on literature values (500-600); a habitat-based estimate of maximum sustained yield ($\hat{S}_{msy}$) of 1,700; and a habitat based estimate of total capacity ($\hat{S}_{rep}$) of 4,400.

We note that the average spawner population size during our assessment period was 480 spawners (or 449 spawners when hatchery brood stock is not included), while our estimate of the effective population size is 296-338. Regardless of the benchmark, therefore, population sizes need to increase from current levels.

HABITAT

The WSP requires an overview of important habitat issues in a CU and the identification of indicators that identify habitat health. The *Watershed Description and Use* section of this research document provides a general overview of habitat issues and could form the basis for the identification of indicators. In general, habitat issues with the potential to impact the chinook population can be classified as those that are likely to increase, remain stable or decrease in the foreseeable future. Increasing impacts are likely to include urbanization from population growth, mining, energy development, improved highway infrastructure and climate change; stable impacts are likely to be those associated with agriculture; and declining impacts are those related to forestry. Potential indicators should be selected based on these anticipated changes and should include, among other things, the monitoring of instream flow and hydrology, water temperature, water quality, the extent of impervious surfaces, highway improvements, land use conversions, sediment load, woody debris and riparian cover.

ECOSYSTEM

The WSP requires the inclusion of ecosystem values in the salmon management and assessment process, including the identification and monitoring of indicators. The process of identifying values and monitoring requirements has only just gotten underway, and is not sufficiently advanced for us to comment regarding its application to Birkenhead Chinook.

LIMITING FACTORS AND THREATS

SMALL POPULATION SIZE

Behaviour, reproductive biology and population genetics affect the minimum viable population (MVP) size for a species. Small populations face unique threats that pose little risk to larger populations: immediate threats such as *density effects* (*e.g.,* depensation – a decline in productivity that accelerates the population's decline, difficulty in finding a mate when there are few animals around, or increased effectiveness of predators as the prey population declines), *random demographic effects* (*e.g.,* a large imbalance in the sex ratio, or there being few survivors in a particular year even though environmental conditions are unchanged) and *random environmental variation* **(***e.g.,* changes in ocean conditions or catastrophes like landslides); and longer term threats such as *genetic processes* (*e.g.,* inbreeding depression and loss of variability), and *ecological feedback* (*e.g.*, important ecological functions like lake fertilization through carcass decomposition).

All of these processes must be taken into account when considering the MVP for Birkenhead Chinook. MVPs chosen in other jurisdictions provide useful comparisons. For example, the number of Snake River Chinook spawners required for the population to persist despite random environmental variation was estimated to be between 1,000 and 5,500 per generation, or 250-1,375 per year (NMFS 1995). Extinction risk from random demographic events increases exponentially as populations decline and should be considered a risk factor for any population of only a few hundred individuals (Goodman 1987). Genetic effects are dealt with by the concept of *effective population size*, which is usually smaller than the observed number of breeders (Frankham 1995). Allendorf *et al.* (1997) used genetic evidence to conclude that salmon populations with fewer than 2,500 spawners per generation (500 per year) would be at high risk where the effective population size is 20% of the number of breeders, a common assumption for Pacific salmon. The Washington Department of Fish and Wildlife (WDFW 1997) recommended a minimum spawning size of 3,000 per generation (600 per year).

The literature MVP values range from 250 to 1,375 spawners per year, with most clustering at about 500-600. As noted earlier (see *Reproductive Isolation*), the so called "50/500" rule suggests that *effective population* sizes of 50 pose an immediate risk of inbreeding depression, and effective populations of more than 500 are required to maintain long term adaptive genetic variation. Currently, the Birkenhead spawner population averages 480 per year, while our estimate of effective population is about 300. This suggests that current low abundances are a threat to the future viability of the population.

CAPTURE IN FISHERIES

We were unable to develop a meaningful stock-recruitment relationship (and associated productivity, estimates of the escapement (S_{msy}) and exploitation rate (*h**) at maximum sustainable production) for Birkenhead Chinook due to the probable biases that would result from uncertainties in estimates of annual escapement and freshwater harvest. Indeed, these uncertainties make our estimates of historic annual survivals and exploitation rates speculative, while current survivals and exploitation rates cannot be accurately assessed. Consequently, we cannot report on current exploitation rates and recommend changes based on metrics such as *h*.* While we cannot provide a technically sophisticated analysis, we can identify the fisheries that most impact Birkenhead Chinook, and discuss recent changes in those impacts in conjunction with observed trends in escapement to infer the level of threat to the population.

Our best estimate of the average exploitation on Birkenhead chinook from CWT data is about 50% (Table 7). The fisheries with the greatest historic and current impact are the Alaskan troll and the First Nations fisheries in the lower Fraser and Lillooet systems. Other marine and freshwater fisheries, while perhaps more important historically, now contribute an average of less than 12% of the impacts. Between 1975 and 2005, we believe that marine exploitation has declined. Exploitation in freshwater fisheries, while impossible to accurately quantify due to poor assessments, may have remained about the same in some fisheries (Lillooet System First Nations) or declined in others (the pattern in the lower Fraser First Nations fisheries is uncertain because, although early season fisheries have been eliminated, changes in gear and fishing intensity may compensate for reductions in total fishing effort). So, while overall exploitation may have declined or have been trendless, the distribution of impacts has likely shifted to freshwater fisheries. At the same time, escapements have been relatively trendless, suggesting either exploitation rates that are similar to historic levels or survival changes that have compensated for reductions in the exploitation rate. We cannot evaluate either possibility because we have inadequate information regarding true exploitation rates in either marine or freshwater fisheries, or survival changes resulting from changes in marine or freshwater habitats.

If fisheries continue to harvest the population at levels near 50%, they likely constitute a threat to the population at current spawner abundances. To significantly reduce the threat, actions would be required to reduce interceptions by the three principle harvesters of the population: Alaska troll, lower Fraser First Nations, and Lillooet System First Nations fisheries.

First Nations fisheries in the lower Fraser mainstem, and the Lillooet/Birkenhead systems have had similar impacts on Birkenhead Chinook. Combined, they are estimated to currently account for more than 50% of fishing mortality. All other Canadian fisheries combined account for only 12% of the catch. Consequently, if large reductions in domestic harvest are desired, such reductions will have to occur primarily in the First Nations fisheries. Better monitoring of catch by these fisheries, however, would be required in conjunction with any management changes. Such actions are problematic because the management of each of the fisheries is complicated. Changes to Alaskan fisheries would likely require an extra-ordinary bilateral process between Canada and the US. Canada would likely need to establish a bilaterally agreed upon escapement goal, show that the goal had not been achieved for a number of years using scientifically defensible assessment techniques, and demonstrate that all reasonable actions had been taken domestically to reduce harvest. First Nations fisheries are similarly complicated, especially in the Lillooet System where Birkenhead Chinook are the only salmon available for a substantial part of the year. Any actions in these fisheries would likely need to be linked to reductions in marine fisheries.

CLIMATE CHANGE

Global climate models predict future climates in southwestern BC that are characterized by warmer temperatures, and precipitation increases in the fall and winter and decreases in the summer (Whitfield *et al.* 2002, 2003). Hydrological models suggest that these climate changes will result in significant shifts in the hydrology of the Lillooet River in the next 80 years, including: a 30-40% increase in total stream flow, with most of the increase occurring in the winter (currently the low flow period); increased frequency and severity of floods resulting from more rain on snow and winter snowmelt events; a progressively earlier and more pronounced spring freshet; and lower summer flows. Similar changes can be expected in the Birkenhead.

There are indications that the climate in the Lillooet System and the predicted changes in river hydrology are already occurring. First, glaciers in the Lillooet watershed have been retreating for decades, and especially since the Pacific Decadal Oscillation in 1976 (Dan Moore, pers. comm.). The Place Glacier, a small glacier in the Birkenhead System, is one of the few that have been intensively monitored over long time periods (since 1965). It has been in rapid retreat since 1977, resulting in declining late-summer stream flows and higher water temperatures in its outflow creek, a tributary of Poole Creek (Moore and Demuth 2001). Second, the 1986-1995 mean discharge pattern for the Lillooet River has changed relative to 1976-1985; the winter flows are higher and more variable, snowmelt begins earlier, and summer flows are lower (Fig. 10).

What are the likely impacts of the predicted future climate on Birkenhead Chinook? First, incubating eggs will be more vulnerable to scouring resulting from high flows associated with more frequent rain on snow and snowmelt events. This could be mitigated to some extent by the provision of more stable natal environments through measures such as improving access to upstream areas such as Taillifer Creek and Birkenhead Lake. Second, the turbidity associated with higher spring flows might reduce predation on emigrant fry. Third, fry survival in the rearing habitats of Lillooet Lake and River might increase if the lower summer flows are associated with warmer water temperatures.

GEOMORPHIC PROCESSES

The upper Lillooet watershed has a history of catastrophic geomorphic events, both rare explosive volcanic eruptions and more frequent massive landslides. The Mount Meager volcanic complex, located 70 km northwest of Lillooet Lake, is part of the Garibaldi volcanic belt formed by the subduction of the Juan de Fuca plate beneath the continental plate. The last eruption, 2,350 years ago, blanketed the area in pumice and sent an ash plume 500 km to the east. Pyroclastic flows dammed the Lillooet River to a depth of 100 m; the failure of the dam resulted in a cataclysmic outburst flood with a volume of 10^9 m^3 that inundated the valley to a height of at least 30 m for 5.5 km downstream from the blockage (Hickson *et al.* 1999). The area remains geologically active; future eruptions are possible. The explosive nature of past eruptions indicates that the volcano can pose a significant threat to downstream habitats; volcano generated debris flows could travel as far as Pemberton (Natural Resources Canada 2005).

In addition to volcanic eruptions, landslides pose a significant threat. Mount Meager is geologically one of the least stable areas in BC, a result of the steep mountain slopes, weak hydrothermally altered volcanic rock, heavy runoff from rainfall or ice and snow melt, and the recent rapid recession of glaciers (Bovis and Jakob 2000; Friele and Clague 2004). It has been the site of three landslides larger than one million cubic meters in the last century, and two prehistoric ones that were two orders of magnitude larger that likely blocked the Lillooet River (Hickson *et al.* 1999; Bovis and Jakob 2000). Because much of the upper Lillooet River flows in a single channel bounded by steep slopes underlain by unstable volcanic rock, it is vulnerable to future blockages by landslides; the accelerating retreat of glaciers and the climate change related increases in annual rainfall are expected to increase the frequency of slope instabilities in the future (Miles and Associates 2001). Such failures have the potential to cause dams and outburst floods that could have a devastating impact on downstream fish habitat and human settlements.

HABITAT ALTERATION

With the recent change in the local economy to urban development and tourism, it seems unlikely that the declining forestry or the stable agricultural sectors pose a sustained threat to the Birkenhead Chinook population. Instead, the principle habitat-related threats appear to be the progressive urbanization associated with rapid population growth and the use of the valleys as transportation corridors (see *Watershed Development)*. Because the principle urban centres, especially Pemberton, are reasonably remote from sensitive Chinook habitat, we focus on the threat from potential derailments on the railroad, especially in the 21 km where the rail line parallels the river and the downstream habitats.

Birkenhead Chinook are highly vulnerable to toxic spills almost year-round in the Birkenhead River: as holding adults from late May to late August; as spawners in September; as eggs and alevins from September to late February; and as migrating fry from March to early May. While less vulnerable as juveniles rearing in Lillooet Lake and River, they would still be impacted by a spill similar to that which occurred in the Cheakamus River in 2005.

DISCUSSION

The Birkenhead is a genetically distinct chinook population with unique local adaptations that make it important to the evolutionary legacy of the species. As such, it meets the COSEWIC definition of a Nationally Significant Population and constitutes a designatable unit. Furthermore, it is likely to cluster with few if any other populations as a conservation unit under DFO’s Wild Salmon Policy and, given its assessment history, is likely to be the population status indicator of any unit to which it is assigned.

An evaluation of population status should consider trends in abundance as well as abundance relative to specific benchmarks. The population has been essentially trendless over our thirty year review period, showing a slight decrease through 2004 and a slight increase through 2005 that reflects the record escapement in that year. Although fishery officer estimates suggest that the population declined from more abundant levels, we consider those reports suspect and lend them little weight unless they are confirmed by the local or traditional aboriginal knowledge that is currently being collected.

Our estimation of total spawner abundance requires a number of simplifying assumptions regarding the relative visibility of spawners when observed from helicopters versus the ground, and the relationship between peak live counts and total population size. While we recognize that the utility of the annual estimates is limited by less than ideal assessments, we consider the time series to be a reasonable indicator of long term average abundance. The population has been relatively small throughout the entire time series, averaging only 480 spawners, and is less abundant than the minimum viable population sizes accepted for chinook salmon populations in other jurisdictions. It is also less than the minimum effective population size in general use among conservation biologists. When considered in conjunction with the population's low levels of heterozygosity and allelic richness, this is an indication that the population should be allowed to grow if its long term viability is not to be placed at risk. That being said, we have not recommended targets for population growth because such benchmarks are established in a policy environment that considers socio-economic factors; the Cultus Recovery Strategy discusses potential benchmark that also could be considered for Birkenhead (Cultus Sockeye Recovery Team 2006). We note, however, that the lowest potential upper benchmark identified in this research document ($\hat{S}_{msy}$ = 1,700) is over three times the average long term abundance, suggesting that there is considerable unrealized production in this system.

Small populations such as the Birkenhead are more vulnerable to environmental variation than are larger ones. This is a topical concern because we have presented evidence that climate change has already caused hydrographic changes in the Harrison-Lillooet System, and future predictions are for more dramatic changes. One aspect of the type of climate change that is predicted for the Georgia Basin is increased fall and winter precipitation in the form of rain-on-snow and snowmelt events that would increase the frequency and amplitude of floods. This is a particular threat to populations such as the Birkenhead because their eggs remain in the gravel for at least five months. Although the population has remained at vulnerable levels for thirty years, the new risks associated with climate change suggest that further delays in implementing actions to promote population growth should be avoided.

We have identified only two potential actions to achieve population growth; ironically, they are the same as those identified and implemented in the 1970s: harvest reductions and enhancement. The main fisheries impacting Birkenhead Chinook are the troll fisheries in Alaska and the First Nations fisheries in the lower Fraser and Lillooet systems. The regulation of these fisheries is complicated; regulatory changes would require international negotiations as well as the consideration of Canada's fiduciary responsibilities to First Nations. We caution, however, against relying solely on enhancement measures in view of the disappointing results of the previous enhancement project. While we believe that procedural changes can improve survivals, we also acknowledge that this assumption may not correct. In that case, enhancement would constitute a threat given that the wild fish removed from the spawning grounds might not be replaced by subsequent production and that fish in hatchery facilities face a small inherent risk of loss from catastrophic failure.

The small apparent population size and the high degree of uncertainty in the assessment data suggest caution in the planning and management of actions that could affect population abundance or productivity. Of concern, then, is the reliance of managers on analytic tools such as the PST chinook model to plan fisheries and assess impact on this chinook population. For example, the CTC chinook model includes the Birkenhead in the *Fraser Early* group, an aggregation of spring and summer run populations that the model assigns a marine distribution that is typical only of the latter. Even the aggregation with other spring run Fraser Chinook populations is a concern given the population's unique marine distribution, run timing, size, age at maturity and terminal abundance pattern. Independent assessment tools are required.

RECOMMENDATIONS

1. **Response Planning:** At current abundances, the future viability of the Birkenhead Chinook population is at risk, and the level of risk will increase as the impact of climate change increases. Consequently, we recommend the development of a comprehensive plan that identifies recovery goals and time frames, and integrates options to improve freshwater survival (*e.g.,* enhancement, stewardship) with harvest control and other measures.

2. **Spawner Population:** Our reconstruction of the time series of escapement estimates, while useful to approximate population abundance, do not constitute the rigorous annual estimates that we believe are necessary for a scientifically defensible characterization of population status. We recommend restructuring the assessment project to permit the generation of AUC escapement estimates:

    - Frequent foot surveys to estimate total spawner-days and to determine the date of peak spawning that triggers the overflight;
    - Annual direct estimates of spawn residence time and observer efficiency;
    - Periodic verification using more accurate techniques such as an enumeration fence or mark-recapture study; and
    - Intensive carcass recovery to better permit the characterization of the effective population size.

3. **Freshwater Fisheries:** Two of the three principle harvesters of Birkenhead Chinook are freshwater First Nations fisheries, yet both suffer assessment deficiencies that limit our ability to characterize population status. This is especially true of the fisheries in the Lillooet System. These fisheries are unrestricted with respect to fishing time and are capable of harvesting at rates that exceed 60%, yet they have not been assessed for almost 15 years. We recommend:

    - Evaluation and improvement of the 2005-2006 fishery assessment pilot project in the Lillooet System. This project, conducted by Lil'wat Nation fisheries technicians, interviews fishers about catch and fishing effort and attempts to raise community awareness about the importance of fishery assessments. The project should be structured to ensure: full temporal coverage of the fishery; that all fishing sites are assessed; that assessments are structured to permit the weekly reporting of effort and catch by species; and that the chinook catch is sampled for stock composition. A similar project is required to assess the In-SHUCK-ch fishery;
    - Annual tissue sampling of the lower Fraser First Nations fisheries for genetic stock composition analyses to replace the current *ad hoc* process.

4. **Marine Fisheries:** Our evaluation of current impacts in the marine fisheries is constrained by our reliance on genetic stock identification techniques that employ sample sizes that are not intended to detect small populations such as Birkenhead. This is becoming a more serious issue given regulatory changes that make the former assessments of CWT recoveries progressively less reliable. We recommend restructuring the assessments to address this issue, either through substantial increases in the marine sampling program, or the re-implementation of CWT marking. If the latter, we also recommend establishing mark incidence assessments and expanding the head recovery system to the freshwater First Nations fisheries.

5. **Habitat:** Habitat issues have been important in the past and are likely to continue to be so in light of the expected human population growth, transportation infrastructure improvements and climate change in the Lillooet System. While the habitat indicators and monitoring requirements required by the WSP have not yet been determined, it seems certain that the Birkenhead will be a significant population in its conservation unit and that assessment of its habitats will be required. In anticipation, efforts should be made to reestablish two key monitoring systems that existed previously but have since lapsed: temperature monitoring

by DFO; and surface flow and sediment monitoring by Environment Canada. Other habitat assessments such as groundwater mapping should also be considered.

PSARC RECOMMENDATIONS

This research document was reviewed by the Pacific Science Advice Review Committee (PSARC) on May 17, 2006. The following is extracted from the Committees report (Riddell 2006).

Several areas emerged as key focal points for the Subcommittee discussion. These were:

- Little is known about juvenile rearing habitats and the factors that limit the population's freshwater productivity;
- The current assessments of terminal (mainly First Nations) harvest and spawning escapement estimates are inadequate to allow a scientifically defensible characterization of population status; improvements are required;
- The available escapement data, while of uncertain accuracy and precision, show a population that is stable but at an abundance that may threaten its future viability;
- Tagging results and genetic assessments indicate that the population is genetically isolated and has attributes that made it distinctive. It represents a relatively unique and significant component of the genetic diversity of chinook in the Fraser River and BC; and
- The genetic assessment also indicated relatively low within-population allelic diversity and heterozygosity which raised concerns about the longer term viability of the population and its ability to adapt to changing environmental conditions.

The Subcommittee concluded that while the Birkenhead River Chinook population appears small and relatively stable, the low abundance and results of the genetic assessment are consistent with it being identified as a *Population of Concern* (COSEWIC terminology) (Riddell 2006). The Subcommittee recommended acceptance of the paper after minor revisions (which have been completed) and additionally made the following specific recommendations:

1. Biological evidence is sufficiently compelling of the relative uniqueness of the Birkenhead River Chinook population that these and certain other lower Fraser River spring populations (*e.g.,* upper Pitt River) warrant consideration as a conservation unit under the WSP.

2. The process currently underway to acquire aboriginal traditional knowledge from Lil'wat Nation elders should be expanded to include the In-SHUCK-ch Nation.

3. A response team should be formed to develop population and habitat assessment frameworks that are consistent with the information requirements for conservation units under the WSP and incorporates recommendations 1-5 of the Working Paper.

4. The large uncertainty in the terminal return data and the lack of a confidence measures around annual escapement estimates necessitates that caution be used in actions that could impact the abundance or productivity of Birkenhead River Chinook.

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LITERATURE CITED

Alexander, C.A.D. 2001. 2000 native catch estimates on the lower Fraser River and recommended improvements for future aerial-access creel surveys. Prepared by ESSA Technologies Ltd. For Department of Fisheries and Oceans, Delta.

Allendorf, F., Bayles, D., Bottom, D.L., Currens, K.P., Frissell, C.A., Hankin, D., Lichatowich, J.A., Nehlsen, W., Trotter, P.C., and Williams, T.H. 1997. Prioritizing Pacific salmon stocks for conservation. Conservation Biology 11: 140-152.

Bailey, D.D., Godin, R.J., and Simpson, K. 1979. Chinook salmon enhancement in the Lillooet-Birkenhead rivers system – watershed information, juvenile studies, spawning ground surveys and hatchery operations 1975-1978. Internal report, Department of Fisheries and Oceans, Vancouver.

Bailey, R.E., Irvine, J.R., Candy, J.R., Parken, C.K., Lemke, S.L., Sullivan, M., and Wetklo, M. 2001. Summary of stock assessment information for selected early returning Chinook salmon populations of the Fraser River watershed. DFO. Canadian Science Advisory Secretariat Research Document 2001/134. Available online at: http://www.dfo-mpo.gc.ca/csas/Csas/publications/ResDocs-DocRech/2001/2001_134_e.htm

BC Parks. 1999a. Management direction statement for Upper Lillooet Provincial Park. Ministry of Environment, Lands and Parks, Garibaldi/Sunshine Coast District, Brackendale, B.C.

BC Parks. 1999b. Birkenhead Lake Provincial Park management plan. Ministry of Environment, Lands and Parks, Garibaldi/Sunshine Coast District, Brackendale, B.C.

Beacham, T.D., Supernault, K.J., Wetklo, M., Deagle, B., Labaree, K., Irvine, J.R., Candy, J.R., Miller, K.M., Nelson, R.J., and Withler, R.E. 2003. The geographic basis for population structure in Fraser River Chinook salmon (*Oncorhynchus tshawytscha*). Fish. Bull. 101(2): 229-242.

Berezay, G., MacKinnon, C.N., and Fedorenko, A.Y. 1988. Birkenhead River Chinook hatchery operational history 1977-1986. Internal report, Department of Fisheries and Oceans, Vancouver.

Bolton, J.L. 1976. Birkenhead River salmon hatchery feasibility report. Prepared for Johnstone Strait, Fraser River and Juan de Fuca Division, Fisheries Service, Environment Canada. Vancouver.

Bovis, M.J., and Jakob, M. 2000. The July 29, 1998, debris flow and landslide dam at Capricorn Creek, Mount Meager volcanic complex, southern Coast Mountains, British Columbia. Can. J. Earth Sci. 37: 1321-1334.

Brown, T.G., and Winchell, P. 2004. Fish community of Shuswap Lake's foreshore. Can. Tech. Rep. Fish. Aquat. Sci. 2568: 39 p.

Candy, J.R., Irvine, J.R., Parken, C.K., Lemke, S.L., Bailey, R.E., Wetklo, M. and Jonsen, K. 2002. A discussion paper on possible new stock groupings (Conservation Units) for Fraser River Chinook salmon. DFO Canadian Science Advisory Secretariat Research Document 2002/085.

Cavalli-Sforza, L.L., and A.W.F. Edwards. 1967. Phyologenetic analysis: models and estimation procedures. Evolution 21: 550-570.

CTC. 2005. Catch and escapement of Chinook salmon under Pacific Salmon Commission jurisdiction 2004. Pacific Salmon Commission, Chinook Technical Committee Report TCCHINOOK (05)-2.

Cultus Sockeye Recovery Team. 2006. National recovery strategy for sockeye salmon (*Oncorhynchus nerka*), Cultus Lake population, in British Columbia. Recovery of Nationally Endangered Wildlife(RENEW). In press.

Dempson, J.B., Irvine J.R., and Bailey, R.E. 1998. Relative abundance and migration timing of Chinook salmon, *Oncorhynchus tshawytscha*, from the Fraser River, British Columbia, Albion Test Fishery, 1981-1995. Can. Manusc. Rep. Fish. Aquat. Sci. 2459: 25 p.

Desloges, J.R., and Gilbert, R. 1992. Sediment sources and hydromorphic inferences from glacial lake sediments; the post-glacial sediment record of Lillooet Lake, British Columbia. Journal of Hydrology 159(1-4): 375-393.

DFO. 2004. Proceedings of the PSARC Salmon Subcommittee Meeting, October 19-20, 2004. DFO Canadian Scientific Advisory Secretariat Proceeding Series 2004/032.

DFO 2005. Canada's policy for conservation of wild Pacific salmon. Fisheries and Oceans Canada, Vancouver. Available online at: http://www.pac.dfo-mpo.gc.ca/fraserriver/firstnations/2005ChinookDocument.pdf

DFO. 2006. Proceedings of the PSARC salmon subcommittee meeting, May 17-18, 2006. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2006/018.

Dickson, R. 1996. Upper Fraser Chinook helicopter ".65" expansion documentation. Department of Fisheries and Oceans, internal memorandum.

Dixon, G. 1985. Birkenhead R. adult Chinook. Department of Fisheries and Oceans, internal memorandum.

English, K.K., Bocking, R.C., and Irvine, J.R. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49: 1982-1989.

Environment Canada. 2006. Archived hydrometric data. Available online at: http://www.wsc.ec.gc.ca/hydat/H2O/

Farwell, M.K., Schubert, N.D., Wilson, K.H., and Harrison, C.R. 1987. Salmon escapements to streams entering statistical areas 28 and 29, 1951 to 1985. Can. Data Rep. Fish. Aquat. Sci. 601: 166 p.

Farwell, M.K., Bailey, R.E., and Rosenberger, B. 1999. Enumeration of the 1995 Nicola River Chinook salmon escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2191: 44 p.

Felsenstein, J. 1993. PHYLIP: Phylogeny Inference Package. University of Washington, Seattle.

Fielden, F.J., and Slaney, T.L. 1991. Review of Fraser River Chinook and coho escapement information for potential index streams. Prepared for Department of Fisheries and Oceans, Fraser River, NBC and Yukon by Aquatic Resources Limited, Vancouver.

Frankham, R. 1995. Conservation genetics. Annu. Rev. Genetics 29: 305-327.

Fraser, F.J., Starr, P.J., and Fedorenko, A.Y. 1982. A review of the Chinook and coho salmon of the Fraser River. Can. Tech. Rep. Fish. Aquat. Sci. 1126: 130 p.

Friele, P.A., and Clague, J.J. 2004. Large Holocene landslides from Pylon Peak, southwest British Columbia. Can. J. Earth Sci. 41: 165-182.

Gilbert, R. 1973. Observations of lacustrine sedimentation at Lillooet Lake, British Columbia. PhD Thesis, University of British Columbia, Vancouver.

Goodman, D. 1987. The demography of chance extinction. Pages 11-34 in M. E. Soulé, ed. Viable populations for conservation. Cambridge University Press, Cambridge, U.K.

Goudet, J. 2001. FSTAT, a program to estimate and test gene diversities and fixation indices (version 2.9.3). Available from http://www2.unil.ch/popgen/softwares/fstat.htm

Greenbank, J. 2005. Escapement monitoring in the Birkenhead River and selected upper Lillooet River tributaries, 2004/05. Prepared for Lil'wat Fisheries Commission by Greenbank Environmental Services, Coquitlam. *In preparation.*

Greenbank, J. 2006. Birkenhead Chinook status report. Prepared for Lil'wat Fisheries Commission by Greenbank Environmental Services, Coquitlam.

Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin 180. Ottawa.

Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). In: C. Groot, and L. Margolis, (eds.). Pacific salmon life histories. UBC Press, Vancouver, Canada.

Hickson, C.J., Russell, J.K., and Stasiuk, M.V. 1999. Volcanology of the 2350 B.P. eruption of Mount Meager volcanic complex, British Columbia, Canada: implications for hazards from eruptions in topographically complex terrain. Bulletin of Volcanology 60: 489-507.

Hilborn, R., and Walters, C.J. 1992. Quantitative stock assessment: choice, dynamics, and uncertainty. Chapman and Hall. New York, N.Y.

Hume, J., MacLellan, J.S., and Shortreed, K. 2000. Comparison of fishing gears in different habitat types in Harrison Lake – 2000 progress report. Internal document, Cultus Lake Salmon Research Laboratory.

Johnson, R., and Sutherland, D. 2004. The upper Birkenhead River watershed, British Columbia: a preliminary water quality assessment. Ministry of Water, Land and Air Protection, Lower Mainland Region.

Jones, L. 2004. Birkenhead Chinook. Letter from Liz Jones, Land and Resources Department, Mount Currie Band, to Jim Wild, Director, Lower Fraser Area, Fisheries and Oceans Canada.

Kerr Wood Leidal Associates. 2002. Straighten the river, lower the lake: the impacts of the last century's river projects, and how Mike 11 helped plan for the future. Presented at the 2002 DHI User Conference, Orlando, Florida.

Korman, J. 2006. Risk, benefits, and uncertainties associated with using hatchery supplementation to recover the Cheakamus River steelhead population, and rules to assess recovery status. Prepared for the Cheakamus Ecosystem Restoration Technical Committee. Available online at: http://www.pskf.ca/publications/cheakums05/SH_Supp_Assessment.pdf

Levings, C.D., Scrivener, J.C., Andersen, B., Shirvell, C., and Lauzier, R. 1985. Results of reconnaissance sampling for juvenile salmonids in the upper Fraser and selected tributaries, August and October, 1984. Can. Data Rep. Fish. Aquat. Sci. 5439: 25 p.

Macdonald, A.L. 1992. The Indian food fishery of the Fraser River: 1991 summary. Can. Data Rep. Fish. Aquat. Sci. 876: 86 p.

Macdonald, R.W., and Paton, D.W. 1998. A reconnaissance of contaminants in the Fraser River drainage basin using dated sediment cores from six lakes. Environment Canada, unpublished. 74 p.

Miles and Associates Ltd. 2001. Effects of climate change on the frequency of slope instabilities in the Georgia Basin, B.C. – Phase 1. Canadian Climate Action Fund Project Number A160. Ottawa.

Moore, R.D., and Demuth, M.N. 2001. Mass balance and streamflow variability at Place Glacier, Canada, in relation to recent climate fluctuations. Hydrological Processes 15 (18): 3473-3486.

Natural Resources Canada. 2005. Catalogue of Canadian volcanoes. Garibaldi volcano belt: Mount Meager volcanic field. Available online at: http://gsc.nrcan.gc.ca/volcanoes/cat/feature_meager_e.php

Nelson, R.J., Small, M.P., Beacham, T.D., and Supernault, K.J. 2001. Population structure of Fraser river Chinook salmon (*Oncorhynchus tshawytscha):* an analysis using microsatellite DNA markers. Fish. Bull. 99: 94-107.

Nicol, S., and Sunderman, R. 2005. Sea-to-Sky land and resource management plan (LRMP): socio-economic base-case update. Prepared for the Province of British Columbia, 64 p.

NFCP Technical Committee. 2005. Nechako Fisheries Conservation Program technical data review: 1988-2002. Prepared by the NFCP Technical Committee for the Nechako Fisheries Conservation Program.

NMFS. 1995. Proposed recovery plan for the Snake River. National Marine Fisheries Service. Seattle.

Northcote, T.G., and Larkin, P.A. 1989. The Fraser River: a major salmonine production system. *In* D.P. Dodge (ed.), Proceedings of the International Large River Symposium. Can. Spec. Publ. Fish. Aquat. Sci. 106: 172-204.

Parken, C.K., McNicol, R.E., and Irvine, J.R. 2006. Habitat-based methods to estimate escapement goals for data limited Chinook salmon stocks in British Columbia, 2004. DFO Canadian Science Advisory Secretariat Research Document 2006/083. Available online at http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2006/RES2006_083_e.pdf

Perrière , G. and Gouy, M. 1996. WWW-Query: An online retrieval system for biological sequence banks. Biochimie 78: 364-369.

PSC. 1987. Joint Chinook technical committee 1986 annual report. TCHINOOK (87) – 4. Pacific Salmon Commission, Vancouver.

Reiman, B.C., and Allendorf, F.W. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21: 756-764.

Rosberg, G.E., and Millar, J. 1987. Juvenile Chinook and coho migration monitoring in the lower reach of the Fraser River mainstem, 1985-1986. Prepared for Fisheries and Oceans Canada by G.E. Rosberg and Associates, Burnaby.

Schaefer, M.B. 1951. A study of the spawning populations of sockeye salmon in the Harrison River system, with special reference to the problem of enumeration by means of marked members. International Pacific Salmon Fisheries Commission Bulletin IV: 207 p.

Schubert, N.D. 1983. The Indian food fishery of the Fraser River: catch summary, 1951-1982. Can. Data Rep. Fish. Aquat. Sci. 412: 357 p.

Schubert, N.D., Paterson, P.G., and McNair, C.M. 1988. The Fraser River Chinook salmon test fishery: data summary, 1980-87. Can. Data Rep. Fish. Aquat. Sci. 709: 193 p.

Scott, W. B., and Crossman, E.J. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184. Ottawa.

Shortreed, K.S., Morton, K.F., Melange, K., and Hume, J.M.B. 2001. Factors limiting juvenile sockeye production and enhancement potential for selected B.C. nursery lakes. DFO. Canadian Stock Assessment Secretariat Research Document 2001/098.

Tabor, R.A., Celedonia, M.T., Mejia, F., Piaskowski, R.M., Low, D.L., Footen, B., and Park, L. 2004. Predation of juvenile Chinook salmon by predatory fishes in three areas of the Lake Washington basin. *In:* Proceedings of the 2004 Greater Lake Washington Chinook Workshop. Available on-line at http://cityofseattle.net

Tajima, F. 1992. Statistical method for estimating the effective population size in Pacific salmon. Journal of Heredity 83(4): 309-311

Teel, D. J., Miller, G. B., Winans, G. A., and Grant, W.S. 2000. Genetic population structure and origin of life history types in Chinook salmon in British Columbia, Canada. Trans. Amer. Fish. Soc. 129: 194-209.

Wang J. 2004. Sibship reconstruction from genetic data with typing errors. Genetics 166: 1963-1979.

Wang, J., and Whitlock, M.C. 2003. Estimating effective population size and migration rates from genetic samples over space and time. Genetics 163: 429-446.

Waples R.S. 1990. Conservation genetics of Pacific Salmon. III. Estimating effective population size. Journal of Heredity 81(4): 277-289.

Waples, R.S. 1991. Definition of “species” under the Endangered Species Act: application to Pacific Salmon. NOAA Technical Memorandum NMFS F/NWC-194.

Waples, R. S., Johnson, O.W., Aebersold, P.B., Shiflett, C.K., VanDoornik, D.M., Teel, D.J., and Cook, A.E. 1993. A genetic monitoring and evaluation program for supplemented populations of salmon and steelhead in the Snake River Basin. Annual Report of Research to the Division of Fish and Wildlife, Bonneville Power Administration, Department of Energy Project 89-096. Northwest Fisheries Science Center, Seattle, Washington.

WDFW. 1997. Final environmental impact statement for the wild salmonid policy. Washington Department of Fish and Wildlife, Olympia, Washington. 133 p.

Whitfield, P.H., Reynolds, C.J., and Cannon, A.J. 2002. Modelling streamflow in present and future climates: examples from the Georgia Basin, British Columbia. Canadian Water Resources Journal 27 (4): 427-456.

Whitfield, P.H., Wang, J.Y., and Cannon, A.J. 2003. Modelling future streamflow extremes – floods and low flows in Georgia Basin, British Columbia. Canadian Water Resources Journal 28 (4): 633-656.

FIGURES

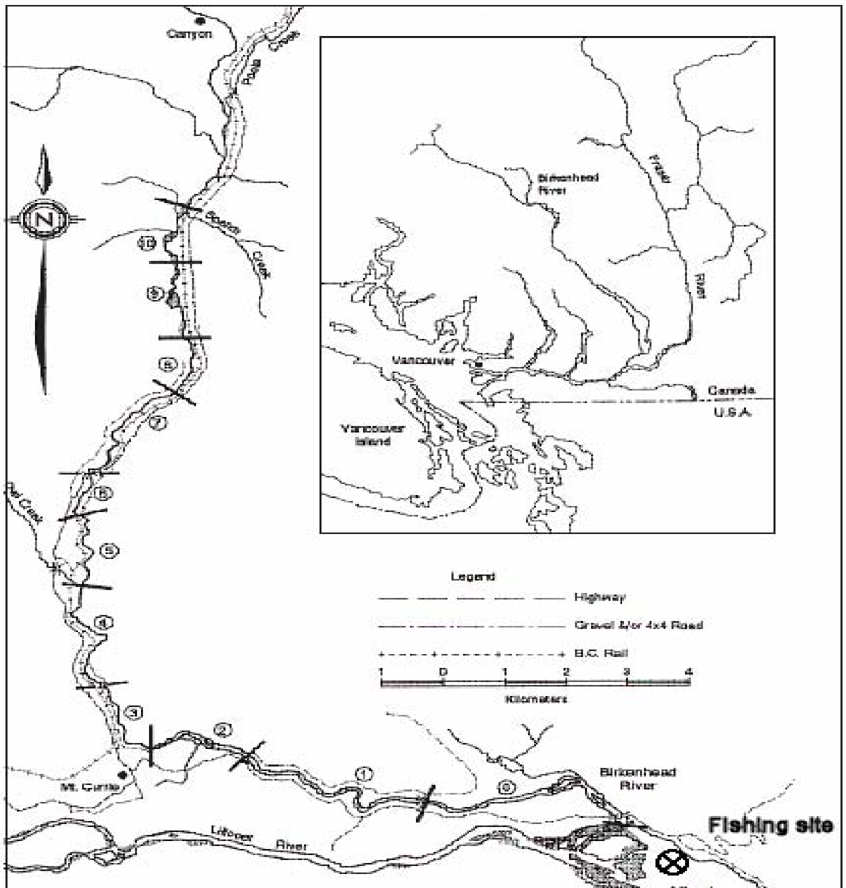


Figure 1. Birkenhead River study area location map

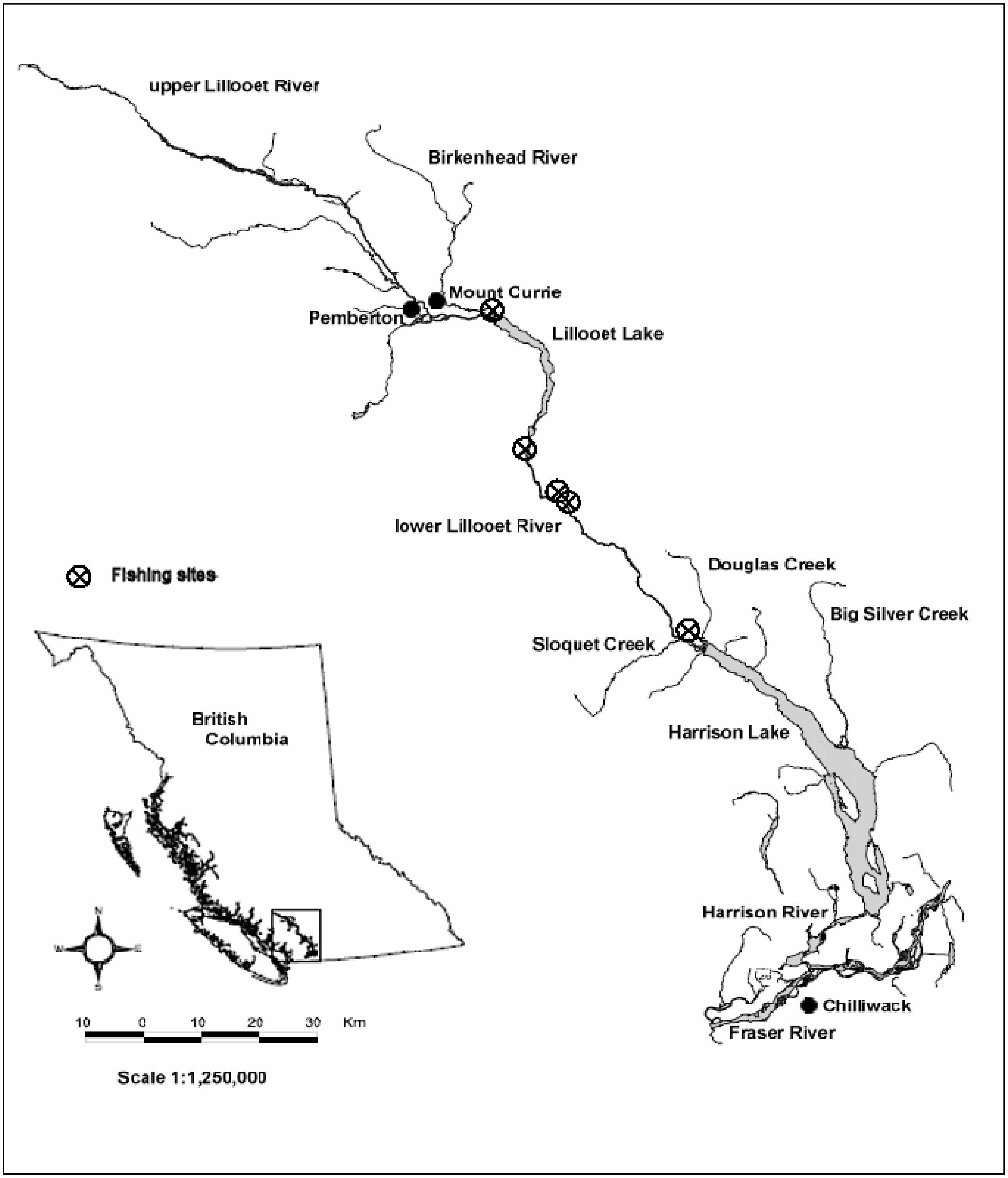


Figure 2. Map of the Harrison-Lillooet River system.

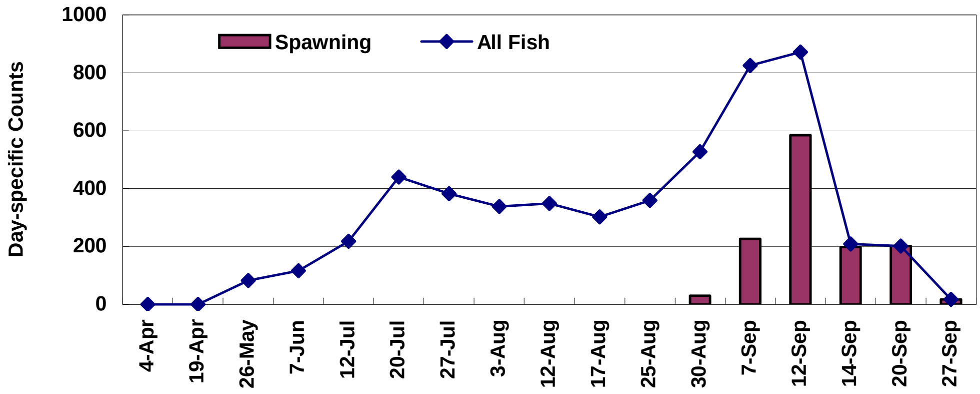


Figure 3. Observations of chinook salmon from foot surveys of the Birkenhead River in 2005. Chinook were observed primarily in the area known as the *flats*; holding and spawning chinook were reported separately.

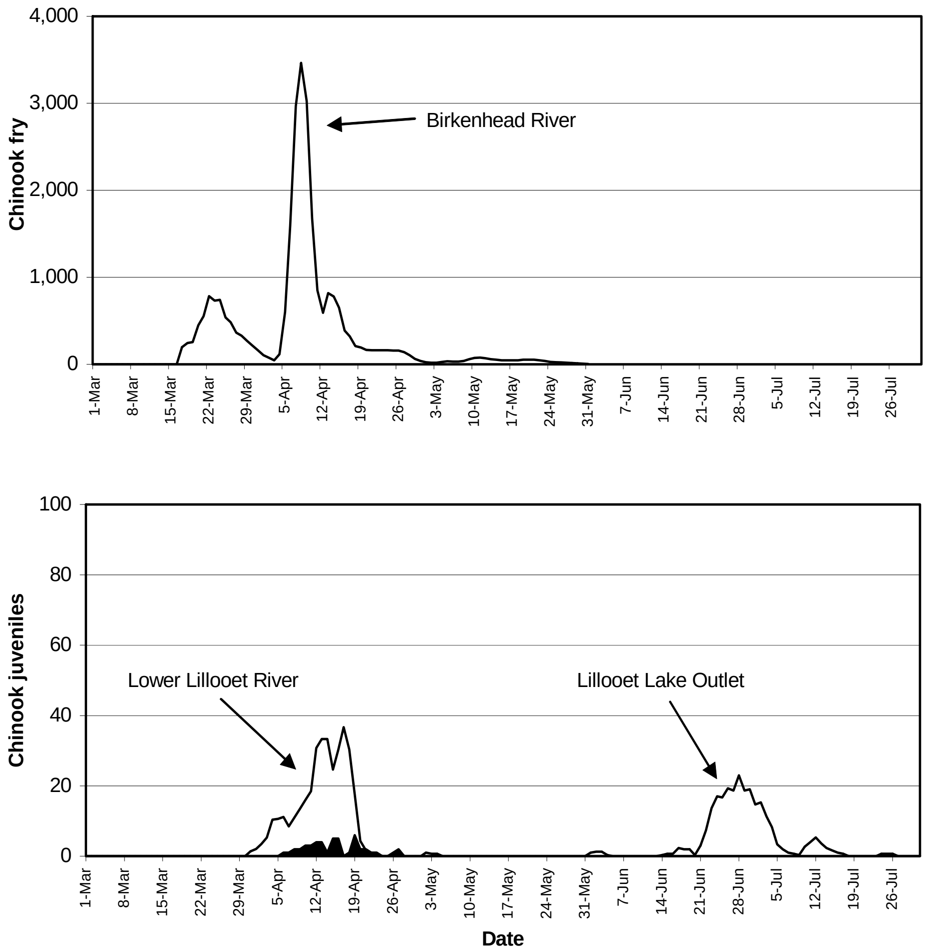


Figure 4. Daily catches of chinook juveniles by inclined plane traps in the Birkenhead River, at the outlet of Lillooet Lake, and in the lower Lillooet River. Lines represent chinook fry, solid areas represent chinook smolts. Data are from Berezay *et al.* (1988).

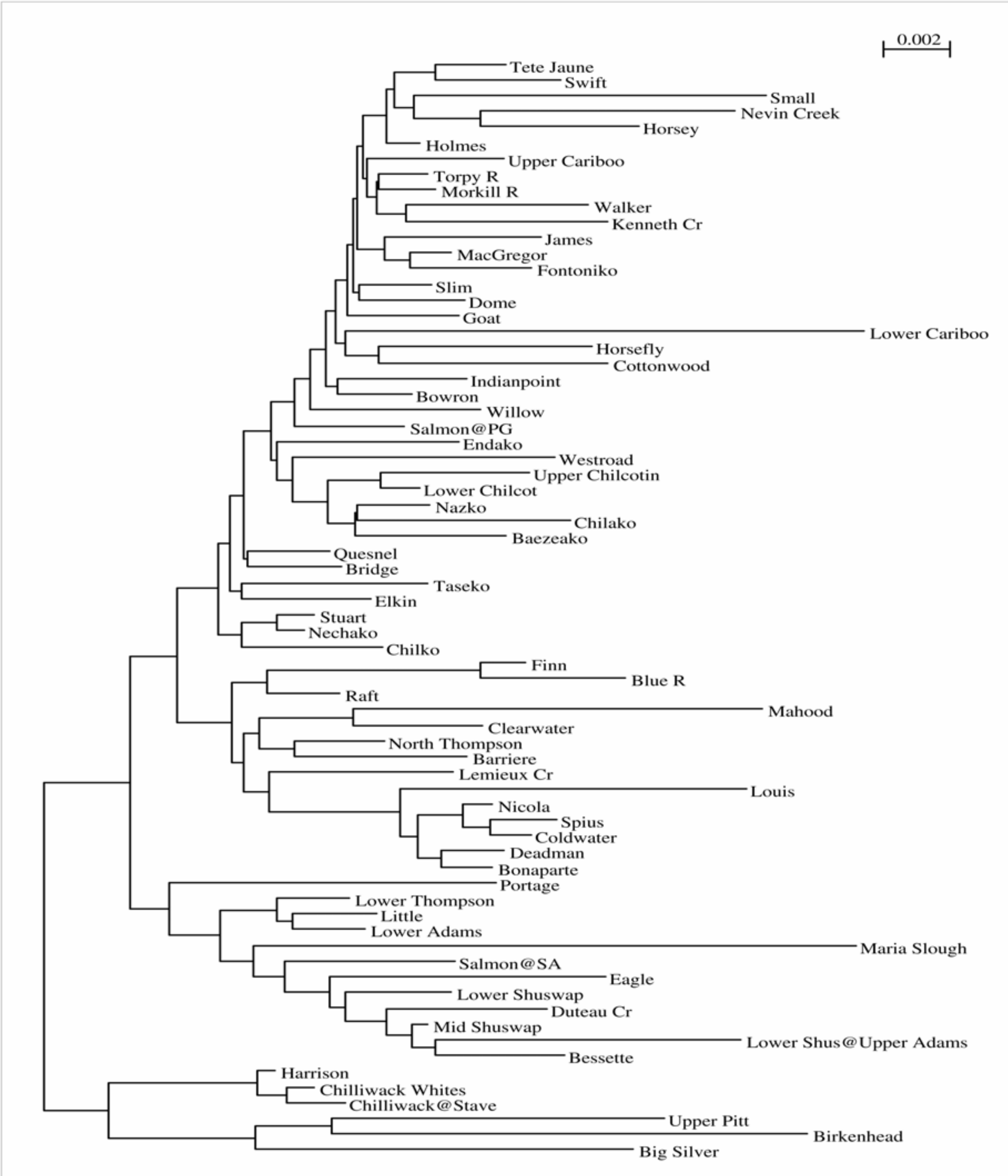


Figure 5. Neighbour-joining dendrogram of Cavalli-Sforza and Edwards (1967) chord distances showing the clustering of Birkenhead River Chinook and other Fraser River Chinook populations.

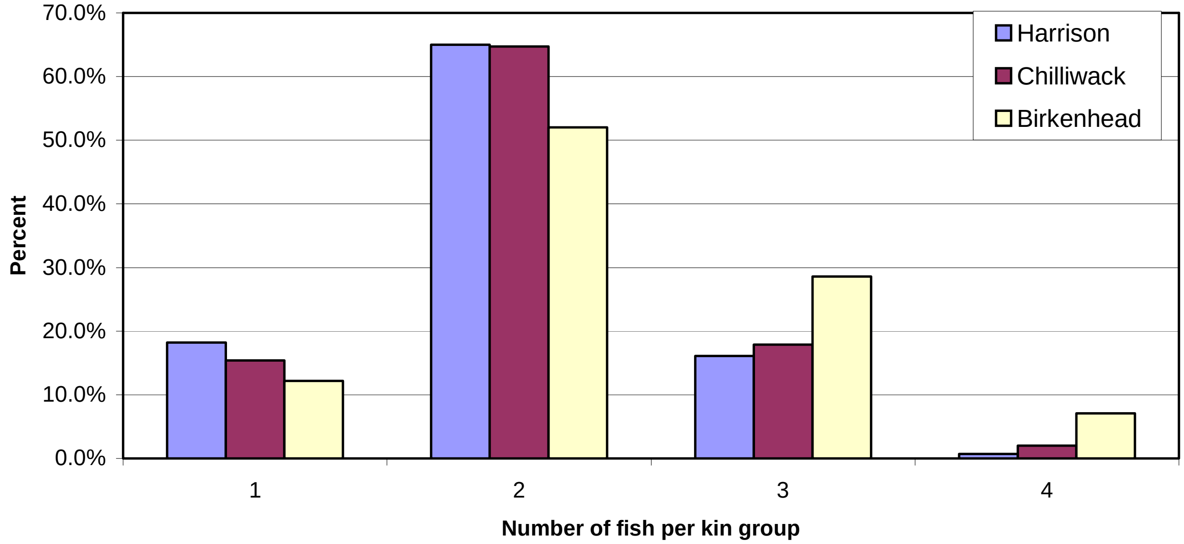


Figure 6. Comparison of family structure in Harrison, Chilliwack and Birkenhead samples. Frequency of kin groups consisting of 2, 3 and 4 fish per group.

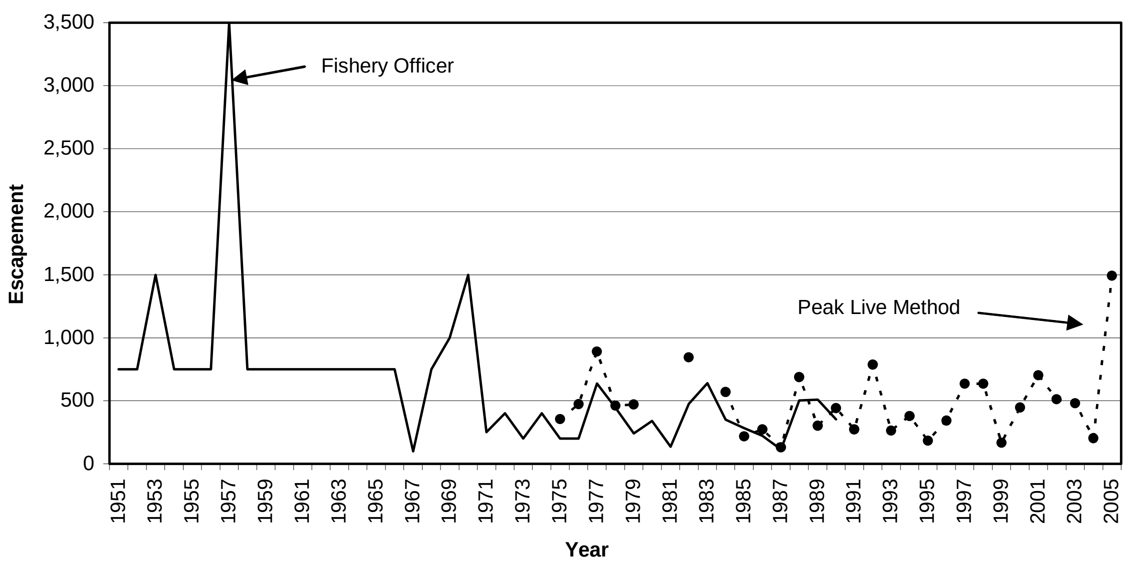


Figure 7. Annual Birkenhead Chinook escapements estimated by fisheries officers (1951-1990; solid line) and using the peak live method described in this research document (1975-2005; dotted line).

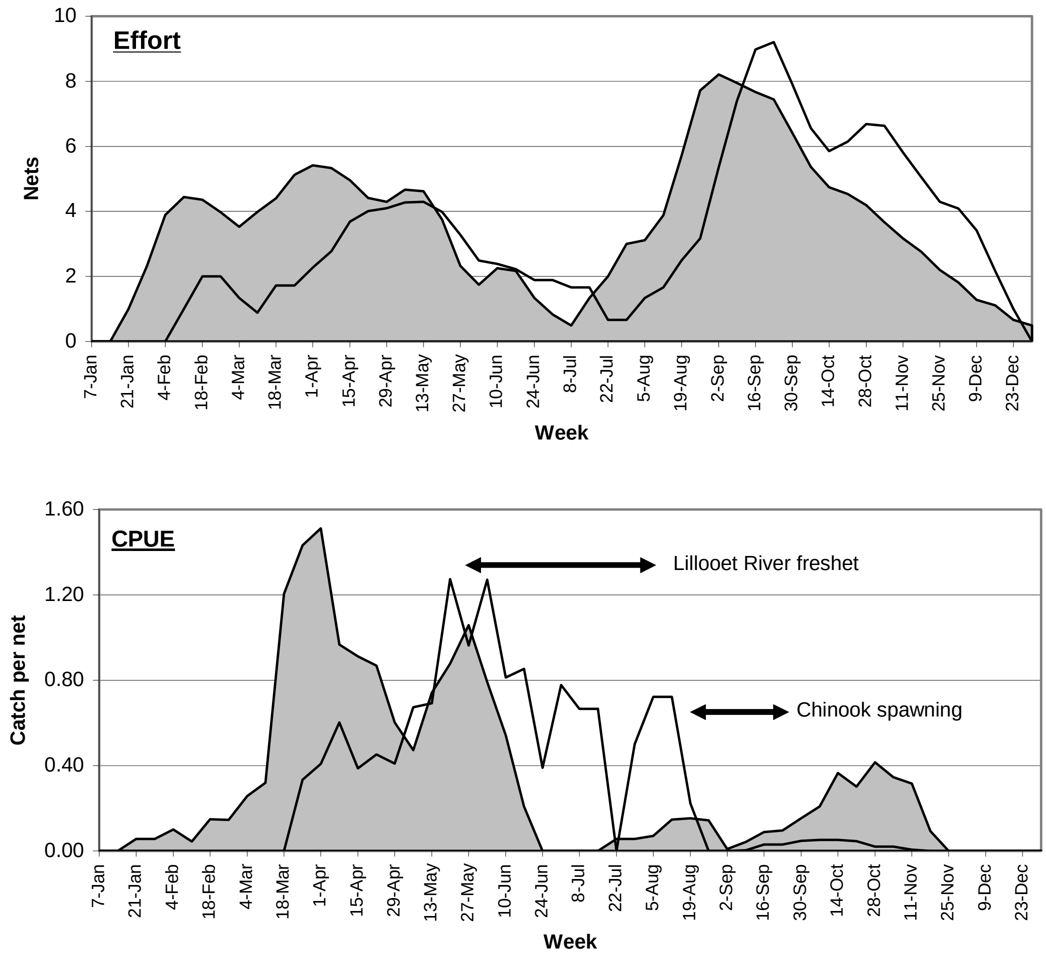


Figure 8. Fishing effort (average nets/week) and Chinook catch per unit effort in the First Nations fisheries of the Lillooet River system. The line is fisheries in Lillooet Lake; the solid area is fisheries in the lower Lillooet River.

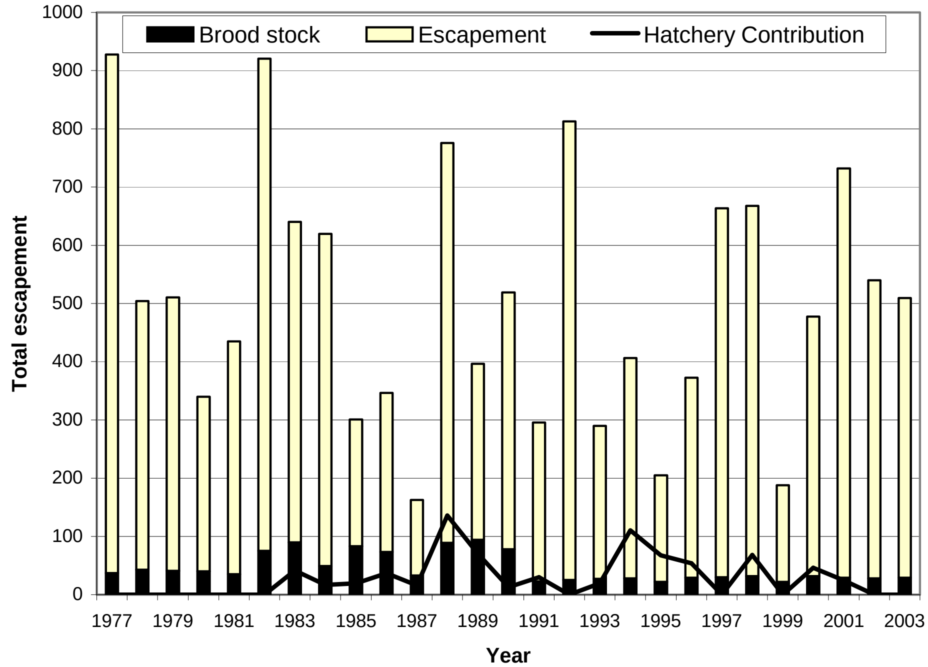
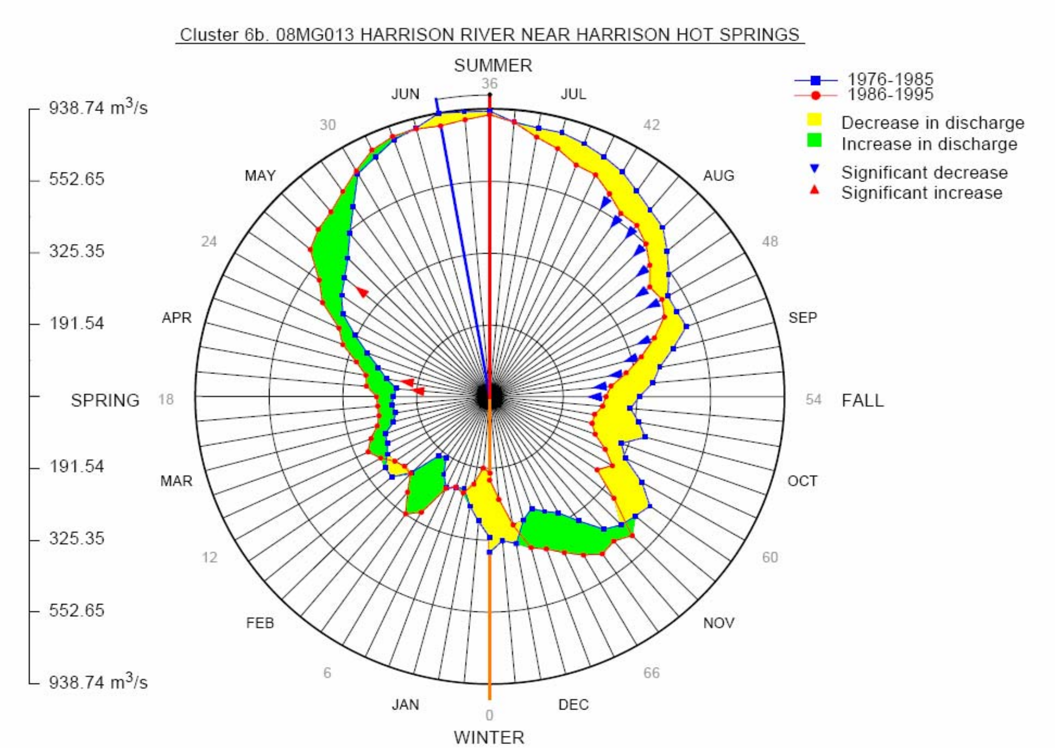


Figure 9. Annual escapement, brood stock removed by the hatchery staff, and the enhanced contribution to the escapement in that year for Birkenhead Chinook, 1977-2003.



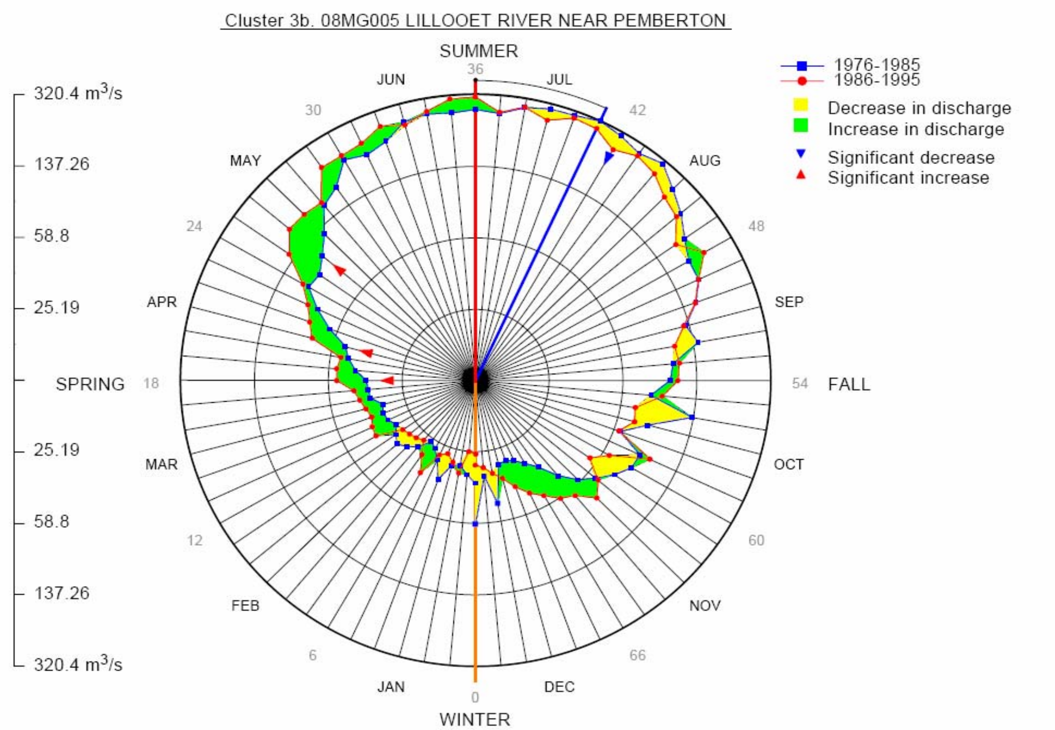


Figure 10. Comparison of 1976-1985 and 1986-1995 average discharges in the Harrison and Lillooet rivers (reproduced by permission from Paul Whitfield, Environment Canada).

TABLES

Table 1. F_{st} values between samples from lower Fraser Chinook salmon populations. The 95% confidence intervals (bracketed) result from bootstrapping over loci.

Population	Timing group	Birkenhead Spring	Big Silver Summer	Upper Pitt Summer	Maria Slough Summer	Harrison Fall
Birkenhead River	Spring					
Big Silver River	Summer	0.11 (0.06 - 0.18)				
Upper Pitt River	Summer	0.09 (0.05 - 0.13)	0.07 (0.04 - 0.90)			
Maria Slough	Summer	0.13 (0.09 - 0.18)	0.12 (0.08 - 0.16)	0.12 (0.10 - 0.17)		
Harrison River	Fall	0.08 (0.04 - 0.13)	0.06 (0.03 - 0.09)	0.07 (0.04 - 0.10)	0.07 (0.05 - 0.09)	
Chilliwack River	Fall	0.09 (0.04 - 0.15)	0.06 (0.03 - 0.10)	0.08 (0.04 - 0.11)	0.08 (0.06 - 0.11)	0.00 (0.00 - 0.01)

Table 2. Levels of allelic richness (A_R) and gene diversity (H_E) for lower Fraser Chinook populations.

Sample location	Years	Sample size	A_R	H_E
Birkenhead River	1991, 1993, 1994, 1996-2003	255	10.6	0.76
Big Silver Creek	1996, 2002, 2003, 2004	115	11.4	0.78
Upper Pitt River	2002, 2003, 2004	104	12.0	0.79
Chilliwack River	1994, 1995, 1998, 1999, 2002	481	15.6	0.84
Harrison River	1988, 1992, 1994, 1999	603	16.3	0.85

Table 3. Estimates of effective number of breeders (N_b) and effective population size (N_e) using Waple's (1990) temporal F_{st} method and Wang and Whitlock's (2003) maximum likelihood method; 95% confidence intervals are bracketed.

Birkenhead samples	Sample sizes	Generations between samples b	Temporal F_{st} method N_b	Maximum likelihood method N_b	Temporal F_{st} method N_e	Maximum likelihood method N_e
1993 - 1996	43:31	3.33	70 (42-130)	73 (46-149)	329 (197-611)	343 (216-700)
1996 - 1998	31:27	3.52	43 (28-70)	48 (34-75)	202 (132-329)	225 (160-352)
1998 - 2000	27:31	3.52	49 (32-78)	58 (39-99)	230 (150-367)	273 (183-465)
2000 - 2003	31:40	3.33	91 (47-238)	109 (63-270)	427 (221-1,119)	512 (296-1,269)
Average	-	-	63 (37-129)	72 (46-148)	296 (173-606)	338 (216-696)

Table 4. Estimated exploitation rate of Birkenhead Chinook in the Lillooet System First Nations fisheries for years when harvest was adequately monitored. Catch estimates are adjusted to exclude other populations (see *Freshwater Fisheries* and Appendix 9) .

	Birkenhead chinook escapement	Lower Lillooet River: Total harvest	Lower Lillooet River: % Birken-head	Lower Lillooet River: Adjusted harvest	Lillooet Lake: Total harvest	Lillooet Lake: % Birken-head	Lillooet Lake: Adjusted harvest	Adjusted total harvest	Harvest rate
1983	640	89	69%	61	45	96%	43	104	14%
1985	218	255	92%	235	141	94%	132	367	63%
1987	130	14	86%	12	21	100%	21	33	20%
1988	687	5	100%	5	7	100%	7	12	2%
1989	303	14	43%	6	50	97%	49	55	15%
Average:			78%			97%			23%

Table 5. Terminal freshwater returns, including First Nations, recreational and test fishery harvest and escapement, of Birkenhead Chinook in years when fish with coded-wire tags were expected to return. Stippling indicates that the harvest or AFC incidence was inferred from other sources; see *Freshwater Fisheries* for caveats regarding the use of these data.

Year	Escape-ment [a]	Escapement sampling: Sample size [b]	Escapement sampling: % with AFC	Escapement sampling: Total AFCs	Lillooet system FN fishery: Birken-head harvest [c]	Lillooet system FN fishery: AFCs [d]	Lower Fraser FN fishery: Birken-head harvest [e]	Lower Fraser FN fishery: AFCs	Lower Fraser sport fishery: Birken-head harvest	Lower Fraser sport fishery: AFCs	Lower Fraser test fishery: Birken-head harvest	Lower Fraser test fishery: AFCs	Return to freshwater: Total	Return to freshwater: AFCs
1981	170	35	0%	0	49	0	25	0	0	0	-	-	245	0
1982	846	75	0%	0	246	0	126	0	0	0	-	-	1,217	0
1983	730	90	7%	49	104	7	96	6	0	0	-	-	930	62
1984	571	34	3%	17	166	5	85	3	0	0	-	-	822	24
1985	218	83	10%	21	367	35	68	7	0	0	-	-	652	63
1986	273	45	13%	36	79	11	41	5	0	0	-	-	394	52
1987	130	33	12%	16	33	4	19	2	0	0	-	-	182	22
1988	687	105	12%	85	12	1	81	10	0	0	-	1	780	97
1989	303	102	25%	72	55	13	41	10	0	0	-	-	399	96
1990	441	78	3%	11	128	3	66	2	0	0	-	-	635	16
1991	273	77	6%	18	79	5	41	3	0	0	-	1	392	26
1992	788	25	0%	0	229	0	117	0	0	0	-	-	1,134	0
1993	263	84	5%	12	76	4	39	2	0	0	-	-	379	18
1994	379	58	21%	79	110	23	56	12	0	0	-	-	545	113
1995	183	60	20%	39	53	11	27	5	0	0	-	1	263	55
1996	344	41	10%	34	100	10	51	5	0	0	-	-	495	48
1997	634	30	0%	0	184	0	172	0	0	0	-	-	990	0
1998 [f]	636	37	8%	52	185	15	28	2	0	0 [g]	-	-	849	69
1999	166	28	0%	0	48	0	36	0	0	0 [g]	-	-	250	0
2000	446	48	10%	47	129	13	75	8	0	0	9	0	660	77
2001	703	29	3%	24	204	7	86	3	5	0	14	0	1,012	48

a. River escapement plus broodstock. The last brood stock was taken in 2003.

b. Brood stock plus carcass sample. CWTs were not applied after 1995; no AFCs were expected to return after 2001.

c. These are revised estimates of Birkenhead chinook harvest based on an average harvest rate from years with adequate survey coverage: 1983, 1985 and 1987-89; see text (see *Freshwater Fisheries*). They replace the fishery officer estimates reported in Appendix 2.

d. Product of total harvest and AFC incidence in the escapement.

e. Birkenhead mean exploitation rate from years with fishery-specific DNA data (1997-2001, 2003) applied to other years to estimate Birkenhead harvest, except 2005 was estimated from Albion test fishery samples.

f. Left ventral clips only; no AFCs recovered.

g. Fishery opened at the end of the Birkenhead migration; Birkenhead harvest assumed to be negligable.

Table 6. Estimates of Birkenhead Chinook harvest and harvest rate in the freshwater fisheries, 1997-2001 and 2003.

	Lower Fraser test fishery		Lower Fraser recreational		Lower Fraser FN fishery		Lillooet System FN fishery [b]			Freshwater summary		
Year [a]	Harvest	Harvest rate	Harvest	Harvest rate	Harvest	Harvest rate	Harvest	Harvest rate	Escape-ment	Total return	Total harvest	Harvest rate
1997	n/a	-	n/a	-	172	17.4%	184	22.5%	634	990	356	36.0%
1998	n/a	-	n/a	-	28	3.4%	185	22.5%	636	849	213	25.1%
1999	n/a	-	n/a	-	36	14.4%	48	22.5%	166	250	84	33.7%
2000	9	1.4%	0	0.0%	75	11.6%	129	22.5%	446	660	214	32.4%
2001	14	1.4%	5	0.5%	86	8.7%	204	22.5%	703	1,012	309	30.5%
2003	n/a	-	n/a	-	45	6.8%	139	22.5%	480	665	184	27.7%
Mean	-	1.4%	-	0.3%	-	10.4%	-	22.5%	-	-	-	30.9%

[a.] Years with DNA sampling in the lower Fraser First Nations fisheries.
[b.] Average harvest rate from years with adequate survey coverage (see *Freshwater Fisheries* and Table 4).

Table 7. Harvest, escapement, exploitation rate and survival by brood year for Birkenhead Chinook hatchery CWT releases.

			Harvest					Exploitation rate			
Brood year	Release stage	Number released	Marine	Fraser River	Lillooet system	Escape-ment	Total return	Marine	Fresh water	Total	Survival
1977	Fed Fry	16,319	42	0	0	0	42	-	-	-	0.26%
1978	Fed Fry	12,963	18	5	5	36	64	28.0%	22.3%	44.0%	0.50%
1979	0+ accel	34,111	33	4	7	28	72	45.7%	27.4%	60.6%	0.21%
	1+ Smolt	14,417	2	0	0	0	2	-	-	-	0.01%
1980	0+ accel	72,413	22	4	21	17	64	34.6%	60.3%	74.0%	0.09%
	1+ Smolt	9,754	6	0	0	0	6	-	-	-	0.06%
1981	0+ accel	36,334	73	7	26	38	144	50.6%	46.7%	73.7%	0.40%
1982	0+ accel	116,199	7	7	5	57	77	9.1%	18.2%	25.6%	0.07%
1983	0+ accel	196,922	85	12	2	94	193	44.0%	13.3%	51.5%	0.10%
1984	0+ accel	72,826	24	10	12	70	116	20.7%	24.0%	39.8%	0.16%
	0+ Smolt	43,140	3	1	2	9	16	18.7%	28.5%	41.8%	0.04%
1985	Fed Fry	63,961	31	4	7	26	67	46.2%	29.1%	61.9%	0.10%
	0+ Smolt	45,018	0	0	0	0	0	-	-	-	0.00%
1986	Fed Fry	123,500	59	4	3	12	77	76.2%	36.3%	84.9%	0.06%
	0+ Smolt	49,500	0	0	0	0	0	-	-	-	0.00%
1987	0+ Smolt	84,863	0	0	0	0	0	-	-	-	0.00%
1988	0+ Smolt	86,510	30	0	0	0	30	-	-	-	0.03%
	Fall fry	71,127	4	0	0	0	4	-	-	-	0.01%
1989	Fed Fry	67,032	54	19	37	138	248	21.8%	29.0%	44.5%	0.37%
	0+ Smolt	57,097	0	1	1	4	6	0.0%	26.5%	26.5%	0.01%
1990	Fed Fry	44,240	18	18	32	109	177	10.2%	31.4%	38.4%	0.40%
	0+ Smolt	43,117	0	0	0	0	0	-	-	-	0.00%
1991	1+ Smolt	35,000	5	0	0	0	5	-	-	-	0.01%
1992	1+ Smolt	22,500	13	0	0	0	13	-	-	-	0.06%
1993 [a]	1+ Smolt	40,922	-	3	20	68	91	-	25.1%	-	0.22%
1995	1+ Smolt	40,800	40	11	21	70	142	28.2%	30.8%	50.3%	0.35%
Total	Fed Fry	328,015	222	49	84	320	676	32.9%	29.5%	52.6%	0.21%
	0+ accel	528,805	244	45	73	303	665	36.7%	28.0%	54.4%	0.13%
	0+ Smolt	409,245	33	2	3	14	52	63.5%	27.9%	73.7%	0.01%
	Fall fry	71,127	4	0	0	0	4	-	-	-	0.01%
	1+ Smolt	163,393	66	14	40	138	259	25.5%	28.1%	46.5%	0.16%
	Total	1,500,585	569	110	201	775	1,656	34.4%	28.6%	53.2%	0.11%

[a.] Left ventral clip only; no estimate of marine harvest.

Table 8. Estimated CWT recoveries (expanded to total release group) of Birkenhead Chinook, totalled by recovery age for 1977-1993 and 1995 brood years.

	Fisheries										Escapement		
					Georgia Strait		Lower Fraser	Lower Fraser	Lillooet				
Recovery age	Alaska	North/ central	WCVI comm.	WCVI sport	Comm.	Sport	River FN	test fishery	system FN	% by age	No.	% by age	Total
2	0	6	0	0	14	14	0	0	0	4%	0	0%	34
3	73	4	0	0	3	36	0	0	0	13%	0	0%	116
4	183	9	7	0	0	10	9	0	26	28%	54	7%	297
5	105	13	2	24	5	54	73	5	137	47%	554	72%	967
6	7	0	0	0	0	0	23	0	38	8%	167	22%	236
Total	368	32	9	24	22	114	105	5	201	-	775	-	1,656
% by fishery	42%	4%	1%	3%	3%	13%	12%	1%	23%	-	-	-	-
% harvested	-	-	-	-	-	-	-	-	-	-	-	-	53%

Table 9. Birkenhead Chinook annual total escapement, hatchery brood stock removals and hatchery contributions, 1977-2003.

		Comparison by year					Brood year contribution to subsequent escapements	
		Removed by hatchery		Hatchery contribution				
Brood year	Total escape-ment	Number	Percent	Number	Percent	Contribution per removal [a]	Number	Contribution per removal
1977	891	37	4.2%	0	-	-	0	0.0
1978	461	43	9.3%	0	-	-	36	0.8
1979	470	41	8.7%	0	-	-	28	0.7
1980	340	40	11.8%	0	-	-	17	0.4
1981	135	35	25.9%	0	0.0%	0.0	38	1.1
1982	846	75	8.9%	0	0.0%	0.0	57	0.8
1983	640	90	14.1%	48	7.4%	0.5	94	1.0
1984	571	49	8.6%	17	2.9%	0.3	79	1.6
1985	218	83	38.1%	20	9.0%	0.2	26	0.3
1986	273	73	26.7%	37	13.5%	0.5	12	0.2
1987	130	33	25.4%	16	12.2%	0.5	0	0.0
1988	687	89	13.0%	136	19.8%	1.5	0	0.0
1989	303	94	31.1%	71	23.3%	0.8	142	1.5
1990	441	78	17.7%	13	2.9%	0.2	109	1.4
1991	273	23	8.4%	30	11.1%	1.3	0	0.0
1992	788	25	3.2%	0	0.0%	0.0	0	0.0
1993	263	27	10.3%	20	7.5%	0.7	68	2.5
1994	379	28	7.4%	110	29.2%	3.9	- [b]	-
1995	183	22	12.0%	67	36.9%	3.1	70	3.2
1996	344	29	8.4%	54	15.6%	1.8	- [b]	-
1997	634	30	4.7%	0	0.0%	0.0	- [b]	-
1998	636	32	5.0%	68	10.7%	2.1	- [b]	-
1999	166	22	13.3%	0	0.0%	0.0	- [b]	-
2000	446	32	7.2%	46	10.4%	1.4	- [b]	-
2001	703	29	4.1%	24	3.4%	0.8	- [b]	-
2002	512	28	5.5%	n/r	-	-	- [b]	-
2003	480	29	6.0%	n/r	-	-	- [b]	-
Average	-	-	12.6%	-	10.3%	0.9	-	0.9

a. 1981 is the first year that 1977 brood production was expected to return to the river.
b. Hatchery production was not tagged; contribution is unknown.

Table 10. Watershed area habitat model predictions of productive capacity (S_{REP}) and spawning abundance producing maximum sustained yield (S_{MSY}) of the Birkenhead watershed.

			Bootstrap Percentiles						
	Estimate	**CV[1]**	**5th**	**10th**	**25th**	**50th**	**75th**	**90th**	**95th**
$\hat{S}_{MSY}$	1,700	0.16	1,300	1,300	1,500	1,700	1,800	2,000	2,100
$\hat{S}_{REP}$	4,400	0.14	3,400	3,500	3,900	4,300	4,800	5,200	5,400

1. Coefficient of variation.

APPENDICES

Appendix 1. Estimated annual escapement of Harrison-Lillooet Chinook populations, 1951-2005.
Note: Fishery Officer (FO) estimates unless noted; brood stock removal added to Birkenhead FO estimates.

	Harrison River populations		Harrison Lake populations			Lower Lillooet River populations			
Year	Chehalis River	Harrison River	Big Silver Creek	Cogburn Creek	Douglas Creek	Lower Lillooet River	Sloquet River	Tipella Creek	Birkenhead River
1951	400	1,500	75	n/r	n/r	n/r	n/r	n/r	750
1952	750	75,000	200	n/r	n/r	n/r	750	n/r	750
1953	75	15,000	200	n/r	n/r	n/r	200	n/r	1,500
1954	750	15,000	75	25	25	n/r	n/r	n/r	750
1955	400	7,500	75	n/r	n/r	n/r	n/r	n/r	750
1956	n/o	3,500	300	n/r	n/r	n/r	n/r	n/r	750
1957	25	3,500	200	n/r	n/r	n/r	n/r	n/r	3,500
1958	25	16,500	25	n/r	n/r	n/r	n/r	25	750
1959	25	18,000	75	n/r	n/r	n/r	n/r	n/r	750
1960	25	3,500	300	n/r	n/r	n/r	n/r	n/r	750
1961	25	5,000	75	25	n/r	n/r	n/r	n/r	750
1962	200	2,000	50	n/r	n/r	n/r	n/r	n/r	750
1963	25	13,500	24	n/r	n/r	n/r	n/r	n/r	750
1964	25	6,000	25	n/r	n/r	n/r	n/r	n/r	750
1965	25	8,500	50	n/r	n/r	n/r	n/r	n/r	750
1966	25	9,000	25	25	n/r	n/r	n/r	n/r	750
1967	25	7,500	25	25	25	n/r	n/r	n/r	100
1968	75	7,500	25	n/r	25	n/r	n/r	n/r	750
1969	n/o	7,500	75	n/r	25	n/r	n/r	n/r	1,000
1970	n/o	7,500	75	n/r	25	n/r	n/r	n/r	1,500
1971	25	15,000	75	n/r	25	n/r	n/r	n/r	250
1972	75	15,000	200	n/r	25	n/r	n/r	n/r	400
1973	75	35,000	200	n/r	25	n/r	n/r	n/r	200
1974	25	35,000	200	n/r	25	n/r	25	n/r	400
1975	25	15,000	75	n/r	25	400	25	n/r	356 [d]
1976	25	7,500	25	n/r	25	400	75	n/r	473 [d]
1977	25	25,000	75	25	25	400	n/r	n/r	891 [d]
1978	25	15,000	25	25	25	400	n/r	n/r	461 [d]
1979	25	15,000	75	n/r	n/r	750	n/r	n/r	470 [d]
1980	25	10,000	20	n/r	n/r	300	n/o	n/r	340
1981	n/r	20,000	100	n/r	n/r	300	25	n/r	135
1982	n/r	22,000	20	10	25	1,000	25	n/r	846 [d]
1983	n/r	6,000	75	n/r	15	650	15	n/r	640
1984	n/r	120,837 [a]	50	n/r	n/r	500	n/r	n/r	571 [d]
1985	10	174,778 [a]	30	n/r	n/r	200	n/r	n/r	218 [d]
1986	n/r	162,596 [a]	25	n/r	n/r	n/r	n/r	n/r	273 [d]
1987	n/r	79,038 [a]	n/r	n/r	n/o	n/r	n/r	n/r	130 [d]
1988	n/r	35,116 [a]	n/r	n/r	n/r	n/r	n/r	n/r	687 [d]
1989	n/r	74,685 [a]	n/r	n/r	n/r	200	n/r	n/r	303 [d]
1990	n/r	177,375 [a]	n/r	n/r	n/r	n/r	n/r	n/r	441 [d]
1991	n/r	90,638 [a]	n/r	n/r	n/r	n/r	n/r	n/r	273 [d]
1992	n/r	130,411 [a]	n/r	n/r	n/r	50	n/r	n/r	788 [d]
1993	n/r	118,998 [a]	n/r	n/r	n/r	n/r	n/r	n/r	263 [d]
1994	n/r	98,334 [a]	n/r	n/r	n/r	n/r	n/r	n/r	379 [d]
1995	n/r	28,616 [a]	n/r	n/r	n/r	n/r	n/r	n/r	183 [d]
1996	n/r	56,809 [a]	n/r	n/r	n/r	n/r	n/r	n/r	344 [d]
1997	n/r	72,277 [a]	n/r	n/r	n/r	n/r	n/r	n/r	634 [d]
1998	n/r	188,420 [a]	n/r	n/r	n/r	n/r	n/r	n/r	636 [d]
1999	n/r	106,995 [a]	n/r	n/r	n/r	n/r	n/r	n/r	166 [d]
2000	n/r	77,754 [a]	n/r	n/r	n/r	n/r	n/r	n/r	446 [d]
2001	n/r	73,134 [a]	n/r	n/r	n/r	n/r	n/r	n/r	703 [d]
2002	n/r	89470 [a]	290 [b]	n/r	30 [c]	n/r	221 [b]	n/r	512 [d]
2003	n/r	246,984 [a]	111 [b]	n/r	n/o	n/r	113 [b]	n/o	480 [d]
2004	n/r	139,126 [a]	n/r	n/r	5 [c]	n/r	151 [b]	1	202 [d]
2005	n/r	87,992 [a]	243 [b]	n/r	n/o	n/r	68 [b]	n/o	1,491 [d]

a. Mark-recapture estimate.
b. Area-under-the-curve estimate.
c. Unadjusted peak live count.
d. Adjusted peak live count (see text).

Appendix 2. Fishery officer estimates of Birkenhead Chinook escapement and harvest in terminal fisheries, 1951-1991. Note: Brood stock removal was added to the escapement estimate in years when the hatchery operated.

		First Nations fishery [a]						First Nations fishery [a]			
Year	Escape-ment estimate	Lillooet River	Lillooet Lake	Total	Terminal Sport	Year	Escape-ment estimate	Lillooet River	Lillooet Lake	Total	Terminal Sport
1951	750	n.r.	n.r.	60	n.r.	1971	250 [b]	n.r.	n.r.	333	n.r.
1952	750	n.r.	n.r.	262	n.r.	1972	400	n.r.	n.r.	n.r.	n.r.
1953	1,500	n.r.	n.r.	255	n.r.	1973	200	n.r.	n.r.	232	n.r.
1954	750	n.r.	n.r.	270	n.r.	1974	400	n.r.	n.r.	135	91 [f]
1955	750	n.r.	n.r.	22	n.r.	1975	200 [c]	n.r.	n.r.	100	64 [f]
1956	750	n.r.	n.r.	179	n.r.	1976	200	n.r.	n.r.	52	closed
1957	3,500	n.r.	n.r.	230	n.r.	1977	637	n.r.	n.r.	31	closed
1958	750	n.r.	n.r.	105	n.r.	1978	443	n.r.	n.r.	36	closed
1959	750	n.r.	n.r.	130	n.r.	1979	241	n.r.	n.r.	50	closed
1960	750	n.r.	n.r.	205	n.r.	1980	340	n.r.	n.r.	25	closed
Mean	1,100	n.r.	n.r.	172	n.r.	Mean	331	n.r.	n.r.	110	n.r.
1961	750	n.r.	n.r.	85	n.r.	1981	135 [b]	n.r.	n.r.	24	closed
1962	750	n.r.	n.r.	90	n.r.	1982	475 [b]	143	79	222	closed
1963	750	n.r.	n.r.	65	n.r.	1983	640	89	45	134	closed
1964	750	n.r.	n.r.	180	n.r.	1984	349 [b]	40	113	153	closed
1965	750	n.r.	n.r.	148	n.r.	1985	283	255	141	396	closed
1966	750	n.r.	n.r.	186	n.r.	1986	223	31	7	38	closed
1967	100	n.r.	n.r.	164	n.r.	1987	113	14	21	35	closed
1968	750	n.r.	n.r.	192	n.r.	1988	501	5	7	12	closed
1969	1,000	n.r.	n.r.	59	n.r.	1989	509	14	50 [d]	64	closed
1970	1,500 [b]	n.r.	n.r.	305	n.r.	1990	353	7	0	7	closed
						1991	n.r. [e]	3	3	6	closed
Mean	789	n.r.	n.r.	154	n.r.	Mean	383	n.r.	n.r.	107	closed

a. Fishery officer estimates compiled from DFO reports (e.g., Schubert 1983, Macdonald 1992), unless noted.

b. Change in observer: 1951-69: Reynolds; 1970: Wheeler; 1971-80: Bentley; 1981: Endurud; 1982-83: Fradette; and 1984-90: Ionson.

c. First year of hatchery staff's helicopter observations at peak spawning.

d. Estimated by hatchery staff.

e. First year of foot surveys at peak spawning.

f. Fishery officer estimate reported by Bailey *et al.* (1979).

Appendix 3. Survey results and Chinook escapement estimates from observations recorded at peak of spawning in the Birkenhead River, 1975-2005.

Year	Survey at peak spawning: Method	Survey condition	Date	Live	Dead	Total	Adjusted peak index 2.02 [b]	Net escape-ment estimate 1.71 [c]	Removed by hatchery [a]: Male	Female	Total	Gross escapement estimate [d]
1975	Aerial [e]	Good	6-Sep	n/r	n/r	103	208	356	0	0	0	356
1976	Aerial [e]	Good	9-Sep	n/r	n/r	137	277	473	0	0	0	473
1977	Aerial [e]	Fair	14-Sep	219	28	247	499	854	12	25	37	891
1978	Aerial [e]	n/r	13-Sep	n/r	n/r	121	245	418	22	21	43	461
1979	Aerial [e]	n/r	12-Sep	124	n/r	124	251	429	12	29	41	470
1980	n.r.	-	-	-	-	-	-	-	15	25	40	-
1981	n.r.	-	-	-	-	-	-	-	12	23	35	-
1982	Aerial [e]	n/r	12-Sep	205	18	223	451	771	36	39	75	846
1983	n.r.	-	-	-	-	-	-	-	29	61	90	-
1984	Aerial [e]	n/r	12-Sep	n/r	n/r	151	305	522	20	29	49	571
1985	Aerial [e]	Good	12-Sep	n/r	n/r	39	79	135	52	31	83	218
1986	Aerial [e]	n/r	11-Sep	n/r	n/r	58	117	200	37	36	73	273
1987	Aerial [e]	Poor	10-Sep	n/r	n/r	28	57	97	16	17	33	130
1988	Aerial [e]	Poor	18/20-Sep	139	34	173	350	598	47	42	89	687
1989	Ground [f]	n/r	13/14-Sep	n/r	n/r	122	122	209	50	44	94	303
1990	Aerial [e]	Poor	13-Sep	n/r	n/r	105	212	363	31	39 [i]	78	441
1991	Ground [f]	n/r	11-Sep	144	2	146	146	250	12	11	23	273
1992	Ground [f]	n/r	9-Sep	n/r	n/r	446	446	763	12	13	25	788
1993	Ground [f]	Good	8/13-Sep	85	53	138	138	236	13	14	27	263
1994	Ground [f]	n/r	12-Sep	205	0	205	205	351	12	16	28	379
1995	Ground [f]	n/r	12-Sep	91	3	94 [h]	94	161	9	13	22	183
1996	Ground [f]	n/r	12-Sep	171	13	184 [h]	184	315	15	14	29	344
1997	Ground [f]	n/r	11/13-Sep	353	0	353 [h]	353	604	13	17	30	634
1998	Ground [f]	n/r	11/12-Sep	348	5	353 [h]	353	604	14	18	32	636
1999	Ground [f]	Poor	11-Sep	81	3	84 [h]	84	144	8	14	22	166
2000	Ground [f]	n/r	11/12-Sep	235	7	242	242	414	17	15	32	446
	Aerial [e]	n/r	06-Sep	123	0	123	-	-	-	-	-	-
2001	Ground [f]	Fair	11/12-Sep	357	37	394	394	674	13	16	29	703
2002	Ground [f]	n/r	12/13-Sep	274	9	283	283	484	8	20	28	512
	Aerial [e]	n/r	12-Sep	245	0	245	*Ratio of ground to aerial counts: [j] 1.12*					
2003	Ground [g]	Fair	12-Sep	247	17	264	264	451	10	19	29	480
	Aerial [g]	Fair	12-Sep	97	0	97	*Ratio of ground to aerial counts: [j] 2.63*					
2004	Ground [g]	Poor	13/14-Sep	117	1	118	118	202	0	0	0	202
	Aerial [g]	Poor	14-Sep	59	0	59	*Ratio of ground to aerial counts: [j] 3.03*					
2005	Ground [g]	Good	12-Sep	872	0	872	872	1,491	0	0	0	1,491
	Aerial [g]	Good	12-Sep	677	0	677	*Ratio of ground to aerial counts: [j] 1.30*					

a. Includes brood stock plus holding mortality (when known).

b. Average relationship between ground and helicopter live counts for 2002-2005.

c. Correlation between peak live count from helicopter surveys and AUC estimate in Nechako River study (see text).

d. Sum of net escapement plus hatchery removals.

e Surveys conducted by DFO staff (DFO, unpublished).

f. Conducted by hatchery staff until 1990, H. Naylor after 1990 (Bailey *et al.* 2001).

g. Surveys conducted by Lil'wat First Nation (Greenbank 2005, 2006) or DFO.

h. Counts are numbers of fish actually observed; observers estimated efficiency as follows (Year-% visable-%of spawning area surveyed) : 1995-70%-90%; 1996-80%-90%; 1997-80%-90%; 1998-75%-100%; 1999-77%-100%.

i. Total includes 8 holding mortalities of unknown sex.

j. The ratio is from counts in areas surveyed by both techniques on the same day. Excludes area surveyed using one method only, and second day of ground counts. The 2000 data are excluded because survey dates were five days apart.

Appendix 4. Annual spawning ground carcass recovery and hatchery brood stock samples, by sex and adipose fin clip status, 1979-2001.

		Carcass survey sample										Hatchery brood stock									
		No. examined					Number with fin clips					No. examined					Number with fin clips [a]				
Year	Sex:	M	F	J	n.r.	Total	M	F	J	n.r.	Total	M	F	J	n.r.	Total	M	F	J	n.r.	Total
1979	No.	0	0	0	0	0	0	0	0	0	0	12	29	0	0	41	0	0	0	0	0
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	-	-	0.0%
1980	No.	0	0	0	0	0	0	0	0	0	0	15	25	0	0	40	0	0	0	0	0
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	-	-	0.0%
1981	No.	0	0	0	0	0	0	0	0	0	0	12	23	0	0	35	0	0	0	0	0
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	-	-	0.0%
1982	No.	0	0	0	0	0	0	0	0	0	0	36	39	0	0	75	0	0	0	0	0
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	-	-	0.0%
1983	No.	0	0	0	0	0	0	0	0	0	0	29	61	0	0	90	2	4	0	0	6
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9%	6.6%	-	-	6.7%
1984	No.	0	0	0	0	0	0	0	0	0	0	4	30	0	0	34	0	1	0	0	1
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	3.3%	-	-	2.9%
1985	No.	0	0	0	0	0	0	0	0	0	0	31	41	11	0	83	4	2	2	0	8
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.9%	4.9%	18.2%	-	9.6%
1986	No.	0	0	0	0	0	0	0	0	0	0	16	26	3	0	45	n.r.	n.r.	n.r.	6	6
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.3%
1987	No.	0	0	0	0	0	0	0	0	0	0	12	17	4	0	33	2	2	0	0	4
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.7%	11.8%	0.0%	-	12.1%
1988	No.	0	0	0	0	0	0	0	0	0	0	38	67	0	0	105	4	9	0	0	13
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.5%	13.4%	-	-	12.4%
1989	No.	1	3	0	4	8	1	3	0	0	4	35	58	1	0	94	10	11	0	0	21
	%	-	-	-	-	-	-	-	-	-	50.0%	-	-	-	-	-	28.6%	19.0%	0.0%	-	22.3%
1990	No.	0	0	0	0	0	0	0	0	0	0	31	39	0	8	78	1	1	0	0	2
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.2%	2.6%	-	-	2.6%
1991	No.	10	32	1	0	43	1	1	0	0	2	16	11	7	0	34	1	2	0	0	3
	%	-	-	-	-	-	10.0%	3.1%	0.0%	-	4.7%	-	-	-	-	-	6.3%	18.2%	0.0%	-	8.8%
1992	No.	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	12	13	0	0	25	0	0	0	0	0
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	-	-	0.0%
1993	No.	16	37	4	0	57	3	0	0	0	3	8	14	5	0	27	1	0	0	0	1
	%	-	-	-	-	-	18.8%	0.0%	0.0%	-	5.3%	-	-	-	-	-	12.5%	0.0%	0.0%	-	3.7%
1994	No.	6	24	0	0	30	1	5	0	0	6	12	16	0	0	28	2	4	0	0	6
	%	-	-	-	-	-	16.7%	20.8%	-	-	20.0%	-	-	-	-	-	16.7%	25.0%	-	-	21.4%
1995	No.	n/r	n/r	n/r	35	35	1	4	0	0	5	9	16	0	0	25	2	5	0	0	7
	%	-	-	-	-	-	-	-	-	-	14.3%	-	-	-	-	-	22.2%	31.3%	-	-	28.0%
1996	No.	0	0	0	0	0	0	0	0	0	0	15	26	0	0	41	2	2	0	0	4
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.3%	7.7%	-	-	9.8%
1997	No.	n/r	n/r	n/r	n/r	0	n/r	n/r	n/r	n/r	0	13	17	0	0	30	0	0	0	0	0
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	-	-	0.0%
1998 [b]	No.	n/r	n/r	n/r	n/r	0	n/r	n/r	n/r	n/r	0	15	22	0	0	37	1	2	0	0	3
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7%	9.1%	-	-	8.1%
1999	No.	0	3	0	0	3	0	0	0	0	0	8	17	0	0	25	0	0	0	0	0
	%	-	-	-	-	-	-	-	-	-	0.0%	-	-	-	-	-	0.0%	0.0%	-	-	0.0%
2000	No.	1	6	0	0	7	0	0	0	0	0	18	21	2	0	41	2	3	0	0	5
	%	-	-	-	-	-	-	-	-	-	0.0%	-	-	-	-	-	11.1%	14.3%	0.0%	-	12.2%
2001	No.	n/r	n/r	n/r	n/r	0	n/r	n/r	n/r	n/r	0	13	16	0	0	29	0	1	0	0	1
	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%	6.3%	-	-	3.4%

[a.] Adipose fin clips unless otherwise noted.
[b.] Left ventral fin clips only.

Appendix 5. Hatchery production and coded-wire tag releases, 1977-2003 brood years.

Brood year	Tag code or mark	Facility [a]	Strategy	Release information: Date	Stage	Size (g)	Location	Release numbers: Tags	Adipose only	Un-marked	Total	Adipose clip incidence
1977	02-16-55	Birkenhead		20-Jul-78	Fed Fry	2.5	Birkenhead R.	14,793	302	1,224	16,319	0.925
1978	02-17-61	Birkenhead		17-Jul-79	Fed Fry	2.5	Birkenhead R.	12,236	378	349	12,963	0.973
1979	02-18-58	Birkenhead		28-Apr-80	0+ accel	3.6	Birkenhead R.	32,908	1,203	0	34,111	1.000
	02-17-11	Birkenhead	Extended rearing	28-Apr-81	1+ Smolt	39.3	Birkenhead R.	13,909	508	0	14,417	1.000
1980	02-18-35	Birkenhead		28-Apr-81	0+ accel	3.1	Birkenhead R.	65,557	2,732	4,124	72,413	0.943
	02-19-15	Birkenhead	Extended rearing	30-Apr-82	1+ Smolt	44.7	Birkenhead R.	8,291	1,463	0	9,754	1.000
1981	02-23-40	Birkenhead	Time of release	30-Apr-82	0+ accel	3.2	Birkenhead R.	26,045	483	0	26,528	1.000
	02-19-59	Birkenhead	Time of release	15-Apr-82	0+ accel	3.7	Birkenhead R.	9,005	426	375	9,806	0.962
1982	02-25-28	Birkenhead	Time of release	12-Apr-83	0+ accel	1.4	Birkenhead R.	43,516	645	0	44,161	1.000
	02-25-29	Birkenhead	Time of release	28-Apr-83	0+ accel	2.2	Birkenhead R.	42,457	374	0	42,831	1.000
	02-25-30	Birkenhead	Time of release	31-May-83	0+ accel	3.5	Birkenhead R.	28,623	584	0	29,207	1.000
1983	02-26-18	Birkenhead	Rearing location	30-Apr-84	0+ accel	3.3	Birkenhead R.	43,059	114	110,685	153,858	0.281
	02-27-24	Inch Creek	Rearing location	30-Apr-84	0+ accel	2.4	Birkenhead R.	40,237	2,219	608	43,064	0.986
1984	02-32-34	Birkenhead	Release size/time	20-Apr-85	0+ accel	3.7	Birkenhead R.	35,398	625	0	36,023	1.000
	02-32-35	Birkenhead	Release size/time	15-May-85	0+ accel	4.0	Birkenhead R.	35,846	582	375	36,803	0.990
	02-33-18	Inch Creek	Release size/time	20-Apr-85	0+ Smolt	6.7	Birkenhead R.	23,487	1,527	0	25,014	1.000
	02-33-19	Inch Creek	Release size/time	15-May-85	0+ Smolt	7.4	Birkenhead R.	17,671	455	0	18,126	1.000
1985	02-37-13	Birkenhead	Release size	15-Jun-86	Fed Fry	2.7	Birkenhead R.	49,460	1,292	13,209	63,961	0.793
	02-37-14	Inch Creek	Release size	15-Jun-86	0+ Smolt	5.7	Birkenhead R.	42,543	322	2,153	45,018	0.952
1986	02-43-21	Birkenhead	Release size	10-May-87	Fed Fry	2.0	Birkenhead R.	50,695	714	72,091	123,500	0.416
	02-43-20	Inch Creek	Release size	10-May-87	0+ Smolt	5.0	Birkenhead R.	48,150	922	428	49,500	0.991
1987	02-47-25	Inch Creek	Release size	10-May-88	0+ Smolt	12.2	Birkenhead R.	24,400	1,016	14,665	40,081	0.634
	02-47-26	Inch Creek	Release size	3-May-88	0+ Smolt	11.1	Birkenhead R.	24,433	407	19,942	44,782	0.555
1988	02-54-08	Inch Creek	Release size	11-May-89	0+ Smolt	12.0	Birkenhead R.	50,833	204	35,473	86,510	0.590
	02-58-40	Birkenhead	Release size/time	11-Oct-89	Fall fry	7.4	Birkenhead R.	23,287	0	200	23,487	0.991
	02-58-41	Birkenhead	Release size/time	11-Oct-89	Fall fry	7.4	Birkenhead R.	23,849	0	120	23,969	0.995
	02-58-42	Birkenhead	Release size/time	11-Oct-89	Fall fry	7.4	Birkenhead R.	23,538	94	39	23,671	0.998
1989	02-07-32	Inch Creek	Release size/time	9-Jun-90	0+ Smolt	15.0	Birkenhead R.	25,184	64	3,360	28,608	0.883
	02-07-33	Inch Creek	Release size/time	9-Jun-90	0+ Smolt	16.5	Birkenhead R.	25,067	62	3,360	28,489	0.882
	02-07-34	Birkenhead	Release size/time	4-Jul-90	Fed Fry	3.6	Birkenhead R.	24,977	63	8,245	33,285	0.752
	02-07-35	Birkenhead	Release size/time	4-Jul-90	Fed Fry	3.8	Birkenhead R.	25,042	63	8,642	33,747	0.744
1990	02-14-63	Tenderfoot	Release size	3-Jul-91	Fed Fry	4.0	Birkenhead R.	25,197	0	19,043	44,240	0.570
	02-15-27	Inch Creek	Release size	3-Jul-91	0+ Smolt	10.8	Birkenhead R.	42,686	431	0	43,117	1.000
1991	18-07-28	Birkenhead [b]	Extended rearing	Jun-93	1+ Smolt	19.0	Fee Ch.	27,125	0	7,875	35,000	0.775
1992	18-07-38	Birkenhead [b]	Extended rearing	15-Apr-94	1+ Smolt	16.1	Fee Ch.	16,900	0	5,600	22,500	0.751
1993	Left Vent.	Birkenhead [b]	Extended rearing	20-Apr-95	1+ Smolt	16.0	Fee Ch.	18,600	12,400	9,922	40,922	0.758
1994	None	Birkenhead [b]		13-Jul-95	Fed Fry	3.4	Birkenhead R.	0	0	9,823	9,823	0.000
	None	Birkenhead [b]	Extended rearing	May-96	1+ Smolt	15.0	Birkenhead R.	0	0	6,350	6,350	0.000
1995	18-15-14	Birkenhead [b]	Extended rearing	Mar-97	1+ Smolt	13.0	Birkenhead R.	40,392	408	0	40,800	1.000
	None	Birkenhead [b]		24-Jun-96	Fed Fry	3.3	Birkenhead R.	0	0	8,000	8,000	0.000
1996	None	Birkenhead [b]		23-Jun-97	Fed Fry	3.2	Birkenhead R.	0	0	62,000	62,000	0.000
1997	None	Birkenhead [b]		24-Jun-98	Fed Fry	4.0	Birkenhead R.	0	0	65,000	65,000	0.000
1998	None	Birkenhead [b]		15-May-99	0+ accel	3.0	Birkenhead R.	0	0	50,000	50,000	0.000
1999	None	Birkenhead [b]		26-Jun-00	Fed Fry	4.0	Birkenhead R.	0	0	46,000	46,000	0.000
2000	None	Birkenhead [b]		15-May-01	0+ accel	4.0	Birkenhead R.	0	0	50,000	50,000	0.000
2001	None	Birkenhead [b]		15-Jun-02	Fed Fry	3.0	Birkenhead R.	0	0	64,500	64,500	0.000
2002	None	Birkenhead [b]	10 K released at lake	15-May-03	Fed Fry	2.8	Birkenhead R.	0	0	78,000	78,000	0.000
2003	None	Birkenhead [b]		31-May-04	Fed Fry	3.0	Birkenhead R.	0	0	8,000	8,000	0.000

[a.] Rearing location determines release size; those reared at Inch Creek Hatchery are larger than at Birkenhead Hatchery.

[b.] Incubation and rearing in hatchery operated by the Pemberton Wildlife Association.

Appendix 6a. Annual age composition of Birkenhead Chinook spawners (both sexes) estimated from samples taken from carcasses and fish removed for enhancement, 1975-2004. Dashes indicate no data available.

		Age [a]							
Year	Sample size	2_1	3_1	3_2	4_1	4_2	5_1	5_2	6_2
1975	26	0.0%	11.5%	7.7%	7.7%	26.9%	0.0%	46.2%	0.0%
1976	42	0.0%	0.0%	2.4%	0.0%	35.7%	0.0%	59.5%	2.4%
1977	146	0.0%	2.7%	3.4%	2.7%	59.6%	1.4%	30.1%	0.0%
1978	54	0.0%	31.5%	0.0%	33.3%	16.7%	0.0%	18.5%	0.0%
1979	61	0.0%	0.0%	3.3%	1.6%	4.9%	1.6%	83.6%	4.9%
1980	58	0.0%	0.0%	3.4%	6.9%	20.7%	1.7%	63.8%	3.4%
1981	31	0.0%	0.0%	3.2%	0.0%	32.3%	0.0%	64.5%	0.0%
1982	70	1.4%	0.0%	2.9%	1.4%	12.9%	1.4%	64.3%	15.7%
1983	71	0.0%	0.0%	0.0%	0.0%	12.7%	0.0%	84.5%	2.8%
1984	28	0.0%	0.0%	0.0%	0.0%	32.1%	0.0%	67.9%	0.0%
1985	38	0.0%	0.0%	0.0%	0.0%	10.5%	0.0%	84.2%	5.3%
1986	0	-	-	-	-	-	-	-	-
1987	7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
1988 [b]	40	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	82.5%	15.0%
1989	14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
1990	0	-	-	-	-	-	-	-	-
1991	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
1992	0	-	-	-	-	-	-	-	-
1993	38	0.0%	0.0%	0.0%	0.0%	15.8%	0.0%	73.7%	10.5%
1994	5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
1995	0	-	-	-	-	-	-	-	-
1996	0	-	-	-	-	-	-	-	-
1997	0	-	-	-	-	-	-	-	-
1998	0	-	-	-	-	-	-	-	-
1999	0	-	-	-	-	-	-	-	-
2000	0	-	-	-	-	-	-	-	-
2001	0	-	-	-	-	-	-	-	-
2002	25	0.0%	0.0%	0.0%	0.0%	32.0%	0.0%	52.0%	16.0%
2003	20	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%	65.0%	10.0%
2004	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	50.0%
Average	26	0.1%	2.3%	1.3%	2.7%	17.0%	0.3%	69.5%	6.8%

[a.] Combines males, females and samples where the sex was not recorded.

[b.] Scale ages before 1988 were changed following a review in the late 1980s. Scale ages should be reviewed for consistency with current practices.

Appendix 6b. Annual age composition of female Birkenhead Chinook spawners estimated from samples taken from carcasses and fish removed for enhancement, 1975-2004. Dashes indicate no data available.

Year	Sample size	Age 2_1	3_1	3_2	4_1	4_2	5_1	5_2	6_2
1975	0	-	-	-	-	-	-	-	-
1976	0	-	-	-	-	-	-	-	-
1977	0	-	-	-	-	-	-	-	-
1978	3	0.0%	0.0%	0.0%	0.0%	66.7%	0.0%	33.3%	0.0%
1979	20	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	85.0%	15.0%
1980	6	0.0%	0.0%	0.0%	16.7%	0.0%	0.0%	83.3%	0.0%
1981	12	0.0%	0.0%	0.0%	0.0%	16.7%	0.0%	83.3%	0.0%
1982	26	0.0%	0.0%	0.0%	0.0%	0.0%	3.8%	76.9%	19.2%
1983	0	-	-	-	-	-	-	-	-
1984	26	0.0%	0.0%	0.0%	0.0%	34.6%	0.0%	65.4%	0.0%
1985	25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	92.0%	8.0%
1986	0	-	-	-	-	-	-	-	-
1987	5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
1988 [a]	0	-	-	-	-	-	-	-	-
1989	0	-	-	-	-	-	-	-	-
1990	0	-	-	-	-	-	-	-	-
1991	0	-	-	-	-	-	-	-	-
1992	0	-	-	-	-	-	-	-	-
1993	0	-	-	-	-	-	-	-	-
1994	0	-	-	-	-	-	-	-	-
1995	0	-	-	-	-	-	-	-	-
1996	0	-	-	-	-	-	-	-	-
1997	0	-	-	-	-	-	-	-	-
1998	0	-	-	-	-	-	-	-	-
1999	0	-	-	-	-	-	-	-	-
2000	0	-	-	-	-	-	-	-	-
2001	0	-	-	-	-	-	-	-	-
2002	9	0.0%	0.0%	0.0%	0.0%	22.2%	0.0%	66.7%	11.1%
2003	13	0.0%	0.0%	0.0%	0.0%	23.1%	0.0%	69.2%	7.7%
2004	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	50.0%
Average	5	0.0%	0.0%	0.0%	1.5%	14.8%	0.3%	73.2%	10.1%

[a.] Scale ages before 1988 were changed following a review in the late 1980s. Scale ages should be reviewed for consistency with current practices.

Appendix 6c. Annual age composition of male Birkenhead Chinook spawners estimated from samples taken from carcasses and fish removed for enhancement, 1975-2004. Dashes indicate no data available.

Year	Sample size	Age 2_1	3_1	3_2	4_1	4_2	5_1	5_2	6_2
1975	0	-	-	-	-	-	-	-	-
1976	0	-	-	-	-	-	-	-	-
1977	0	-	-	-	-	-	-	-	-
1978	1	0%	0%	0%	0%	0%	0%	100%	0%
1979	12	0%	0%	8%	0%	8%	0%	83%	0%
1980	4	0%	0%	0%	0%	50%	0%	50%	0%
1981	10	0%	0%	0%	0%	40%	0%	60%	0%
1982	16	6%	0%	13%	6%	38%	0%	38%	0%
1983	0	-	-	-	-	-	-	-	-
1984	0	-	-	-	-	-	-	-	-
1985	11	0%	0%	0%	0%	36%	0%	64%	0%
1986	0	-	-	-	-	-	-	-	-
1987	1	0%	0%	0%	0%	0%	0%	100%	0%
1988 [a]	0	-	-	-	-	-	-	-	-
1989	0	-	-	-	-	-	-	-	-
1990	0	-	-	-	-	-	-	-	-
1991	0	-	-	-	-	-	-	-	-
1992	0	-	-	-	-	-	-	-	-
1993	0	-	-	-	-	-	-	-	-
1994	0	-	-	-	-	-	-	-	-
1995	0	-	-	-	-	-	-	-	-
1996	0	-	-	-	-	-	-	-	-
1997	0	-	-	-	-	-	-	-	-
1998	0	-	-	-	-	-	-	-	-
1999	0	-	-	-	-	-	-	-	-
2000	0	-	-	-	-	-	-	-	-
2001	0	-	-	-	-	-	-	-	-
2002	7	0%	0%	0%	0%	29%	0%	57%	14%
2003	6	0%	0%	0%	0%	17%	0%	67%	17%
2004	0	-	-	-	-	-	-	-	-
Average	2	0.7%	0.0%	2.3%	0.7%	24.2%	0.0%	68.7%	3.4%

[a.] Scale ages before 1988 were changed following a review in the late 1980s. Scale ages should be reviewed for consistency with current practices.

Appendix 7. Mean post orbital-hypural plate (POH) length, by sex and age, of Birkenhead Chinook salmon, 1979-2004.

Year	Sex	Sample size	Mean POH length (mm) at age								Total
			2_1	3_1	3_2	4_1	4_2	5_1	5_2	6_2	
1979	Male	25	-	-	414	-	674	-	716	-	689
	Female	38	-	-	-	655	482	748	718	809	717
	Total	63	-	-	414	655	610	748	717	809	706
1980 [a]	Male	1	-	-	-	-	512	-	-	-	512
	Female	3	-	-	-	-	-	-	772	-	772
	Total	4	-	-	-	-	512	-	772	-	707
1981 [a]	Male	10	-	-	-	-	597	-	709	-	665
	Female	11	-	-	-	-	620	-	691	-	684
	Total	21	-	-	-	-	602	-	698	-	675
1982 [a]	Male	15	400	-	458	654	531	-	720	-	584
	Female	13	-	-	-	-	-	817	683	797	728
	Total	28	400	-	458	654	531	817	697	797	651
1983 [b]	Male	9	-	-	-	-	587	-	756	-	700
	Female	35	-	-	-	-	667	-	718	924	721
	Total	44	-	-	-	-	619	-	724	924	717
1984 [b]	Male	2	-	-	-	-	713	-	670	-	692
	Female	25	-	-	-	-	685	-	748	-	727
	Total	27	-	-	-	-	688	-	743	-	725
1985 [b]	Male	9	-	-	-	-	555	-	728	-	651
	Female	25	-	-	-	-	-	-	703	781	709
	Total	34	-	-	-	-	555	-	707	781	694
1986 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1987 [a]	Male	1	-	-	-	-	-	-	787	-	787
	Female	5	-	-	-	-	-	-	730	-	730
	Total	6	-	-	-	-	-	-	740	-	740
1988 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1989 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1990 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1991 [b]	Male	0	-	-	-	-	-	-	-	-	-
	Female	2	-	-	-	-	-	-	-	749	749
	Total	2	-	-	-	-	-	-	-	749	749
1992 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1993 [b]	Male	17	-	-	-	-	568	-	741	835	691
	Female	21	-	-	-	-	-	-	686	748	692
	Total	38	-	-	-	-	568	-	704	791	692
1994 [b]	Male	0	-	-	-	-	-	-	-	-	-
	Female	3	-	-	-	-	-	-	678	-	678
	Total	3	-	-	-	-	-	-	678	-	678

Continued

Appendix 7. Mean post orbital-hypural plate (POH) length, by sex and age, of Birkenhead Chinook salmon, 1979-2004, continued.

Year	Sex	Sample size	Mean POH length (mm) at age 2_1	3_1	3_2	4_1	4_2	5_1	5_2	6_2	Total
1995 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1996 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1997 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1998 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
1999 [d]	Male	0	-	-	-	-	-	-	-	-	-
	Female	0	-	-	-	-	-	-	-	-	-
	Total	0	-	-	-	-	-	-	-	-	-
2000 [b]	Male	1	-	-	-	-	-	-	725	-	725
	Female	3	-	-	-	-	-	-	703	-	703
	Total	4	-	-	-	-	-	-	709	-	709
2001 [b]	Male	0	-	-	-	-	-	-	-	-	-
	Female	1	-	-	-	-	-	-	-	860	860
	Total	1	-	-	-	-	-	-	-	860	860
2002 [c]	Male	7	-	-	-	-	774	-	777	850	787
	Female	8	-	-	-	-	610	-	702	795	702
	Total	15	-	-	-	-	719	-	732	823	742
2003 [c]	Male	6	-	-	-	-	795	-	796	860	806
	Female	13	-	-	-	-	728	-	709	690	712
	Total	19	-	-	-	-	745	-	736	775	742
2004 [c]	Male	0	-	-	-	-	-	-	-	-	-
	Female	6	-	-	-	-	-	-	719	797	758
	Total	6	-	-	-	-	-	-	719	797	758
Total	Male	78	400	-	458	654	590	-	742	845	680
	Female	174	-	-	-	-	682	817	710	788	716
	Total	252	400	-	458	654	622	817	717	799	705

[a.] Data from DFO Fish Ageing Laboratory ageing card pdf.files

[b.] Data from DFO OHEB hatchery data files

[c.] Data from DFO Stock Assessment files

[d.] No data available

Appendix 8. Estimated CWT recoveries (expanded to total release group) by tag code of Birkenhead Chinook, 1977-1993 and 1995 brood years.

Brood year	Tag code release date and status		Recovery age	Alaska	North/ central	WCVI comm.	WCVI sport	Georgia Strait comm.	Georgia Strait sport	Lower Fraser River FN	Lower Fraser Test Fishery	Lillooet system FN	Escape-ment	Total	Sur-vival	Exploit-ation rate
1977	Code:	02-16-55	2	-	-	-	-	6	10	-	-	-	-	16		
	Date:	20-Jul-78	3	-	-	-	-	3	4	-	-	-	-	7		
	Grams:	2.5	4	12	-	7	-	-	-	-	-	-	-	19		
	Type:	Fed Fry	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	16,319		12	0	7	0	9	14	0	0	0	0	42	0.26%	-
1978	Code:	02-17-61	2	-	2	-	-	-	4	-	-	-	-	6		
	Date:	17-Jul-79	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	2.5	4	4	-	-	-	-	-	-	-	-	-	4		
	Type:	Fed Fry	5	5	-	-	-	-	3	5	-	5	36	54		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	12,963		9	2	0	0	0	7	5	0	5	36	64	0.50%	44.0%
1979	Code:	02-18-58	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	28-Apr-80	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.6	4	26	-	-	-	-	-	2	-	2	12	41		
	Type:	0+ accel	5	2	-	-	-	-	5	3	-	5	17	31		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	34,111		28	0	0	0	0	5	4	0	7	28	72	0.21%	60.6%
1979	Code:	02-17-11	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	28-Apr-81	3	2	-	-	-	-	-	-	-	-	-	2		
	Size:	39.3	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	1+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	14,417		2	0	0	0	0	0	0	0	0	0	2	0.01%	-
1980	Code:	02-18-35	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	28-Apr-81	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.1	4	4	-	-	-	-	-	-	-	-	-	4		
	Type:	0+ accel	5	6	-	-	-	-	12	3	-	19	10	50		
			6	-	-	-	-	-	-	1	-	2	6	9		
	Total:	72,413		10	0	0	0	0	12	4	0	21	17	64	0.09%	74.0%
1980	Code:	02-19-15	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	30-Apr-82	3	-	-	-	-	-	6	-	-	-	-	6		
	Size:	44.7	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	1+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	9,754		0	0	0	0	0	6	0	0	0	0	6	0.06%	-
1981	Code:	02-23-40	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	30-Apr-82	3	68	-	-	-	-	-	-	-	-	-	68		
	Size:	3.2	4	-	-	-	-	-	3	3	-	18	9	33		
	Type:	0+ accel	5	2	-	-	-	-	-	4	-	7	24	37		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	26,528		70	0	0	0	0	3	7	0	25	34	138	0.52%	75.6%
1981	Code:	02-19-59	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	15-Apr-82	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.7	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ accel	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	1	-	1	4	6		
	Total:	9,806		0	0	0	0	0	0	1	0	1	4	6	0.06%	28.5%
1982	Code:	02-25-28	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	12-Apr-83	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	1.4	4	1	-	-	-	-	-	-	-	-	-	1		
	Type:	0+ accel	5	-	-	-	-	-	-	1	-	1	4	6		
			6	4	-	-	-	-	-	2	-	0	13	19		
	Total:	44,161		5	0	0	0	0	0	2	0	1	17	25	0.06%	32.9%

Appendix 8. Estimated CWT recoveries (expanded to total release group) by tag code of Birkenhead Chinook, 1977-1993 and 1995 brood years, continued.

Brood year	Tag code release date and status		Recovery age	Alaska	North/ central	WCVI comm.	WCVI sport	Georgia Strait comm.	Georgia Strait sport	Lower Fraser River FN	Lower Fraser Test Fishery	Lillooet system FN	Escape- ment	Total	Sur- vival	Exploit- ation rate
1982	Code:	02-25-29	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	28-Apr-83	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	2.2	4	-	-	-	-	-	-	1	-	2	6	9		
	Type:	0+ accel	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	2	-	0	13	15		
	Total:	42,831		0	0	0	0	0	0	2	0	2	19	24	0.06%	18.8%
1982	Code:	02-25-30	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	31-May-83	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.5	4	2	-	-	-	-	-	-	-	-	-	2		
	Type:	0+ accel	5	-	-	-	-	-	-	1	-	2	8	11		
			6	-	-	-	-	-	-	2	-	0	13	15		
	Total:	29,207		2	0	0	0	0	0	3	0	2	21	28	0.10%	24.8%
1983	Code:	02-26-18	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	30-Apr-84	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.3	4	20	-	-	-	-	-	-	-	-	-	20		
	Type:	0+ accel	5	13	-	-	-	-	-	8	-	1	70	92		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	153,858		33	0	0	0	0	0	8	0	1	70	112	0.07%	37.8%
1983	Code:	02-27-24	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	30-Apr-84	3	-	4	-	-	-	8	-	-	-	-	12		
	Size:	2.4	4	7	5	-	-	-	-	-	-	-	-	12		
	Type:	0+ accel	5	8	-	2	17	1	-	2	1	0	20	52		
			6	-	-	-	-	-	-	1	-	1	4	5		
	Total:	43,064		15	9	2	17	1	8	3	1	1	24	81	0.19%	69.4%
1984	Code:	02-32-34	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	20-Apr-85	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.7	4	5	-	-	-	-	-	-	-	-	-	5		
	Type:	0+ accel	5	6	-	-	-	-	-	4	-	5	26	41		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	36,023		11	0	0	0	0	0	4	0	5	26	46	0.13%	43.2%
1984	Code:	02-32-35	2	-	4	-	-	-	-	-	-	-	-	4		
	Date:	15-May-85	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	4.0	4	2	-	-	-	-	-	1	-	0	7	10		
	Type:	0+ accel	5	-	-	-	7	-	-	5	-	7	37	57		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	36,803		2	4	0	7	0	0	6	0	7	44	70	0.19%	37.5%
1984	Code:	02-33-18	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	20-Apr-85	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	6.7	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	3	-	-	-	-	-	-	-	-	3		
			6	-	-	-	-	-	-	1	-	2	6	8		
	Total:	25,014		0	3	0	0	0	0	1	0	2	6	11	0.04%	49.2%
1984	Code:	02-33-19	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	15-May-85	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	7.4	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	-	-	-	-	-	1	-	1	4	5		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	18,126		0	0	0	0	0	0	1	0	1	4	5	0.03%	25.1%

Appendix 8. Estimated CWT recoveries (expanded to total release group) by tag code of Birkenhead Chinook, 1977-1993 and 1995 brood years, continued.

Brood year	Tag code release date and status		Recovery age	Alaska	North/ central	WCVI comm.	WCVI sport	Georgia Strait comm.	Georgia Strait sport	Lower Fraser River FN	Lower Fraser Test Fishery	Lillooet system FN	Escape- ment	Total	Sur- vival	Exploit- ation rate
1985	Code:	02-37-13	2	-	-	-	-	8	-	-	-	-	-	8		
	Date:	15-Jun-86	3	-	-	-	-	-	13	-	-	-	-	13		
	Size:	2.7	4	3	4	-	-	-	-	-	-	-	-	7		
	Type:	Fed Fry	5	-	-	-	-	-	-	1	-	2	7	10		
			6	3	-	-	-	-	-	2	-	5	18	29		
	Total:	63,961		6	4	0	0	8	13	4	0	7	26	67	0.10%	61.9%
1985	Code:	02-37-14	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	15-Jun-86	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	5.7	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	45,018		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1986	Code:	02-43-21	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	10-May-87	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	2.0	4	11	-	-	-	-	-	-	-	-	-	11		
	Type:	Fed Fry	5	26	-	-	-	2	20	2	2	3	12	66		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	123,500		37	0	0	0	2	20	2	2	3	12	77	0.06%	82.3%
1986	Code:	02-43-20	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	10-May-87	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	5.0	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	49,500		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1987	Code:	02-47-25	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	10-May-88	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	12.2	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	40,081		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1987	Code:	02-47-26	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	03-May-88	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	11.1	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	44,782		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1988	Code:	02-54-08	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	11-May-89	3	3	-	-	-	-	-	-	-	-	-	3		
	Size:	12.0	4	14	-	-	-	-	7	-	-	-	-	21		
	Type:	0+ Smolt	5	-	-	-	-	-	6	-	-	-	-	6		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	86,510		17	0	0	0	0	13	0	0	0	0	30	0.03%	-
1988	Code:	02-58-40	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	11-Oct-89	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	7.4	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	Fall fry	5	4	-	-	-	-	-	-	-	-	-	4		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	23,487		4	0	0	0	0	0	0	0	0	0	4	0.02%	-

Appendix 8. Estimated CWT recoveries (expanded to total release group) by tag code of Birkenhead Chinook, 1977-1993 and 1995 brood years, continued.

Brood year	Tag code release	date and status	Recovery age	Alaska	North/ central	WCVI comm.	WCVI sport	Georgia Strait comm.	Georgia Strait sport	Lower Fraser River FN	Lower Fraser Test Fishery	Lillooet system FN	Escape-ment	Total	Sur-vival	Exploit-ation rate
1988	Code:	02-58-41	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	11-Oct-89	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	7.4	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	Fall fry	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	23,969		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1988	Code:	02-58-42	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	11-Oct-89	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	7.4	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	Fall fry	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	23,671		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1989	Code:	02-07-32	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	09-Jun-90	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	15.0	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	28,608		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1989	Code:	02-07-33	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	09-Jun-90	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	16.5	4	-	-	-	-	-	-	1	-	1	4	6		
	Type:	0+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	28,489		0	0	0	0	0	0	1	0	1	4	6	0.02%	26.5%
1989	Code:	02-07-34	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	04-Jul-90	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.6	4	16	-	-	-	-	-	-	-	-	-	16		
	Type:	Fed Fry	5	7	-	-	-	-	4	6	-	12	44	73		
			6	-	-	-	-	-	-	2	-	3	12	17		
	Total:	33,285		23	0	0	0	0	4	8	0	15	56	106	0.32%	47.3%
1989	Code:	02-07-35	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	04-Jul-90	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	3.8	4	20	-	-	-	-	-	2	-	4	15	41		
	Type:	Fed Fry	5	3	-	-	-	-	4	9	-	18	67	101		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	33,747		23	0	0	0	0	4	11	0	22	82	142	0.42%	42.4%
1990	Code:	02-14-63	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	03-Jul-91	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	4.0	4	8	-	-	-	-	-	-	-	-	-	8		
	Type:	Fed Fry	5	-	8	-	-	2	-	7	2	14	55	89		
			6	-	-	-	-	-	-	9	-	17	54	79		
	Total:	44,240		8	8	0	0	2	0	16	2	32	109	177	0.40%	37.2%
1990	Code:	02-15-27	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	03-Jul-91	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	10.8	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	0+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	43,117		0	0	0	0	0	0	0	0	0	0	0	0.00%	-
1991	Code:	18-07-28	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	Jun-93	3	-	-	-	-	-	5	-	-	-	-	5		
	Size:	19.0	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	1+ Smolt	5	-	-	-	-	-	-	-	-	-	-	0		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	35,000		0	0	0	0	0	5	0	0	0	0	5	0.01%	-

Appendix 8. Estimated CWT recoveries (expanded to total release group) by tag code of Birkenhead Chinook, 1977-1993 and 1995 brood years, continued.

Brood year	Tag code release date and status		Recovery age	Alaska	North/ central	WCVI comm.	WCVI sport	Georgia Strait comm.	Georgia Strait sport	Lower Fraser River FN	Lower Fraser Test Fishery	Lillooet system FN	Escape-ment	Total	Sur-vival	Exploit-ation rate
1992	Code:	18-07-38	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	15-Apr-94	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	16.1	4	9	-	-	-	-	-	-	-	-	-	9		
	Type:	1+ Smolt	5	4	-	-	-	-	-	-	-	-	-	4		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	22,500		13	0	0	0	0	0	0	0	0	0	13	0.06%	-
1993 [a]	Code:	LV clip	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	20-Apr-95	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	16.0	4	-	-	-	-	-	-	-	-	-	-	0		
	Type:	1+ Smolt	5	-	-	-	-	-	-	3	-	20	68	91		
			6	-	-	-	-	-	-	-	-	-	-	0		
	Total:	40,922		0	0	0	0	0	0	3	0	20	68	91	0.22%	25.1%
1995	Code:	18-15-14	2	-	-	-	-	-	-	-	-	-	-	0		
	Date:	Mar-97	3	-	-	-	-	-	-	-	-	-	-	0		
	Size:	13.0	4	19	-	-	-	-	-	-	-	-	-	19		
	Type:	1+ Smolt	5	19	2	-	-	-	-	8	-	13	46	88		
			6	-	-	-	-	-	-	3	-	7	24	34		
	Total:	40,800		38	2	0	0	0	0	11	0	21	70	142	0.35%	50.3%

[a] No estimate of exploitation in marine fisheries; survival and exploitation rates are under-estimated.

Appendix 9a. Weekly Chinook harvest estimates in the Lower Lillooet River First Nations fishery.

Week ending	Weekly chinook harvest 1983	1984	1985	1986	1987	1988	1989	1990	1991	Mean CPUE (3-point smoothing)
7-Jan	-	-	-	-	-	-	-	-	-	0.00
14-Jan	-	-	-	-	-	-	-	-	-	0.00
21-Jan	-	-	-	-	-	-	-	-	-	0.06
28-Jan	-	-	-	1	-	-	0	-	-	0.06
4-Feb	-	-	-	-	-	0	0	-	-	0.10
11-Feb	-	-	-	-	2	0	0	-	-	0.04
18-Feb	-	-	-	-	0	0	0	-	-	0.15
25-Feb	-	-	1	-	0	0	1	-	-	0.15
4-Mar	-	-	1	-	0	-	0	-	0	0.26
11-Mar	6	-	2	0	0	-	0	-	0	0.32
18-Mar	4	-	11	0	0	1	0	1	0	1.21
25-Mar	5	6	20	0	0	1	0	-	0	1.43
1-Apr	15	-	20	3	0	0	0	5	0	1.51
8-Apr	-	20	20	1	1	-	2	0	0	0.97
15-Apr	4	-	23	1	3	2	0	0	0	0.91
22-Apr	3	-	11	4	0	0	2	0	0	0.87
29-Apr	5	-	9	3	1	0	0	0	1	0.60
6-May	2	-	15	2	0	0	0	0	1	0.47
13-May	8	-	11	0	0	1	-	0	-	0.74
20-May	2	0	74	0	0	0	0	1	-	0.88
27-May	-	9	-	0	0	0	-	0	0	1.06
3-Jun	0	-	-	-	3	-	-	0	1	0.79
10-Jun	5	0	-	-	-	-	-	-	-	0.54
17-Jun	-	-	11	-	-	-	-	-	-	0.21
24-Jun	-	-	4	-	-	-	-	-	-	0.00
1-Jul	-	-	-	-	-	-	-	-	-	0.00
8-Jul	-	-	0	-	-	-	0	-	-	0.00
15-Jul	-	-	1	-	-	-	-	-	-	0.00
22-Jul	-	-	0	-	-	-	0	-	-	0.06
29-Jul	-	0	-	-	-	-	1	-	-	0.06
5-Aug	0	0	0	-	-	0	0	-	-	0.07
12-Aug	-	0	1	0	0	0	0	-	-	0.15
19-Aug	2	0	-	0	-	0	0	-	-	0.15
26-Aug	0	0	0	-	1	0	0	-	-	0.14
2-Sep	0	0	0	0	1	0	0	-	-	0.01
9-Sep	0	0	0	0	0	0	0	-	-	0.04
16-Sep	0	2	4	0	0	0	0	-	-	0.09
23-Sep	0	0	1	0	1	0	8	-	-	0.09
30-Sep	0	0	1	0	0	0	0	-	0	0.15
7-Oct	5	1	1	5	0	0	0	-	0	0.21
14-Oct	1	-	0	10	0	0	0	-	0	0.36
21-Oct	5	2	10	1	1	0	0	-	0	0.30
28-Oct	2	0	1	0	0	0	0	-	0	0.42
4-Nov	10	-	2	-	0	0	0	0	-	0.35
11-Nov	5	0	0	-	0	0	0	-	-	0.31
18-Nov	0	0	0	-	0	0	-	-	-	0.09
25-Nov	-	0	-	-	0	0	0	-	0	0.00
2-Dec	-	0	-	0	0	-	0	-	-	0.00
9-Dec	-	0	-	0	-	-	0	-	-	0.00
16-Dec	-	-	-	0	-	-	0	-	-	0.00
23-Dec	-	-	-	0	-	-	-	-	-	0.00
30-Dec	-	-	-	0	-	-	-	-	-	0.00
Was the assessment adequate?:	Yes	No	Yes	No	Yes	Yes	Yes	No	No	-
Total	89	-	255	-	14	5	14	-	-	-
Total to 9-Sep:	61	-	235	-	12	5	6	-	-	-
Ppn to 9-Sep	0.69	-	0.92	-	0.86	1.00	0.43	-	-	-

Notes: "-" indicates there was no assessment in that week.
Stippling in 3-Jun to 27-Jul indicates main freshet; normally very limited if any fishing during this period.
Stippling in 9-Sep to 30-Dec denotes post-peak spawning in Birkenhead; harvest is unlikely to be Birkenhead chinook.

Appendix 9b. Weekly Chinook harvest estimates in the Lillooet Lake First Nations fishery.

Week ending	Weekly chinook harvest 1983	1984	1985	1986	1987	1988	1989	1990	1991	Mean CPUE (3-point smoothing)
7-Jan	-	-	-	-	-	-	-	-	-	0.00
14-Jan	-	-	-	-	-	-	-	-	-	0.00
21-Jan	-	-	-	-	-	-	-	-	-	0.00
28-Jan	-	-	-	-	-	-	-	-	-	0.00
4-Feb	-	-	-	-	-	-	-	-	-	0.00
11-Feb	-	-	-	-	-	-	-	-	-	0.00
18-Feb	-	-	-	-	-	0	-	-	-	0.00
25-Feb	-	-	-	-	-	0	-	-	-	0.00
4-Mar	-	-	-	-	-	-	-	-	-	0.00
11-Mar	-	-	-	-	0	-	0	-	-	0.00
18-Mar	-	-	0	-	0	0	-	-	-	0.00
25-Mar	-	-	0	-	-	0	-	-	-	0.33
1-Apr	-	-	1	-	-	-	-	-	-	0.41
8-Apr	-	0	2	-	-	-	-	0	-	0.60
15-Apr	5	0	4	-	-	0	-	-	-	0.39
22-Apr	5	-	6	-	0	2	0	0	0	0.45
29-Apr	10	-	0	-	0	0	0	0	-	0.41
6-May	6	-	20	-	1	0	0	0	0	0.67
13-May	6	-	56	0	0	0	6	0	0	0.69
20-May	6	-	25	0	0	0	0	0	0	1.27
27-May	0	85	5	7	0	5	0	0	0	0.96
3-Jun	0	0	-	-	0	0	0	0	3	1.27
10-Jun	5	15	1	-	0	0	-	0	0	0.81
17-Jun	-	-	5	-	0	-	-	0	-	0.85
24-Jun	0	0	2	-	-	-	-	-	-	0.39
1-Jul	-	-	0	-	-	-	-	-	0	0.78
8-Jul	-	-	0	-	20	-	-	-	-	0.67
15-Jul	-	-	0	-	-	-	-	-	-	0.67
22-Jul	-	-	0	-	-	-	-	-	-	0.00
29-Jul	-	-	-	-	-	-	-	-	-	0.50
5-Aug	-	-	3	-	-	-	0	-	-	0.72
12-Aug	-	-	2	-	-	-	-	-	-	0.72
19-Aug	-	-	-	-	-	-	0	-	-	0.22
26-Aug	0	0	0	-	0	0	0	-	-	0.00
2-Sep	0	0	0	-	0	0	0	-	-	0.00
9-Sep	0	0	0	0	0	0	0	-	-	0.00
16-Sep	0	1	0	0	0	0	0	-	0	0.03
23-Sep	0	12	0	0	0	0	0	-	0	0.03
30-Sep	0	0	0	0	0	0	0	-	0	0.05
7-Oct	0	0	3	0	0	0	1	-	0	0.05
14-Oct	0	-	4	0	0	0	0	-	-	0.05
21-Oct	0	0	0	0	0	0	0	-	-	0.05
28-Oct	0	0	2	0	0	0	0	-	0	0.02
4-Nov	2	-	0	0	0	0	0	0	-	0.02
11-Nov	0	-	0	0	0	0	0	-	0	0.01
18-Nov	0	-	0	0	0	0	0	-	0	0.00
25-Nov	0	-	-	0	0	0	0	-	0	0.00
2-Dec	0	-	-	0	0	-	0	-	-	0.00
9-Dec	-	-	-	0	-	-	0	-	-	0.00
16-Dec	-	-	-	0	-	-	0	-	-	0.00
23-Dec	-	-	-	-	-	-	-	-	-	0.00
30-Dec	-	-	-	-	-	-	-	-	-	0.00
Was the assessment adequate?:	Yes	No	Yes	No	Yes	Yes	No	No	No	-
Total	45	-	141	-	21	7	-	-	-	-
Total to 9-Sep:	43	-	132	-	21	7	-	-	-	-
Ppn to 9-Sep	0.96	-	0.94	-	1.00	1.00	-	-	-	-

Notes: "-" indicates there was no assessment in that week.
Stippling in 3-Jun to 27-Jul indicates main freshet; normally very limited if any fishing during this period.
Stippling in 9-Sep to 30-Dec denotes post-peak spawning in Birkenhead; harvest is unlikely to be Birkenhead chinook.

Appendix 10. Annual early season (January 1 to April 30) fishing effort, Chinook harvest and management actions by area in the lower Fraser River First Nations fisheries, 1969-2005. Note: dates indicate week ending periods.

	Steveston Area					Deas Island to Mission					Mission to Harrison [a]					
Year	Start date	Days open	Net-days	Chinook harvest	Weeks with no assess-ment	Start date	Days open	Net-days	Chinook harvest	Weeks with no assess-ment	Start date	Days open	Net-days	Chinook harvest	Weeks with no assess-ment	Total harvest all areas
1969	-	-	0	0	0 [b]	n.r	51	n.r	0	17	n.r	51	n.r	89	14	89
1970	-	-	0	0	0 [b]	n.r	54	n.r	0	18	n.r	54	n.r	271	13	271
1971	-	-	0	0	0 [b]	n.r	54	n.r	0	18	n.r	54	n.r	129	13	129
1972	-	-	0	0	0 [b]	n.r	51	n.r	0	18	n.r	51	n.r	224	11	224
1973	-	-	0	0	0 [b]	n.r	51	n.r	0	17	n.r	51	n.r	105	2	105
1974	-	-	35	4	0 [b]	n.r	51	n.r	0	17	6-Jan	51	1,257	288	0	292
1975	-	-	0	0	0 [b]	19-Jan	51	87	0	10	5-Jan	51	1,503	308	1	308
1976	-	-	0	0	0 [b]	11-Jan	54	219	65	2	4-Jan	54	2,175	525	0	590
1977	-	-	0	0	0 [b]	6-Mar	38	85	80	10	2-Jan	38	898	222	0	302
1978	-	-	0	0	0 [b]	26-Mar	42	45	89	13	22-Jan	42	494	188	6	277
1979	-	-	0	0	0 [b]	1-Apr	39	47	31	12	14-Jan	39	780	196	2	227
1980	-	-	20	4	0 [b]	10-Feb	39	152	35	5	6-Jan	39	438	93	5	132
1981	12-Apr	16	8	25	14 [c]	11-Jan	44	187	157	3	4-Jan	44	893	144	1	326
1982	28-Feb	26	17	15	13	3-Jan	50	115	19	3	31-Jan	50	1,146	144	5	178
1983	20-Mar	27	21	21	11	6-Feb	54	165	42	9	6-Mar	54	1,332	153	10	216
1984	1-Apr	24	21	14	12	29-Jan	43	205	39	3	15-Jan	43	1,102	114	1	167
1985	7-Apr	21	25	16	13	20-Jan	33	49	19	9	20-Jan	33	529	205	5	240
1986	23-Mar	21	13	1	11	12-Jan	33	81	2	5	5-Jan	33	627	63	4	66
1987	11-Jan	22	51	33	5	4-Jan	34	149	62	3	4-Jan	34	629	69	0	164
1988	31-Jan	22	60	34	0	31-Jan	34	105	23	5	10-Jan	34	1,014	174	2	231
1989	n.r	22	32	11	8	n.r	34	43	7	13	n.r	34	237	41	12	59
1990	n.r	21	44	17	8	n.r	33	47	12	10	n.r	33	327	104	10	133
1991	n.r	21	33	10	6	n.r	33	n.r	0	17	n.r	33	24	n.r.	16	17
1992	3-Jan	17	43	65	8	1-Jan	17	4	10	16	4-Jan	17	60	79	13	154
1993	19-Feb	10	23	31	4	29-Jan	1	0	22	1 [c]	11-Feb	15	228	139	1	192
1994	26-Feb	8	9	5	6	14-May			6	0	28-Jan	11	100	122	0	133
1995	1-Apr	5	38	22	0	1-Apr	3	58	127	0	1-Apr	5	112	150	0	299
1996	7-Apr	8	38	81	0	7-Apr	2	48	75	0	7-Apr	4	119	138	0	294
1997	4-Apr	8	48	130	0	1-Mar	4	102	177	0	1-Mar	12	270	389	0	696
1998 [d]	4-Apr	6	28	71	0	22-Mar	3	61	71	0	20-Mar	10	107	49	0	191
1999 [d]	2-Jan	29	30	85	0	23-Jan	5	117	99	0	1-Jan	22	111	106	0	290
2000 [d]	11-Mar	10	27	38	0	22-Jan	6	117	162	0	22-Jan	22	174	148	7	348
2001 [d]	17-Mar	8	38	62	0	17-Mar	4	105	199	0	16-Mar	14	105	209	0	470
2002 [d]	16-Mar	8	31	65	0	9-Feb	6	90	171	0	22-Mar	12	121	155	0	391
2003 [d]	15-Mar	8	36	43	0	22-Mar	3	58	203	0	21-Mar	12	145	181	0	427
2004 [d]	13-Mar	10	24	63	0	13-Mar	4	71	169	0	13-Mar	11	112	104	0	336
2005 [d]	13-Mar	10	20	28	0	19-Mar	3	76	81	0	19-Mar	8	81	28	0	137

[a.] The Mission to Harrison catch region was established in 2002. For prior years, the catch was estimated from the average proportion of the Mission to Hope catch that occurred below the Harrison in 2002 to 2005.

[b.] Steveston area fishery was by special permit only; all openings were assessed.

[c.] First year of drifted gill net fishery; drifted gill nets were used in all subsequent years.

[d.] Structured assessments using access site-aerial overflight techniques or mandatory landing sites replaced subjective fishery officer assessments (e.g., see Alexander (2001).

Appendix 11. DNA sampling results in the lower Fraser River First Nations and Albion test fisheries, and estimated harvest of Birkenhead Chinook salmon in the First Nations fisheries from the mouth to Harrison River, and Harrison River to Sawmill Creek, 1997-2001, 2003 and 2005.

		Mouth to Harrison First Nations fisheries					Harrison to Sawmill First Nations fisheries						Test fishery sample		
		Total chinook	Sample		Birkenhead		Total chinook	Sample		Birkenhead		Total Birken-head			% Birken-
Period	Year	catch	N	SD	%	Catch	catch	N	SD	%	Catch	catch	N	SD	head
To April 19	1997	610	33	6.8%	18.3%	112	1,067	52	2.6%	3.1%	33	145	-	-	-
	1998	99	46	5.4%	17.2%	17	511	62	1.6%	1.7%	9	26	-	-	-
	1999	137	68	4.9%	21.6%	30	237	34	0.4%	0.0%	0	30	-	-	-
	2000	281	44	6.6%	26.8%	75	1,090	60	0.2%	0.0%	0	75	28	7.5%	24.3%
	2001	370	12	11.4%	23.1%	85	830	-	-	-	-	85	37	7.2%	26.6%
	2003	259	28	6.5%	13.9%	36	524	-	-	-	-	36	-	-	-
	2005	64	-	-	-	-	117	-	-	-	-	-	20	10.6%	47.6%
20-Apr to 30-Apr	1997	129	23	5.8%	8.4%	11	241	8	1.4%	0.2%	0	11	-	-	-
	1998	96	18	3.1%	0.9%	1	134	11	1.0%	0.1%	0	1	-	-	-
	1999	155	87	1.9%	3.0%	5	206	97	1.9%	0.0%	0	5	-	-	-
	2000	82	53	0.2%	0.0%	0	235	59	0.2%	0.0%	0	0	21	6.1%	9.1%
	2001	126	27	0.5%	0.1%	0	184	-	-	-	-	0	19	6.6%	10.1%
	2003	168	3	3.0%	0.5%	1	602	-	-	-	-	1	-	-	-
	2005	73	-	-	-	-	109	-	-	-	-	-	10	8.5%	9.6%
01-May to 10-May	1997	460	29	4.5%	3.4%	16	645	14	1.0%	0.1%	1	16	-	-	-
	1998	90	101	1.4%	2.0%	2	148	46	0.3%	0.0%	0	2	-	-	-
	1999	126	143	0.1%	0.0%	0	489	55	0.2%	0.0%	0	0	-	-	-
	2000	186	46	0.2%	0.0%	0	403	90	0.1%	0.0%	0	0	16	0.8%	0.1%
	2001	497	26	0.4%	0.1%	0	600	-	-	-	-	0	23	4.0%	4.2%
	2003	492	67	1.4%	1.5%	7	1,194	-	-	-	-	7	-	-	-
	2005	57	-	-	-	-	306	-	-	-	-	-	10	0.9%	0.1%
11-May to 20-May	1997	139	-	-	-	-	151	-	-	-		0	-	-	-
	1998	219	76	0.2%	0.0%	0	476	56	0.2%	0.0%	0	0	-	-	-
	1999	671	83	0.1%	0.0%	0	1,269	40	0.3%	0.0%	0	0	-	-	-
	2000	423	46	0.2%	0.0%	0	1,626	73	0.2%	0.0%	0	0	23	0.4%	0.1%
	2001	228	66	0.2%	0.0%	0	1,285	-	-	-	-	0	15	0.8%	0.1%
	2003	198	n.r.	0.4%	0.1%	0	545	-	-	-	-	0	-	-	-
	2005	138	-	-	-	-	291	-	-	-	-	-	9	1.1%	0.1%
21-May to 30-May	1997	575	-	-	-	-	883	-	-	-	-	0	-	-	-
	1998	700	240	0.1%	0.0%	0	1,180	125	0.2%	0.0%	0	0	-	-	-
	1999	145	81	1.2%	1.2%	2	139	41	0.2%	0.0%	0	2	-	-	-
	2000	123	37	0.3%	0.0%	0	107	83	0.2%	0.0%	0	0	24	0.4%	0.1%
	2001	450	36	0.2%	0.0%	0	658	-	-	-	-	0	-	-	-
	2003	569	26	0.4%	0.1%	1	900	-	-	-	-	1	-	-	-
	2005	109	-	-	-	-	881	-	-	-	-	-	75	1.1%	0.5%
Total	1997	1,913	-	-	-	138	2,987	-	-	-	34	172	-	-	-
	1998	1,204	-	-	-	20	2,449	-	-	-	9	28	-	-	-
	1999	1,234	-	-	-	36	2,340	-	-	-	0	36	-	-	-
	2000	1,095	-	-	-	75	3,461	-	-	-	0	75	-	-	-
	2001	1,671	-	-	-	86	3,557	-	-	-	0	86	-	-	-
	2003	1,686	-	-	-	45	3,765	-	-	-	0	45	-	-	-
	2005	441	-	-	-	-	1,704	-	-	-	-	-	-	-	-

Appendix 12. Birkenhead chinook fishery mortality distribution from CWT recoveries (1983-2000) and the estimated 2001-05 distribution based on historical CWT recoveries scaled by catch. Commercial and sport fishery data are from the Regional Mark Information System (RMIS); FN data are estimated in this research document (see *Fisheries*).

	S.E. Alaska Troll [a]			North Troll [b]			W. Coast Vancouver Is. (WCVI) Troll		
Recovery year	Catch	Est. CWT	% Fishing Mortality	Catch	Est. CWT	% Fishing Mortality	Catch	Est. CWT	% Fishing Mortality
1983	269,821	10.9	36.9%	162,837	0.0	0.0%	395,636	6.3	21.5%
1984	235,622	72.5	86.2%	185,134	0.0	0.0%	471,294	0.0	0.0%
1985	215,811	2.4	4.1%	165,845	0.0	0.0%	345,937	0.0	0.0%
1986	237,703	4.1	10.7%	175,715	7.7	20.2%	350,227	1.9	4.9%
1987	242,562	11.6	40.0%	177,457	5.0	17.1%	378,931	0.0	0.0%
1988	231,364	16.9	26.4%	152,369	7.6	11.9%	408,668	2.3	3.6%
1989	235,716	8.1	15.4%	207,679	6.6	12.5%	203,751	0.0	0.0%
1990	287,939	4.3	45.0%	154,109	0.0	0.0%	297,858	0.0	0.0%
1991	264,106	11.3	36.1%	194,018	3.1	9.9%	203,035	0.0	0.0%
1992	183,759	21.6	.	142,340	0.0		340,146	0.0	
1993	226,866	26.6	74.3%	161,686	0.0	0.0%	277,033	0.0	0.0%
1994	186,331	12.4	21.6%	164,581	0.0	0.0%	150,039	0.0	0.0%
1995	138,117	26.8	55.4%	56,857	4.4	9.0%	81,454	0.0	0.0%
1996	141,452	0.0		21	0.0		4	0.0	
1997	246,409	0.0		83,488	0.0		52,748	0.0	
1998	192,066	0.0		107,837	0.0		2,282	0.0	
1999	146,219	18.7		56,499	0.0		5,307	0.0	
2000	158,717	18.9	45.6%	9,800	2.2	5.3%	63,400	0.0	0.0%
Historical Average [c]	225,437	17	39.2%	151,391	3	6.3%	279,020	1	1.8%
2001 [d]	153,280	11.9	27.6%	13,100	0.2	0.6%	77,491	0.2	0.5%
2002 [d]	325,308	25.2	46.6%	103,038	1.9	3.5%	132,921	0.4	0.7%
2003 [d]	330,692	25.6	51.6%	137,357	2.6	5.1%	151,826	0.4	0.9%
2004 [d]	354,664	27.4	42.1%	167,508	3.1	4.8%	174,128	0.5	0.8%
2005 [d]	338,400	26.2	22.3%	174,806	3.2	2.8%	143,614	0.4	0.4%
Average 2001-2005	300,469	23	35.3%	119,162	2	3.4%	135,996	0	0.6%

	WCVI/Juan de Fuca Str. Sport			Georgia Strait/Fraser Net			Georgia Strait Sport		
Recovery year	Catch	Est. CWT	% Fishing Mortality	Catch	Est. CWT	% Fishing Mortality	Catch	Est. CWT	% Fishing Mortality
1983	28,000	0.0	0.0%	17,520	0.0	0.0%	198,433	0.0	0.0%
1984	44,162	0.0	0.0%	19,851	0.0	0.0%	369,445	4.4	5.2%
1985	21,587	0.0	0.0%	31,006	0.0	0.0%	234,838	14.2	24.9%
1986	13,158	0.0	0.0%	32,359	0.9	2.4%	181,896	7.7	20.1%
1987	38,283	0.0	0.0%	13,016	6.3	21.8%	121,081	0.0	0.0%
1988	35,820	15.9	24.9%	8,373	0.0	0.0%	119,117	10.0	15.7%
1989	55,239	7.2	13.7%	23,833	6.2	11.8%	132,846	0.0	0.0%
1990	69,723	0.0	0.0%	15,298	0.0	0.0%	111,914	0.0	0.0%
1991	96,058	0.0	0.0%	15,407	1.0	3.2%	115,523	8.3	26.3%
1992	80,201	0.0		9,159	0.0		116,581	4.1	
1993	88,916	0.0	0.0%	16,153	0.0	0.0%	127,576	3.4	9.4%
1994	62,839	0.0	0.0%	14,078	0.0	0.0%	70,839	10.1	17.7%
1995	35,631	0.0	0.0%	6,263	1.0	2.1%	62,173	0.0	0.0%
1996	12,495	0.0		9,591	0.0		89,589	0.0	
1997	53,755	0.0		28,342	0.0		56,332	0.0	
1998	62,240	0.0		6,779	0.0		20,923	0.0	
1999	86,082	0.0		3,906	0.0		43,588	0.0	
2000	48,225	0.0	0.0%	5,584	0.0	0.0%	32,750	0.0	0.0%
Historical Average [c]	49,049	2	4.0%	16,826	1	2.7%	144,495	4	10.0%
2001 [d]	50,361	1.8	4.3%	4,301	0.3	0.7%	31,259	1.0	2.2%
2002 [d]	70,586	2.6	4.7%	8,980	0.6	1.2%	52,979	1.6	3.0%
2003 [d]	83,202	3.0	6.1%	12,277	0.9	1.7%	19,981	0.6	1.2%
2004 [d]	116,465	4.2	6.5%	12,318	0.9	1.3%	13,475	0.4	0.6%
2005 [d]	109,421	4.0	3.4%	5,296	0.4	0.3%	11,972	0.4	0.3%
Average 2001-2005	86,007	3	4.7%	8,634	1	0.9%	25,933	1	1.2%

a. Includes net recoveries for 1983 and 1990.

Continued

b. Includes a net recovery in 1986.

c. Stippled years not included in historical average because FN CWT estimates could not be calculated, or no ocean recoveries reported.

d. Fishery mortality distribution calculated as the historical average number of recoveries by fishery multiplied by the ratio of the historical average catch to 2005 catch (assumes the 2005 Birkenhead density in each fishery was the same as the 1983-2000 average density).

Appendix 12 cont'd. Birkenhead chinook fishery mortality distribution from CWT recoveries (1983-2000) and the estimated 2001-05 distribution based on historical CWT recoveries scaled by catch. Commercial and sport fishery data are from the Regional Mark Information System (RMIS); FN data are estimated in this research document (see *Fisheries*).

	Lower Fraser R. FN			Lillooet FN			Total	
Recovery year	Catch	Est. CWT	% Fishing Mortality	Catch	Est. CWT	% Fishing Mortality	% Fishing Mortality	Est. CWT
1983	86	5.5	18.8%	104	6.7	22.8%	100.0%	29.5
1984	85	2.4	2.9%	169	4.8	5.7%	100.0%	84.0
1985	67	6.3	11.0%	367	34.4	60.0%	100.0%	57.3
1986	41	5.3	14.0%	81	10.6	27.7%	100.0%	38.2
1987	19	2.2	7.6%	33	3.9	13.4%	100.0%	29.0
1988	80	9.8	15.2%	12	1.5	2.3%	100.0%	64.0
1989	41	11.3	21.4%	55	13.2	25.1%	100.0%	52.5
1990	66	2.2	23.1%	130	3.1	31.9%	100.0%	9.6
1991	41	2.6	8.2%	81	5.1	16.3%	100.0%	31.3
1992	117	0.0		233	0.0			25.7
1993	39	2.2	6.2%	78	3.6	10.1%	100.0%	35.8
1994	56	11.7	20.4%	112	23.1	40.3%	100.0%	57.2
1995	27	5.4	11.2%	54	10.8	22.3%	100.0%	48.4
1996	51	0.0		102	0.0			0.0
1997	172	0.0		187	0.0			0.0
1998	28	0.0		188	0.0			0.0
1999	36	0.0		49	0.0			18.7
2000	75	7.8	18.8%	132	12.5	30.3%	100.0%	41.3
Historical Average [c]	56	6	12.9%	108	10	23.0%	100.0%	44
2001 [d]	86	9.2	21.4%	191	18.3	42.7%	100.0%	43.0
2002 [d]	72	7.7	14.3%	144	13.9	25.7%	100.0%	53.9
2003 [d]	45	4.8	9.5%	136	13.0	25.5%	100.0%	50.9
2004 [d]	222	23.8	36.1%	57	5.5	8.3%	100.0%	65.8
2005 [d]	399	42.8	36.3%	421	40.4	34.3%	100.0%	117.7
Average 2001-2005	165	18	26.7%	190	18	27.5%	100.0%	66

a. Includes net recoveries for 1983 and 1990.

b. Includes a net recovery in 1986.

c. Stippled years not included in historical average because FN CWT estimates could not be calculated, or no ocean recoveries reported.

d. Fishery mortality distribution calculated as the historical average number of recoveries by fishery multiplied by the ratio of the historical average catch to the 2005 catch (assumes the 2005 Birkenhead density in each fishery was the same as the 1983-2000 average density).